Volunteer Groundwater Monitoring:

Implementation of a Community-Based Well Water Monitoring Network

Laila B. Parker

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A volunteer-based groundwater monitoring program was established in the Southern Willamette Valley of Oregon in 2006. The program was designed to involve rural resident volunteers in testing their own and their neighbors' wells for nitrate. Volunteers were responsible for taking water samples, conducting nitrate tests and communicating the results to their neighbors. The goals of the program were to 1) heighten awareness of groundwater issues and influence behaviors which affect groundwater quality and 2) generate monthly nitrate information to serve both as a screening tool for residents and to inform future groundwater management decisions. A sampling and analysis plan was developed which was designed to balance these goals and make the necessary trade-offs between an accurate sampling methodology and an easy-to-implement sampling protocol. This plan was approved by the Oregon Department of Environmental Quality and, in the first three months of the program, was successfully implemented by 22 volunteer monitors sampling over 100 domestic wells each month.

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Laila Belkov Parker

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INTRODUCTION

This paper documents the establishment of a volunteer-based groundwater monitoring program in the Southern Willamette Valley of Oregon. Agricultural, industrial and residential activities, combined with vulnerable shallow aquifers, have yielded high groundwater nitrate concentrations in many of the regions' drinking water wells. This volunteer monitoring program is designed to involve rural residents in testing their own and their neighbors' wells for nitrate. In the process, we hope both to learn more about the extent of the nitrate contamination and to improve public involvement in groundwater management.

In contrast to many agricultural and industrial practices, most residential practices which contribute nitrate to the groundwater are unregulated. In addition, while municipal water supply wells are regularly monitored, the quality of private residential wells is subject to neither monitoring nor regulation. Therefore the most effective tool for minimizing rural residential nitrate contributions and nitrate consumption may be through outreach and education. By involving residents throughout the Southern Willamette Valley in monitoring, giving them responsibility for conducting nitrate tests and communicating the results, and structuring the testing in the form of localized neighborhood networks, we hope to heighten awareness of groundwater issues and to influence behaviors which affect groundwater quality. The results of the nitrate monitoring may serve both as a screening tool for residents and potentially as a dataset for other interested parties.

The success of the program hinges on the degree of participation and on the ease with which volunteers can conduct the monitoring. To accommodate the dual outreach/education and data-gathering goals of the program, it was necessary to make trade-offs between an accurate sampling methodology and an easy-to-implement sampling protocol. Groundwater monitoring

data collected by government or academic scientists are most likely of higher quality than the data collected by the volunteers in this program. However, the benefits of this volunteer-based approach are in both the number of samples which can be taken by local monitors, and in the increased awareness and consideration of the resource that is usually associated with environmental monitoring.

This paper particularly focuses on the development of a sampling and analysis plan designed to balance these goals. Future work will address volunteer management, volunteer motivation, and changes in volunteer behavior as a result of participation in the program. In this paper, the first section reviews the literature on nitrate in the Southern Willamette Valley and on volunteer-based environmental monitoring. Particular focus is given to data quality issues and methodology trade-offs. The Project Discussion section describes the approach used in developing the sampling and analysis plan, some of the initial stages of the monitoring program and some specific challenges and lessons learned in the development of the program. Finally, the Conclusion section summarizes some potential impacts and successes of the program.

LITERATURE REVIEW

1. Nitrate in the Willamette Valley

1.1 Nitrate Overview

Nitrogen is a key building block of life, with its availability controlling many aspects of ecosystem function. Humans contribute roughly 60%, or 14.4×10^{13} g, of the nitrogen added to the Earth's land surface each year, with fertilizer alone contributing at least 8.0×10^{13} g of nitrogen per year (Schlesinger, 1997). Other anthropogenic sources include septic systems, animal feedlots, and above-ground application of wastewater. These additions increase the size of the pool of biologically available forms of nitrogen such as nitrate, which is usually present in groundwater at levels of 1-3 parts per million (ppm) but can be found at much higher concentrations in areas affected by human activity.

Nitrate is an environmental contaminant of concern largely because of its potential health effects. Early work linking nitrate to methemoglobinemia (blue-baby syndrome) formed the basis for the EPA's establishment of 10 ppm nitrate-nitrogen (nitrate-N or NO_3^--N) as the maximum contaminant level (MCL) in drinking water. Some studies have linked drinking nitrate-contaminated water to health concerns including cancer, adverse reproductive outcomes, and diabetes, however further research is needed before these conditions can be conclusively linked to drinking-water nitrate (Ward et al., 2005). From a broader perspective, the correlation between nitrate concentrations and human activity means that high nitrate concentrations may be an indication of the presence of other pollutants in the water supply.

Nitrate has been documented to be present at levels above the MCL in drinking water aquifers around the world (e.g. Ozcan and Kavdir, 2005; Rajagopal and Tobin, 1992). Nolan and

Stoner (2000) found that samples from at least 15 % of major aquifers surveyed in the U.S. exceeded the MCL; others have found that 22% of domestic wells in agricultural areas exceed the MCL (Ward et al., 2005). These data are troubling because estimates suggest that roughly half of the U.S. population relies on groundwater for drinking water (Nolan and Stoner, 2000 (>50%); Ward et al., 2005 (42%)). In Oregon, that proportion rises to 70% (Kite-Powell and Harding, 2006).

1.2 Southern Willamette Valley groundwater nitrate sources

Nitrate-contaminated aquifers are usually shallow and lie below areas of dense human habitation and intensive irrigated agriculture (Hinkle, 1997; Nolan and Stoner, 2000; Rajagopal and Tobin, 1992). One such area is the Southern Willamette Valley of Oregon. Located in Western Oregon, this valley is bounded on the West by the Oregon Coast Range, on the East by the Southern Cascades, to the North by the Salem Hills, and to the South by the Eugene foothills. The hydrogeology of the Valley is characterized by the surficial Willamette aquifer, composed of alluvial sediments from the Cascades, and overlain in many areas by the fine-grained Willamette silt (Mutti, 2006). This silt acts as a confining layer in much of the valley, but it is not present in the floodplain region and thus the aquifer there is more susceptible to contamination.

Due to its location, climate, and soils, the Willamette Valley as a whole is a fertile region both for agricultural production and population growth. Roughly 68% of the area underlain by the above-described alluvium is devoted to agricultural lands (Hinkle, 1997) producing grains, hay and forage, seed crops, field crops, vegetables, fruits, and a variety of specialty crops (LCOG, 2006). These agricultural activities have historically meant high rates of fertilizer application, which may have recently decreased due both to educational campaigns and to an

increase in the cultivation of nitrogen-scavenging grass seed crops (LCOG, 2006). The Southern Willamette Valley is a heavily settled region, and its three main counties, Benton, Lane and Linn, rank within the top fifteen counties in Oregon in terms of density and population (Oregon Blue Book 2006; U.S. Census Bureau, 2006). As the area is predominantly agricultural, with the exception of larger cities like Corvallis and Eugene, roughly a third of the area's residents live in rural areas which often are not serviced by drinking water suppliers or wastewater treatment facilities (LCOG, 2006). Rural residences contribute to groundwater nitrate concentrations largely through septic system effluent, as well as through small-scale farming practices and failure to properly abandon unused wells. While the degree to which these inputs affect water quality is debated, there is evidence of high nitrate concentrations in densely populated, unsewered areas (Hinkle, 1997; Vick, 2004).

While rural residents may contribute to elevated nitrate levels, they are also more prone than urban residents to drink nitrate-contaminated water. Private wells, unlike public water supply systems, are only required to be tested in Oregon when the property is sold (Eldridge, 2004; Kite-Powell and Harding, 2006). Furthermore, Jaffe (1987) suggests that should residents find their private wells to be contaminated, they are unlikely to be able to garner political support to address either the source of contamination or their source of drinking water. Ultimately, water quality professionals often feel that funding for monitoring private wells and responding to contamination should come from the well owners themselves (Rajagopal and Tobin, 1992). In contrast, 73% of rural residents in the Southern Willamette Valley surveyed in 2002 expressed support for regulations which would protect the region's groundwater quality (Kite-Powell and Harding, 2006).

In this same survey of 100 residents, 67% thought that a reasonable response to findings that the region's groundwater was impacted would be for homeowners to test their well water annually (Kite-Powell and Harding, 2006). While the rate at which rural residents test their wells in the Southern Willamette Valley is unknown, anecdotal evidence from private water quality laboratories and a free OSU Well Water Extension water testing service suggests that the number is less than 10%.

1.3 Southern Willamette Valley groundwater nitrate concentrations

Nitrate levels in the Valley's groundwater have been professionally monitored for the past two decades. In the mid-1980s, the Oregon Department of Environmental Quality (DEQ) sampled 45 shallow wells in Lane and Linn counties. While no wells were seen to have nitrate concentrations above the 10 ppm MCL, at least 17 wells had nitrate concentrations greater than 3 ppm (Eldridge, 2004), suggesting an increase in nitrate above natural background levels. Further study in 1991 and 1993 by the U.S. Geological Survey (USGS) in the Willamette Basin found that of the 70 wells surveyed, 9% of the samples exceeded the MCL (Hinkle, 1997). Wells in this study were randomly selected from all shallow domestic wells drawing from the alluvium in the Willamette Basin which had available well construction data and certain pump-specific properties.

In 2000-2001, the DEQ, in cooperation with state and federal agencies, completed an area-wide survey of 476 private residential wells. This survey was conducted in a 780 mi^2 section of the Southern Willamette Valley where nitrate contamination was thought to be more of a concern based on geology, land use, residential reliance on private wells for drinking water, and expected population growth. The geographic distribution of these results is shown in Figure 1. Of the 476

wells sampled, 100 had nitrate levels higher than 7.0 mg/L (Eldridge, 2004), the level at which Oregon statute provides for further management actions (ORS 468B.180(1)). These data and others are summarized in Table 1.

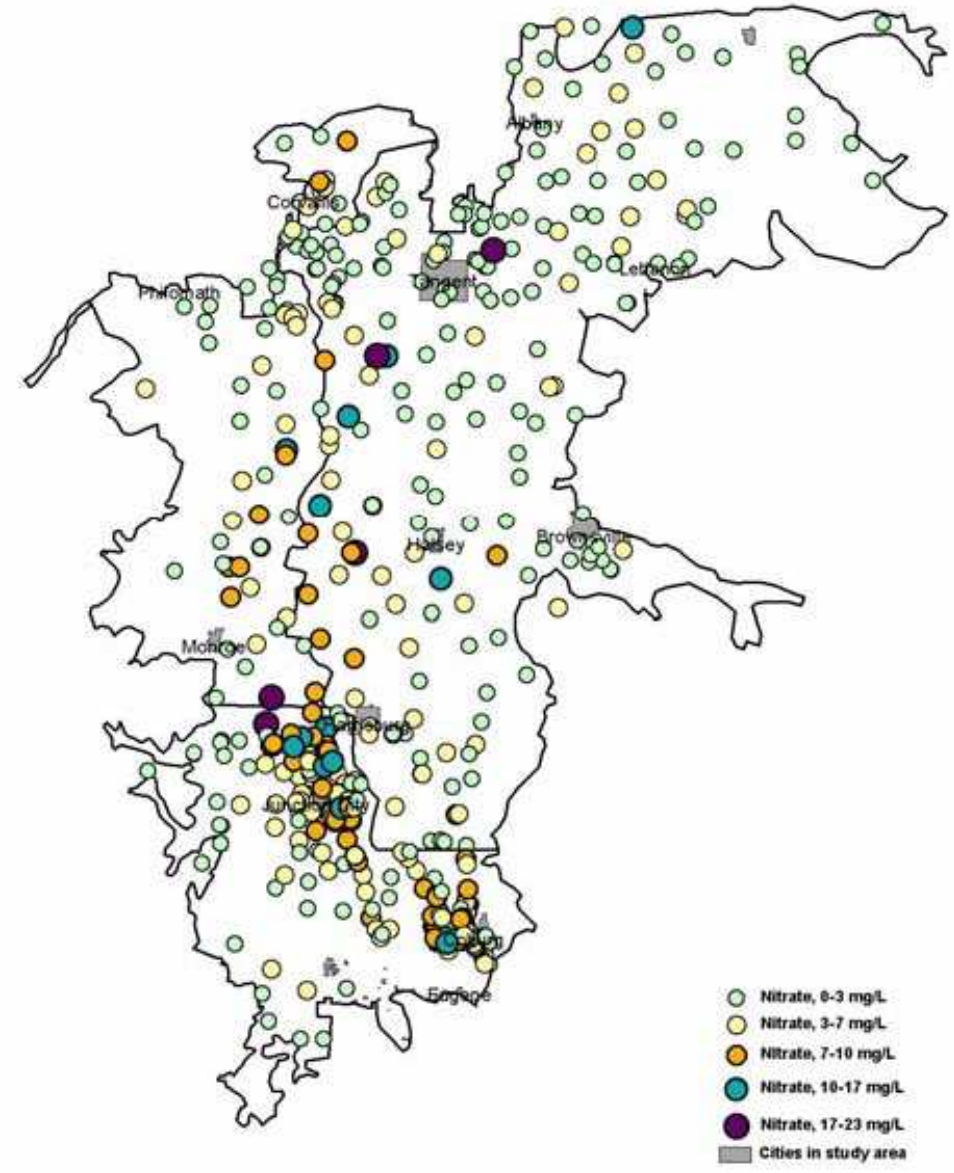

Figure 1. Nitrate concentrations in 476 wells sampled by the DEQ in 2000-2001. After Eldridge, 2004.

Table 1. Summary of two decades of well-water nitrate studies in the Willamette Valley

Date of Study	# of wells tested	Wells selection basis	% higher than 3 ppm NO_3^--N	% higher than 10 ppm NO_3^--N	Conducted by:	Source:
1985-1987	45	Shallow, in Lane/Linn counties	At least 38%	0	DEQ, local, state & federal agencies	Eldridge, 2004
1991, 1993	30	Entire Willamette Basin, random selection based on well properties	33%	13%	USGS	Hinkle, 1997
1993-1994	60	Prioritized areas based on expected contamination or vulnerability	~50%	~17%	DEQ	Eldridge, 2004
1989-1996	564	Real estate transactions in S. Willamette Valley	37%	6%	Private laboratories	Eldridge, 2004
1995-1997	~500	Northern Lane County	72%	33%	OSU Extension Service, Lane County	Eldridge, 2004
2000-2001	476	Expected contamination or vulnerability	52%	7%	DEQ, state and federal agencies	Eldridge, 2004; Kite-Powell and Harding, 2006
2002	87	Concentrations above 7 ppm in 2000-2001 study	94%	48%	DEQ, state agencies, OSU	Eldridge, 2004; Kite-Powell and Harding 2006
2003	120	Well depth, well age, geology, land use	~	8.3%	OSU	Vick, 2004

1.4 Responses to findings of elevated nitrate

There have been two major classes of response to the evidence suggesting that groundwater in the Willamette Valley contains elevated nitrate levels. The first response, coming largely from Oregon State University scientists, has been to attempt to describe the temporal and spatial distribution of nitrate and to identify sources of contamination. The second, coming from the DEQ with the help of local agencies, has been to push for new management approaches. These two approaches are linked, as management changes can be better targeted if nitrate sources can be clearly identified, but they will be considered separately here.

A number of authors have examined the linkage between hydrogeologic units and nitrate concentrations. Hinkle (1997) found a relationship between overlying clay thickness and nitrate concentrations. Vick (2004) found higher nitrate concentrations in the unconfined Willamette

aquifer. Kite-Powell and Harding (2006) found nitrate-N concentrations to be higher in the more permeable units, including the Pleistocene sand and gravel post-Missoula Flood deposits and the Holocene Willamette River alluvium. Vick also attempted to determine the source of nitrate using isotopic data, and found a correlation between septic leachate and nitrate concentrations in the Coburg and Junction City areas in the southern portion of the study area (Vick, 2004).

Researchers in other regions have found significant seasonality in nitrate concentrations, with seasonal variations in a single well of more than 5 ppm nitrate-N or greater than 50% of the concentration (Mutti, 2006). Mutti sampled 19 shallow (less than 50 feet deep) wells in the Southern Willamette Valley at monthly intervals for 15 months, and found such a high degree of inter-site variability that no network-wide seasonality could be detected (with seasonality defined as a statistically significant difference in groundwater nitrate concentrations for a specific time period). However, evidence of seasonal trends at the majority of the individual wells suggests that this topic deserves more study to account for confounding factors such as geology, soils and land use (Mutti, 2006).

Concurrently with these detailed examinations of nitrate distribution, in 2003 the DEQ began official proceedings for the declaration of a Groundwater Management Area in the Southern Willamette Valley (Hallock, 2004). Groundwater management areas are a form of differential protection policy used in several states which focuses the pollution control resources of a state on areas based on their observed or expected need for protection (Henderson, 1987). While they are often designated by state agencies, usually the area itself is managed by local entities, allowing for increased buy-in, local knowledge, and awareness-raising (Sandoval, 2004) and often emphasizing education and outreach approaches (CBGWMA, 2006; de Loe¨ and Kreutzwiser, 2005).

The Oregon Groundwater Protection Act of 1989 first established the concept of groundwater management areas in the state. The state DEQ has the authority to designate groundwater management areas "if, as a result of information provided to the department or from its statewide monitoring and assessment activities under ORS 468B.190, the department confirms that, as a result of suspected nonpoint source activities, there is present in the ground water: (a) Nitrate contaminants at levels greater than 70 percent of the levels established pursuant to ORS 468B.165" (ORS 468B.180(1)). The DEQ invoked this authority for the third time in 2004 with the designation of the Southern Willamette Valley Groundwater Management Area (GWMA). Following the designation, the DEQ formed a stakeholder group, known as the GWMA Committee, which was charged with developing an Action Plan for reducing nitrate levels. This plan was drafted during 2005 and 2006, submitted for public review and comment and subsequently approved by the GWMA Committee in the fall of 2006. Strategies outlined in the plan include education and outreach efforts, technical and financial assistance, and proposed regulatory changes (LCOG, 2006).

During the process of drafting the Action Plan, it was recognized that evaluation of the success of the plan would rely on the development of a comprehensive long-term monitoring program. Groundwater monitoring is recommended as instrumental in the development of water resource management strategies (Jaffe, 1987). While there is no paucity of studies on groundwater nitrate in the Valley, long-term monitoring in consistent locations ranged across the area would establish baseline nitrate data and identify trends in nitrate concentrations as the action items are implemented. The variability observed by Mutti (2006) suggests the importance of long-term monitoring in the Southern Willamette Valley. The GWMA Action Plan outlines a number of approaches for monitoring which have already begun, including DEQ-run quarterly

monitoring of a network of 40 shallow wells begun in August 2006, and the community-based monitoring network which is the subject of this paper.

2. Volunteer Monitoring

2.1 Overview

By delineating the status and/or trends of a resource, environmental monitoring provides essential information for making policy decisions regarding that resource (Olsen et al., 1999). Monitoring may serve to establish normal ranges of parameters such as water quality, enabling managers to identify outliers which may be cause for concern (Russek-Cohen, 2004), or may be designed to quantify the response of a parameter to management interventions (Brashares and Sam, 2005).

Environmental monitoring is often conducted by professional staff from the local, state or federal agency which has jurisdiction over the resource in question. However, under-funding of government-run environmental programs is common, and budget cuts often hit monitoring programs first (e.g. Au et al., 2000 (Britain); Penrose and Call, 1995 (U.S.A.); Reynoldson et al., 1986 (Alberta, Canada); Savan et al., 2003 (Ontario, Canada)). The funding and staffing constraints on monitoring mean that reliable water quality information is often scarce. Fore et al. (1997) found that in 1996, water quality information existed for only 4% of Washington State's surface water bodies.

With increasing frequency, professional monitoring gaps are being filled, at least in part, by volunteer-based monitoring programs. Programs in which non-professionals with minimal training conduct monitoring go by a variety of names, including 'participatory monitoring', 'community-based monitoring' or 'locally-based monitoring' (Danielson et al., 2005). This

paper will treat these terms as interchangeable, and will primarily use the term 'volunteer monitoring' based on its popular use in programs throughout the United States.

An advantage to volunteer monitoring programs is that they incorporate oft-ignored 'local knowledge' (Carolan, 2006; Carr, 2004). For example, people who monitor a stream in their backyard are able to watch for changing conditions and report them more rapidly than professional scientists who may make infrequent visits to a studied spot (Engell and Voshell, 2002; Kingham, 2002). Fore et al. (2001) remind us that in fields such as astronomy and ornithology, "volunteers and amateurs have added to scientific knowledge for centuries". Ecologists and others have recently emphasized the value of incorporating amateur observations into their work. For example, Primack and Miller-Rushing (2006) used a personal journal documenting the annual arrival of birds in the spring to support other research on changes in migratory patterns. These authors find that "even though these sources of data have limitations related to varying sampling intensity and lack of continuity, they are relatively common and surprisingly robust and reliable". Such observations may be more useful to resource managers when they are formalized in a monitoring program which can add to professional monitoring networks and also generate public interest into environmental issues.

While the merits of volunteer monitoring programs have been realized for several decades in some areas of water quality, volunteer programs devoted to monitoring groundwater quality are few and far between. This may be due to the 'invisible' nature of groundwater which both makes it difficult to study and masks its importance as a resource (e.g. Moench, 2004). A review of the published literature reveals no documentation of a groundwater monitoring program in which citizen volunteers conduct the field monitoring and reporting as they would in a surface water monitoring program. Components of such a program have been implemented. For

example, in some cases homeowners bring well water samples to a central location to be tested or collect and mail in water samples (e.g. Bonness, 2005; Brahmani, 1993; Erickson, 2000). Alternatively, in other cases, staff or professional volunteers (e.g. Master Gardeners in Oregon) visit domestic wells and test them using low-cost commercial field test kits (Eldridge, 2004; Erickson, 2000). However, there is little evidence that programs exist wherein trained volunteers collect, analyze and report groundwater quality data on a regular basis. Due to the dearth of documented volunteer-based groundwater monitoring programs, this paper will review a variety of water quality monitoring examples with applications to groundwater.

2.2 Evaluating Volunteer Monitoring Programs

Despite the increase in the number of volunteer monitoring programs, scientists and resource managers often question the validity and effectiveness of volunteer-generated data (e.g. Fore et al., 2001). Some have found that volunteer programs exhibit a lack of objectivity (Sharpe & Conrad, 2006), which others have suggested is due to participant bias (Root & Alpert, 1994). More frequently what is questioned is the ability of volunteers to collect high-quality data (Engell and Voshell, 2002; Gouveia et al., 2004; Kingham, 2002; Nicholson, 2002). Evaluation of the effectiveness of a monitoring program should consider the purpose of the program. Programs which focus on awareness-raising may find success in increased involvement of community members in resource management or increased cooperation between previously opposed parties (Kenney, 1999). In contrast, programs which aim to inform decision-making may need to demonstrate data quality comparable to professional data (e.g. Reynoldson et al., 1986).

2.3 Purposes of Volunteer Monitoring Programs

Complicating the evaluation is the fact that volunteer monitoring programs may be designed with multiple objectives in mind. In a survey mailed to 8000 recipients of *The Volunteer Monitor* (an EPA-supported national newsletter of volunteer water quality monitoring), 85% of the 517 respondents said that the purpose of their program was public awareness followed by (in order) problem identification, local decision making, research, non-point source assessment, watershed planning, and habitat restoration, with some programs listing multiple purposes (Kerr et al., 1994). Au et al. (2000) find four major reasons for participation in volunteer monitoring programs: increased public support for management plans, input of local knowledge, saving government resources and an increase in public trust of the authorities. In some sense, all monitoring programs have an influence on management at some level, whether the individual, local, state, or even national. Danielson et al. (2005) find that while monitoring programs are usually designed to produce data that will be used by professional managers, such a program "is management in its own right…the simple presence of people showing an interest in an area generally has an unquantified but real benefit in terms of reducing threats".

As cited from Kerr et al. (1994), the majority of volunteer programs have education as a goal. In cases where the monitoring occurs as part of a school program the learning occurs within a formalized structure (Au et al., 2000; Reynoldson et al., 1986). In contrast, many monitoring programs are designed not just to inform participants of the workings of the natural world, but to affect their interactions with environmental resources. This may come in the form of acceptance of changes in environmental planning (Au et al., 2000), or in adjustments in behavior in response to an increased understanding of the resource (Danielson et al., 2005; Gouveia et al., 2004; Penrose and Call, 1995).

The effects of volunteer programs on individual management decisions may be widespread yet are difficult to track. A more tangible result may be data-sharing which informs agencies of the need to address specific issues within a given area (Au et al., 2000; Brashares and Sam, 2005; Young-Morse, 2000), or which can facilitate interactions between scientists or decision-makers and those with local or practical knowledge, thereby improving resource management (Carolan, 2005). Many volunteers participate in these programs because they wish their data to be incorporated into resource management decisions, and express frustration with the concept of 'monitoring for the sake of monitoring' (Kingham, 2002; Sharpe and Conrad, 2006).

States may often investigate the feasibility of using volunteer-generated data when the level of monitoring necessary exceeds available resources (Penrose and Call, 1995). In many cases, government agencies do determine that volunteer-generated data may be substituted for professionally gathered data. A milestone for many programs was the EPA's 1991 decision that states could submit volunteer-monitor-generated data in fulfillment of their biennial 305(b) reporting requirements under the Clean Water Act. As of 1994, 27 state regulatory agencies had submitted some volunteer-generated monitoring data in their 305(b) report to Congress (Mayio, 1994). Because both state and federal decision makers use these reports in allocating funds and attention, this decision represented an important step in the political relevance of volunteer monitoring programs.

2.4 Comparison of volunteer and professionally-generated data

One approach to convincing decision-makers of the value of volunteer-generated data has been comparisons of the volunteer data to data generated by professional scientists. The studies reviewed below offer comparisons of professional and volunteer-collected water quality data.

Where numerous studies exist on a specific parameter or group of parameters, such as benthic invertebrates, bacteria, or chemical properties, these will be discussed together. The purpose of this review is to assess whether simplified techniques, limited materials, and relatively inexperienced operators affects the quality of the data. For that reason, while this study's nitrate monitoring program may appear to have more in common with those studies evaluating the assessment of chemical properties, its use of an unsophisticated technique which depends on visual assessment and some degree of volunteer judgment makes the biomonitoring and bacteria count programs relevant as well.

2.4.1 Biomonitoring

Biomonitoring uses biological organisms as indicators to provide a picture of the overall environmental quality of a stream which many find more informative than the temporal snapshot afforded by water chemistry analysis (Savan et al., 2003). As biomonitoring may be conducted with minimal equipment and training (Penrose and Call, 1995), it is becoming increasingly popular among volunteer monitoring groups (e.g. *The Volunteer Monitor 17(2)*). A number of studies have reviewed the accuracy of volunteer data from biomonitoring projects (Engel and Voshell, 2002; Fore et al., 2001; Penrose and Call, 1995; Reynoldson et al., 1986). In most cases, volunteers identify collected organisms to the family level (Fore et al., 2001; Penrose and Call, 1995). Using these counts, volunteers often calculate one or more biological metrics, such as total taxon richness, and compute a multi-metric index score (Fore et al., 2001). As a number of different indices exist, and often depend upon more sophisticated assessment methods, in some cases indices are developed or adapted specifically for a volunteer monitoring program (Engell and Voshell, 2002; Penrose and Call,1995). This procedure means that volunteers can

err in two main ways: in collecting and identifying organisms and in computation of the index (Engell and Voshell, 2002).

One group, reviewed by Reynoldson et al. (1986), did not compute indices from their counts of taxa abundance and diversity. In this case, Reynoldson et al. (1986) found that the biomonitoring data collected by student groups in Alberta was adequate to be used for government agencies. While at relatively 'unpolluted' sampling stations they found that the students counts were (not significantly) lower than that of the government scientists, at downstream sites more susceptible to pollution little difference was noted between the two groups' counts. In reviewing the distribution of taxa, both groups' data showed similar responses in the downstream population. Similarly, Fore et al. (2001) found that when volunteers calculated the same indices as did professionals, the results of both analyses were highly correlated. In contrast, in a case when volunteer groups used a simplified metric to describe their counts, this simplification was found to cause a discrepancy between volunteer and professional predictions of ecological condition (Engell and Voshell, 2002).

2.4.2 Coliform Bacteria

Studies reviewing volunteer monitoring of coliform bacteria have found high degrees of precision and accuracy. Au et al. (2000) studied a program which trained high school students in Ontario to conduct water quality assessments using total coliforms and *E. coli*, as well as physical properties such as dissolved oxygen and hardness. The researchers evaluated the precision of the students' simplified method to identify *E. coli*, as well as the precision of the total coliform counts obtained by different groups of students. The precision of the *E. coli* test

was found to be equivalent to that of a more complicated test, while the variability in total coliform counts was similar between three separate groups of students.

In a comparison of nine different volunteer groups which had undergone side-by-side sampling events with the Oregon DEQ, Hanson (2006) found that volunteer data had the same degree of accuracy as did the DEQ's own duplicate samples. Results from programs which conducted their own testing (either multiple tube fermentation or the Colilert® Quanti-Tray method) matched those from programs which sent samples to outside labs for analysis.

2.4.3 Physical/Chemical Properties

Mattson et al. (1994) evaluated the Acid Rain Monitoring Project, in which Massachusetts volunteers sampled streams and lakes for pH, alkalinity, and major cations and anions over the course of a decade. In the study, professional staff sampled the volunteers' sites on the same day without the volunteer knowing. Both samples were sent to a lab for analysis, with the volunteers submitting their samples as usual. The methodology of 135 out of 200 volunteers was tested in this manner, and very good agreement between volunteer and professional data was found ($R^2 = 0.986$).

In a study comparing stream data collected by a number of Waterwatch Victoria volunteer groups with data collected by government and private-sector scientists in the Victorian Water Quality Monitoring Network, Nicholson et al. (2002) found fairly good agreement between the two groups' measurements of pH, turbidity, electrical conductivity and phosphorus. The authors of this study admit to low statistical power, which prevented them from making strong conclusions about the accuracy of the volunteer collected data. In addition, as the specific

equipment used by each group varied, and was not specified in the paper, it is difficult to assess the accuracy of certain methods.

2.5 Quality Assurance Plans

Overall, it is quite possible for volunteers to generate professional-quality monitoring data. Yet even in cases where volunteers do not expect to generate professional-quality data, it is useful to be able to describe the quality of the data so that potential users can evaluate the data in relation to their own needs (Shampine, 1993). A quality assurance plan is a means for documenting data quality, and can include both quality assurance (QA) and quality control (QC) components (Sharpe and Conrad, 2006). Shampine (1993) defines quality assurance as "all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements of quality", while quality control is "the operational techniques and the activities used to fulfill requirements of quality".

Development of a quality assurance plan can be a useful tool for thinking about the development of a monitoring program. The EPA has developed guidance documents to facilitate the development of quality assurance plans for volunteer programs, partially in response to concerns that volunteer-generated data was not useful to state agencies (Penrose and Call, 1995) culminating in a proposed amendment to prevent the U.S. Department of Interior from using volunteer-generated data (Root and Alpert, 1994). In turn, states such as Arizona, Iowa, Ohio and Oregon require that volunteer groups submit some assurance of data quality in return for partnering with the state (Hanson, 2004).

The Oregon DEQ has adopted an approach to facilitate the development of QA/QC plans following the EPA's guidelines. The DEQ offers volunteer groups a template of a Sampling and

Analysis Plan, which is designed to meet EPA requirements for a Quality Assurance Project Plan. If groups submit an approved plan, addressing elements including volunteer training, sample collection and analysis and data analysis, reporting and storage, they can then receive material and technical support from the DEQ. This section will address some of the issues involved in the development and implementation of such a plan, focusing on sample collection and analysis and data management.

2.5.1 Sample Collection & Analysis

An essential component of the quality assurance plan is a description of sample collection and analysis. This may involve the instrumentation used and the protocol with which samples are collected and analyzed. Other programs have found that although volunteers were adept at following clearly defined protocols, their method of evaluating the collected samples could significantly affect the results (Engell and Voshell, 2002). In contrast, programs in which volunteer-collected samples are sent to professional laboratories often reveal a high degree of agreement between volunteer and professional results (Mattson, 1994). As a result, some organizations, such as the Oregon Department of Environmental Quality, have made provisions to loan volunteer groups high-quality analysis equipment (Hanson, 2006). However, in some cases volunteer groups may choose less sophisticated instrumentation in the interest of cost, educational value, and/or ease of program operation.

2.5.1.1 Measurement Approaches & Implications

Volunteer monitoring programs usually adopt instrumentation which offer a combination of simplicity and accuracy. Brunialti et al. (2004) recommend striking a balance between a

complex sampling protocol and one which would be so simple as to cause large data errors. A very successful example is the use of the Secchi disk for evaluating turbidity in surface water bodies. The plastic disk, which is clearly marked with black and white segments, is lowered into a water body until it can no longer be distinctly seen. This "Secchi depth" is recorded and used as a proxy for water clarity, and thus level of pollution. This test has proved so useful in volunteer monitoring programs that the EPA and the North American Lakes Management Society jointly sponsor the annual Great North American Secchi Dip-in (EPA, 2003).

The corollary to the Secchi disk in groundwater monitoring is color comparator test kits, which are often used in soil and water analysis because they are relatively inexpensive, usually easy to operate, and can present real-time results (Bischoff et al., 1996; Chen et al., 1998; Schmidhalter, 2005).

Most researchers have found that color-based field test kit methods are not as accurate as laboratory assays (Ball and Izbicki, 2004; Hodgkins and McCoy, 1999; Melamed, 2004). Inaccuracy sometimes stems from susceptibility to other compounds in groundwater. Ball and Izbicki (2004) found that the colors produced by an on-site color comparator method for detecting groundwater chromium were sensitive to the presence of organic compounds dissolved in the water. Similarly, in a review of methods to detect arsenic, Melamed (2004) found that color comparator test kits could produce inaccurate results when sulfur, selenium or tellurium compounds were present in the water. However, in a study using color-based test strips to screen wells for nitrate, Bischoff et al (1996) found no difference in test strip readings of nitrate concentrations between groundwater samples and laboratory standards, suggesting a lack of influence of groundwater constituents on this particular method. This finding was corroborated

by measurements of pH, dissolved oxygen and certain anions which were not found to correlate with test strip readings.

An additional concern with color comparator test kits is the degree of variability in readings produced by subsequent readers (Bischoff et al., 1996; Hodgkin and McCoy, 1999). Many researchers improve the accuracy of color comparator field methods by using a hand-held automated device, such as a reflectometer or a colorimeter, which can minimize operator error (Ball and Izbicki, 2004; Melamed, 2004; Özcan and Kavdir, 2005; Schmidhalter, 2005). However, the instruments can be prohibitively expensive for a volunteer program in which multiple volunteers run simultaneous tests in dispersed locations. Despite the inherent variability of data generated by multiple subjective observers, many programs in areas outside water quality (such as assessments of leaf damage) rely on visually-based assessment measures (Lorenzini et al., 2000; Wulff, 2004). While visual measurements are less accurate, they can be significantly cheaper and quicker than more sophisticated methods (Brunialti et al., 2004). Katznelson (1997) emphasizes that the inherent variability in color comparator kits does not prevent them from elucidating spatial and temporal trends.

A final consideration in the choice of sample collection and analysis method is the costs and benefits for the volunteer operators themselves. Factors such as educational value and safety often outweigh accuracy. Nicholson et al. (2002) in a review of Waterwatch Victoria data noted that a less accurate total phosphorus kit was commonly used because its color comparator reader was considered to be more educational than a digital output meter. Selection of an appropriate nitrate test kit often involves deciding between two methods, cadmium reduction and zinc reduction, which differ in their accuracy and safety. While the cadmium-reduction is more accurate at lower nitrate concentrations, cadmium, unlike zinc, is a toxic chemical. Many

therefore caution against its use in a volunteer program (Hodgkins and McCoy, 1999; Katznelson, 1997). Specific waste disposal practices must be followed when using the cadmium kit, which may be complicated for volunteers (Özcan and Kavdir, 2005).

Some researchers have specifically addressed the effects of simplification of sample collection and analysis on data quality. Au et al. (2000) considered ice storage for microbiological samples to be too cumbersome for volunteers who were collecting several samples at inconvenient locations. They compared total coliform counts from samples which were stored on ice prior to plating with those that were stored at room temperature, and found high correlation between the results from both samples. In contrast, as described in an earlier section, Engel and Voshell (2002) found that simplification of the calculation of a biotic index based on macro invertebrate counts led to discrepancies in the predictions of stream quality made by professionals and volunteers. To our knowledge, no one has published a comparison of nitrate concentration results from lab analysis with those gathered using a color comparator field kit, however researchers using nitrate test strips have found good agreement with analytical laboratory results (Bischoff et al., 1996; Schmidhalter, 2005).

2.5.2 Data analysis

Olsen et al. (1999) review some of the statistical issues common to major national environmental monitoring programs, and raise a number of considerations which are particularly relevant to volunteer-based programs. These include site selection issues, selectivity, measurement issues including choice of protocols and variance, and data confidentiality. Many of these issues reflect the degree of discord between a volunteer structure and traditional statistical approaches. For example, many volunteer-based programs use convenience sampling

to select monitoring sites based on semi-political factors such as landowner cooperation, volunteer availability or site proximity to volunteers (e.g. Engell and Voshell, 2002). While this approach may be more socially viable, it may mean that the sampled population differs widely from the intended target population, such that the data may be less representative of the parameter of interest. In addition, even those landowners who may be willing to allow monitoring on their property may be less willing for that data to be shared, especially if they believe that the data while encourage regulatory action (Olsen et al., 1999).

While Olsen et al. (1999) review major national environmental monitoring programs which may easily draw on a wealth of statistical expertise, many volunteer monitoring programs do not have such resources. Often statistical approaches which would aid decision-making involve a commitment of time, funding and experience which is not available to most groups. For example, Zimmerman et al. (1996) use statistical process control charts to quickly identify changes in water quality trends which would warrant agency action. While this could be a useful application of volunteer-generated data, the researchers admit to not possessing either the funding to develop the appropriate software for volunteer use or the means to train volunteers in using the software. However, a number of more simplified approaches exist which can describe trends and identify outliers. Wilderman and Vastine (2005) recommend the use of the box-and-whisker plot, while resources on the DEQ Volunteer Monitoring website suggest a variety of approaches depending on the scenario.

2.5.3 Data reporting

Many researchers advocate the use of web-based platforms for collecting and sharing volunteer-generated data. GIS-based websites are thought to facilitate community decision

making (Kingston et al., 2000). Yet many of these sites are isolated and limited in geographic scope, such as the Map Reflections GIS-based website described by Savan et al. (2003) which was designed for volunteer monitors in Ontario to share their findings. The U.S. Environmental Protection Agency's STORET database offers a nation-wide place to store water quality and biological data, however entering data into the program requires some degree of technical experience (Mayio, 2005), and the program is not formatted to be browsed by concerned community members. Some states have interactive GIS-based monitoring databases, such as the Oregon Department of Environmental Quality's LASER database[1] or the Iowa Water Monitoring Atlas[2]. While GIS-based websites offer the opportunity for many users to interact with the dataset, they do present challenges to privacy and data confidentiality (Olsen et al., 1999). Programs may release site specific information to Internet databases without disclosing exact site locations, but if enough geographical reference information is provided (e.g. streams), interested parties may be able to identify specific sites.

2.6 Summary

In summary, volunteer monitoring programs invariably involve trade-offs which affect data quality. Regardless, it is possible for volunteer-generated data to serve a purpose, both in raising community awareness and in affecting management decisions, particularly if the group develops a quality assurance plan.

[1] http://www.deq.state.or.us/wq/lasar/lasarhome.htm
[2] http://igsims.igsb.uiowa.edu/website/Water_Monitoring/viewer.htm

PROJECT DISCUSSION

This section reviews the methodology used in establishing the volunteer monitoring program. In particular, this section will focus on the development of a DEQ-approved Sampling and Analysis Plan, and examine how decisions about the sampling protocol were made to meet both data quality objectives and volunteer needs. Certain program establishment components such as volunteer recruitment and management will be described more fully in a forthcoming document (Moscowitz, unpublished).

3. Description of Sampling & Analysis Plan

Several trade-offs were made in this program in favor of successful volunteer implementation and program longevity over high standards for data quality. These decisions were documented in a quality assurance plan so that potential users, from residential groups to the DEQ, could evaluate the data in relation to their own needs. The plan follows a format developed by the DEQ to meet the requirements of an EPA-approved Quality Assurance Project Plan. All Oregon volunteer monitoring groups which submit plans following this template are eligible to receive technical and material assistance from the DEQ. This system is similar to that practiced in other states such as Arizona, Iowa and Ohio (Hanson, 2004).

A challenge in developing the Sampling and Analysis Plan (SAP) for this program was identifying appropriate groundwater monitoring practices for volunteers. While over 50 volunteer programs have participated in the DEQ's Volunteer Monitoring Program, none have been groundwater-based programs. As discussed in the Literature Review, there is little evidence in the published literature of volunteer-based groundwater monitoring. Thus methodologies used both in surface-water volunteer monitoring programs and in professional groundwater monitoring were incorporated into the development of this protocol.

The SAP addresses a wide range of elements including volunteer training, sample collection and analysis and data analysis, reporting and storage. While the Discussion will not address every line of the SAP, it will detail some of the more important decisions reflected in that document. The remainder of the Discussion will be organized in a similar fashion to the plan as found attached at the end of this document, with reference to specific sections as applicable.

4. Project Management

4.1 Purpose Statement (SAP A5)

As discussed in the literature review, widespread nitrate contamination throughout the Southern Willamette Valley has prompted the DEQ to declare a Groundwater Management Area (GWMA) in the region. As declared by the GWMA committee, rural residents are one of four major parties playing a role in groundwater nitrate management. This volunteer monitoring program was designed to investigate and assist in that role.

4.2 Project Description (SAP A6)

A major component in the design of the project was the concept that monitoring should occur in neighborhood networks, with each volunteer monitor responsible for testing a small number of wells in their immediate vicinity. Thus, volunteers were recruited to serve one of two roles in the program. 'Well volunteers' volunteered their well to be tested for nitrate on a monthly basis, while 'monitors' volunteered to test other wells in addition to their own on a monthly basis. Monitor-conducted nitrate sampling was expected to continue for at least one year, with the potential for extension based on funding.

The program was designed to involve 20 monitors who would each be responsible for testing three to five wells, including their own, for a total of 60 – 100 wells. While these expectations exceeded the call in the GWMA Action Plan for 50 GWMA residents to be participating in a volunteer monitoring program by June 2007, volunteer participation exceeded expectations. As of November 2006, at least 68 GWMA residents were participating in the program, out of a total of 118 volunteers (22 monitors and 96 well volunteers). This number was partially a result of the 22 monitors' active recruitment of well volunteers. By November 2006, the number of wells in a network ranged from 2 to 10, with an average of almost six wells. An additional 66 individuals had expressed interest in the program, but were determined not to qualify based either on their home's location or because they did not rely on a private well for drinking water.

4.3 Measurement Quality Objectives (SAP A7)

4.3.1 Selection of Test Kit

Measurement quality objectives were affected by the decision to use a simple color comparator test kit (#3354, LaMotte Co., Chestertown, MD) to analyze the volunteer-conducted nitrate samples. Other alternatives, such as sending the samples to a lab for analysis, might have yielded better quality data, but at a cost both to the program and to the experience of the volunteers. By conducting the sample analysis themselves and communicating the results to their neighbors, we hoped volunteers would engage more fully in understanding nitrate and groundwater issues.

This kit was selected out of other field-based color test kit options based on consideration of issues of safety and affordability. The kit uses a two-step reagent addition and dissolution process. The first reagent contains zinc which reduces nitrate to nitrite, while the second reagent

reacts with the nitrite to form a pink color. The color of the sample is then matched to a color standard using a slide viewer system, with darker colors indicating higher nitrate levels. Concentrations are read as the concentration of nitrogen within nitrate (nitrate-N), using units of parts per million (ppm). For reference, the EPA drinking water standard is 10 ppm nitrate-N.

There are two features of the kit's slide viewer (shown in Figure 2) which specifically complicate the reporting of values. The slide viewer contains 8 colors, ranging from <1 – 15 ppm nitrate-N, at the intervals 0, 1, 2, 4, 6, 8, 10, and 15 ppm nitrate-N. When a sample appears to be between two colors, e.g. those corresponding to 6 and 8 ppm nitrate-N, one must interpret the value to be in between those colors, e.g. 7 ppm. Additionally, the marking of the lowest interval as 0 ppm nitrate-N color is misleading, as it is most likely that samples matching that color do contain nitrate, but at levels not detectable with this instrument.

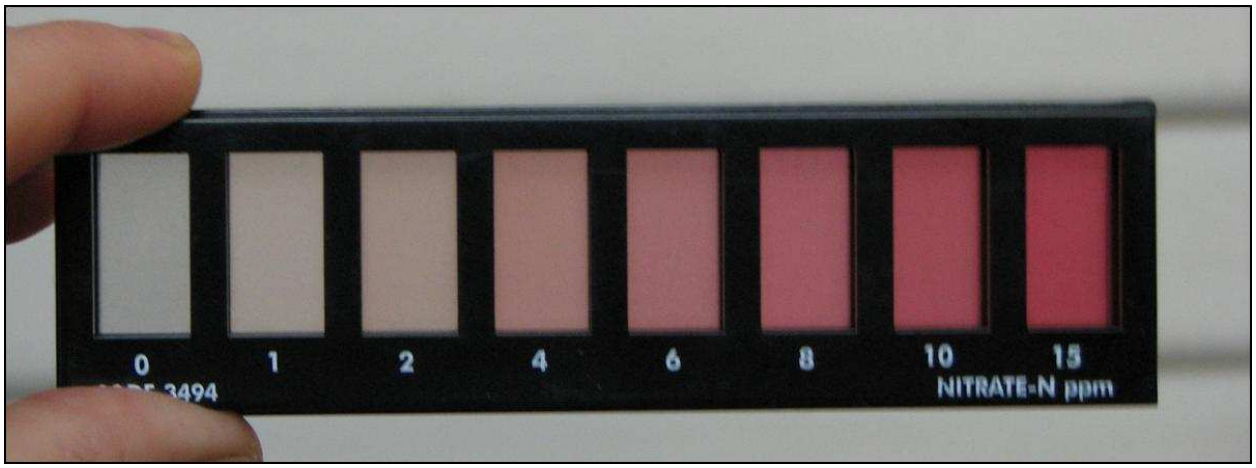

Figure 2. Slide viewer used in LaMotte nitrate test kit.

Field tests for nitrate generally are based on either a cadmium reduction or zinc reduction method (Hodgkins and McCoy, 1999). Both methods involve reduction of the nitrate by the metal to form nitrite, and subsequent reaction with a reagent and the nitrite, coloring the solution. Cadmium reduction is often the preferred method because it is more accurate when measuring

low levels of nitrate (<1 ppm) which may be of great environmental significance. However, the by-products of the cadmium reduction are toxic, posing both a health risk and a problem of appropriate waste disposal to the user. In contrast, the zinc reduction product is non-toxic, and thus seemed to be a better choice for volunteer use (Katznelson, 1997).

Color comparator test kits have been found to be inaccurate and to exhibit a high degree of variability between readings from each participant (e.g. Ball and Izbicki, 2004; Bischoff et al., 1996; Hodgkins and McCoy, 1999; Melamed, 2005). Many researchers use an electronic colorimeter with these kits, which takes the reading by measuring the transmittance or absorbance of light by the sample. However, these tools cost roughly $1000, in contrast to the $41.45 price of a LaMotte test kit with reagents for 50 tests. Purchasing a colorimeter for each monitor, while representing an increase in data quality, would be cost-prohibitive.

4.3.2 Accuracy and Precision Targets

While we knew that the test kit chosen for the program had some degree of inaccuracy, the DEQ's SAP template required that we express this numerically. As such numbers did not appear to be published for this kit, we developed an experiment to quantify the accuracy of the test kit when used by multiple readers. Twelve graduate students volunteered to participate in this experiment, most of whom were unfamiliar with using the kit. All water samples used in this experiment were from residential wells and had previously been analyzed for nitrate by Pacific Analytical Lab in Corvallis, OR, using the nitrate electrode method (SM 4500-NO_3^-- D, Eaton et al., 1995). Samples were stored at 3°C for 30 days following analysis and then donated to this program.

Each participant was given four water samples, each of a different nitrate concentration, marked only with a letter (A, B, C, etc.). The two reagents had already been added to these

samples and they had been allowed to stand for five minutes, following the LaMotte protocol. Each participant then used the color slide to read the nitrate concentrations of a set of four water samples. Due to available sample size, six of the participants read one set of four concentrations (9.1, 6.0, 3.0, and 1.0 ppm nitrate-N), and the other six read from another set of four concentrations (8.8, 7.2, 4.4, and 1.9 ppm nitrate-N).

The concentrations reported by the participants were compared with the nitrate concentrations of the samples as determined by the professional lab ('actual values'). The mean difference between the kit values and the actual values was 1.9 ppm ± 0.2 ppm (mean percent error of 35% ± 3%). With few exceptions, values reported by participants were less than the actual value. While this difference increased with increasing concentrations, the variability of the percent error decreased at higher concentrations (Figure 3).

Because much of this error results from the subjectivity of the color slide, we considered having monitors compare samples to a reference standard. This approach has been questioned by authors such as Katznelson (1997), who suggests that standards are often mis-read using inexpensive color comparator field kits. An additional component to the experiment described above was designed to evaluate the potential effectiveness of using a color reference standard. After reading the first set of four samples, half of the participants were given a reference standard at 4 ppm nitrate which was made from nitric acid buffered with NaOH. These six participants were told to read the standard before reading each sample. The other six participants read their second set of concentrations without a standard. The order in which each participant read the four concentrations differed between the first and second sets.

The bias of this second set of readings, shown in Figure 4, was then examined. No significant change in bias was noted when the standard was used (t-test, $P > 0.05$). The mean

difference between the values reported by participants using a standard and actual values was 2.0 ppm ± 0.3 ppm (mean percent error of 42% ± 6%), while that difference was 1.8 ppm ± 0.2 ppm (mean percent error of 32% ± 5%) when no standard was used. As a result, monitors were not given a reference standard to use in their sample analysis.

The color comparator is clearly an inexact measurement tool, with error resulting from the process of comparing the color of the sample to the color slide. Differences in ambient light or in individuals' visual perception can affect the reported nitrate value. This effect is aggravated by the kits' resolution of 1 ppm, such that a mis-reading changes the reported value by at least 1 ppm. The inaccuracy of the test kit may not preclude its utility in meeting program goals. The degree of error shown in these tests is not so great as to prevent the elucidation of trends. Results generated by the volunteers should be able to be used to identify wells where drinking water may be contaminated, or to identify regions of high nitrate contamination.

An issue of potentially greater concern is whether monitors will become disillusioned by the limitations of the kit. Many of the monitors have described concerns regarding the subjectivity of the color slide, or have reported experiences of retesting a sample and seeing different nitrate concentrations. While they seem to think that the kit can be valuable in elucidating overall trends in a well or in a region, it is possible that some volunteers may grow frustrated with the methodology, and decide to support the investigation of a more exact measurement approach.

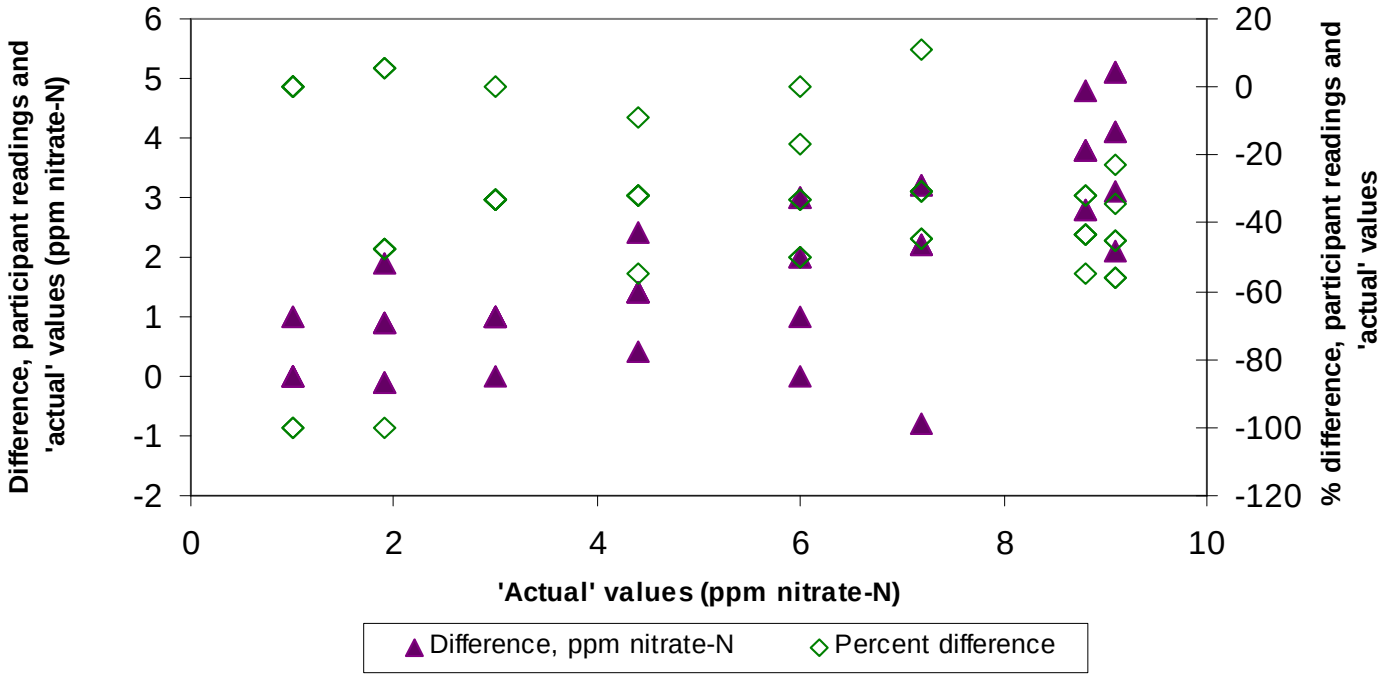

Figure 3. Bias in nitrate values as reported by readings with the test kit compared with nitrate electrode analysis.

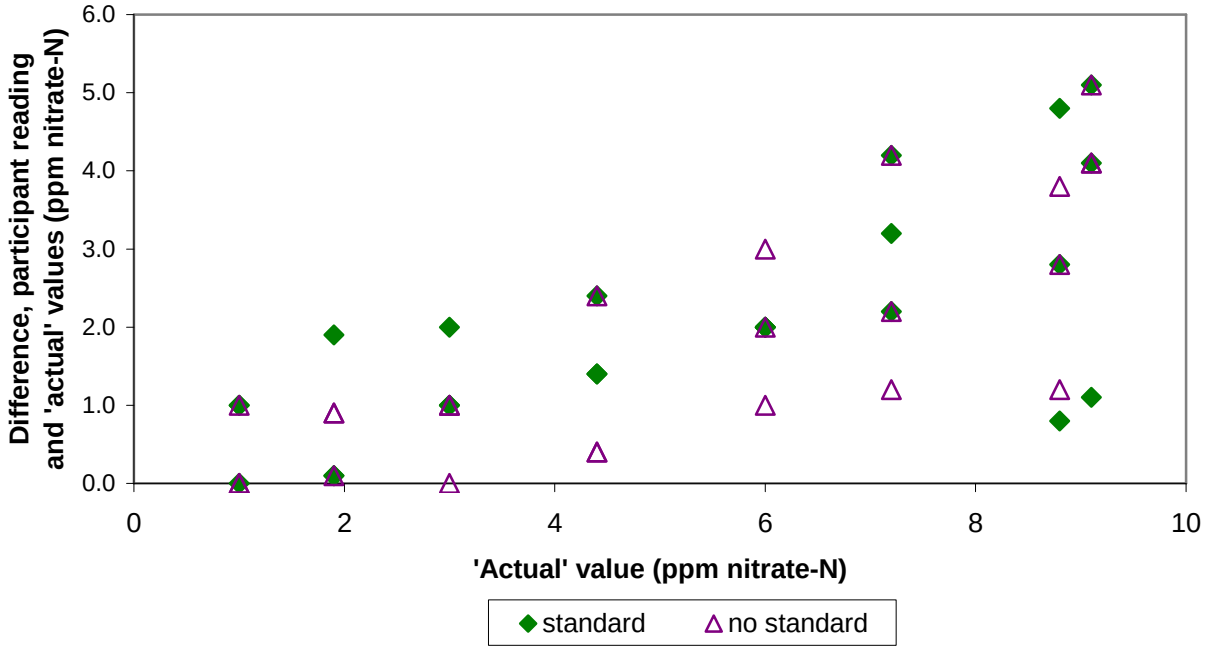

Figure 4. Bias of nitrate values with and without the use of a reference standard.

4.3.3 Well-specific site selection and sample collection

Two decisions were made regarding well selection and sample collection that differ from common groundwater monitoring practices. The first was that no constraints were placed on well construction, age, depth, or similar parameters often used to select wells (e.g. DEQ, 2004; Mutti, 2006; Vick, 2004). Imposing these constraints could have severely restricted the number of participants in the program. Specific information regarding the characteristics and construction of wells is obtainable in Oregon in the form of well logs for most wells built beginning in the 1950s. However, many wells within the study area were either constructed before that time or constructed outside of the legal system. In addition, names and addresses associated with a particular well have changed as home ownership changes hands and increasing development changes the names of roads. These factors contribute to the difficulty of locating a well log for a particular well.

Additionally, wells were not purged because they are production wells and therefore assumed to be sufficiently purged by daily activities (DEQ, 2004). It was assumed that collected samples would represent what the homeowner is drinking. Allowing for instantaneous sample collection mimics the ease with which surface water monitors can collect a grab sample, and also reduces the impact on the well volunteer.

4.4 Training Requirements and Certification (SAP A8)

By the beginning of the program, all monitors had participated in at least one training session in the use of the field kit and in sampling protocol; most monitors had attended two training sessions. Monitors who came to training meetings were given a nitrate test kit with which to familiarize themselves with the method before beginning sampling.

The first training session, attended by four monitors (including one pair) was a full-day Well Water Training held at Oregon State University on June 22, 2006. This program included more in-depth review of groundwater issues, and less focus on the monitoring program itself, however the use of the nitrate test kit was reviewed.

All volunteers who had joined the program as of June 26, 2006 (20 monitors or monitor pairs and 34 well volunteers) were invited to participate in upcoming training sessions. These meetings were designed to facilitate the formation of sampling networks, train monitors in the use of the nitrate test kits, recruit assistance in sampling protocol development, and discuss groundwater and nitrate basics. Evening meetings were scheduled at locations in Coburg, Corvallis, Harrisburg, Junction City and Monroe over the course of a week in mid-July (see Figure 5 for city locations). These meetings were attended by 22 monitors (including three monitor pairs).

Finally, regional training and organizational sessions for monitors were held October 4, 2006 in Junction City and October 11, 2006 in Corvallis. With one exception, all participating monitors attended the October trainings. These trainings were designed to organize the assignment of volunteered wells, to distribute additional testing materials, and to review the testing protocol. Monitors were given a manual (SAP Section E3) containing a review of the sampling protocol, a discussion of how to report data, a map of all sampling sites, a calendar of sampling days for the first year, and a list of additional groundwater resources.

At the training, all volunteers were given two unlabeled water samples of nitrate concentrations 2 ppm and 6 ppm, which they tested independently using the provided manual. Each person entered their results into a data form similar to that used during sampling. Monitors were asked for feedback on using the manual and the data form. Their reported results were

analyzed after the meeting, and the mean difference between the lab values and the values read using the kit was 0.8 ppm ± 0.2 ppm with a mean percent error of 23% ± 5% (n=9). This error is on the magnitude of the kit's resolution. Comparison of these data with those from the experiment conducted by OSU graduate students may suggest that the monitors' experience with the kit over the course of the summer had improved their abilities in taking readings.

5. Data Generation and Acquisition

5.1 Sample Process Design (SAP B1)

5.1.1 Site Selection

Sites in this program were selected through what is termed convenience sampling. Those who wished to participate in the program and met basic requirements for location and well usage were included in the program. Volunteers were recruited through a variety of outlets, including newspaper and newsletter articles, flyers, event announcements, radio messages, OSU Extension Well Water Program events, and conversations with neighbors who had already joined the program.

The monitoring program was originally expected to extend throughout the 230 mi^2 Groundwater Management Area (GWMA). The high volume of responses to the recruitment effort from outside that area led to the decision to expand the program to the 780 mi^2 area used in previous DEQ groundwater nitrate studies. As of June 2006, the program's geographical extent encompassed the rural lowlands in the southern portion of the Willamette Valley, bounded to the East by the Cascade Range, to the West by the Oregon Coast Range, to the North by the Salem Hills, and to the South by Eugene (see Figure 5).

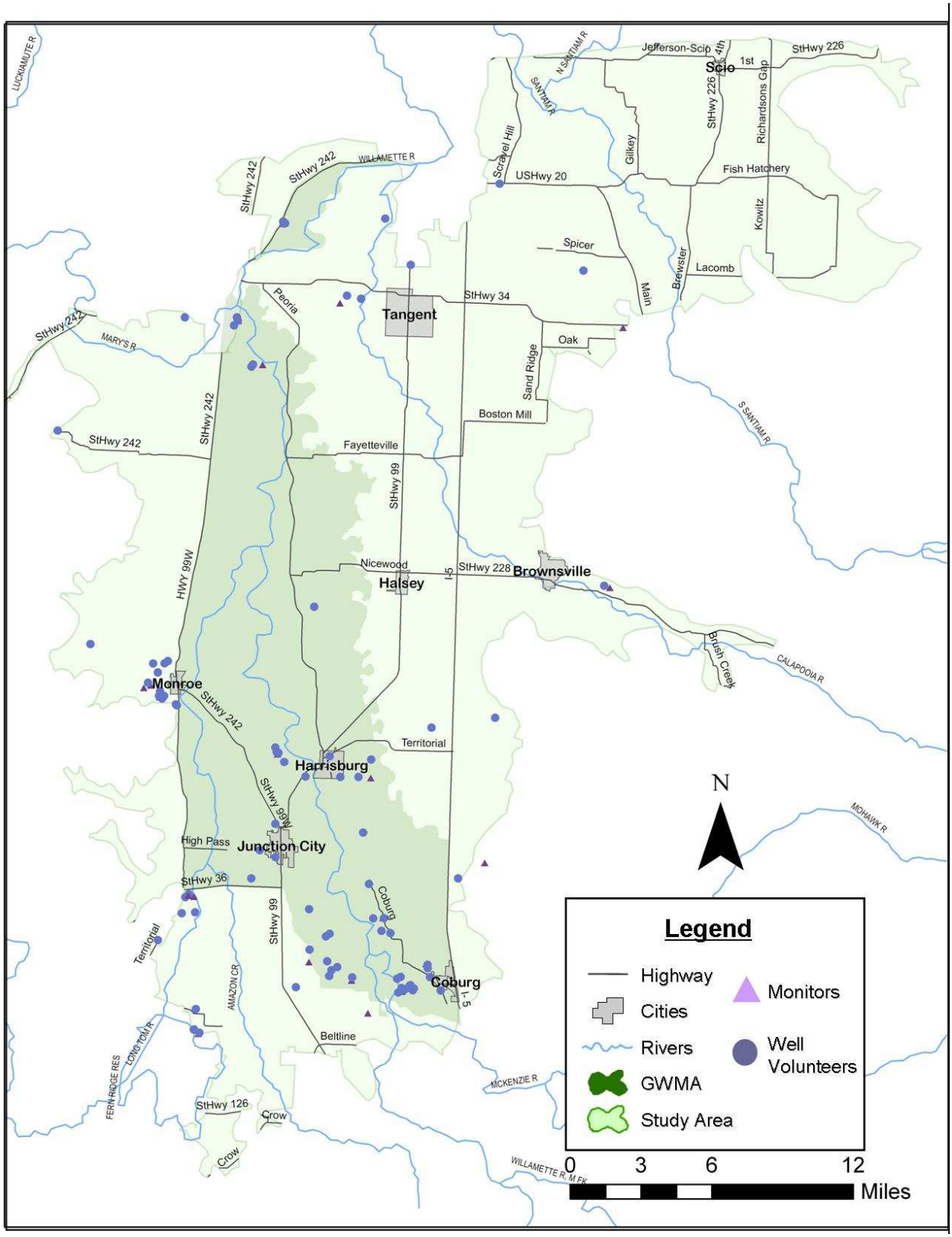

Figure 5. Location of all well volunteers and monitors within the study area. Monitors are marked by purple triangles, while well volunteers are marked by blue dots. In some cases, the distance between wells is too small to be resolved at this scale, so the number of wells visibly marked on the map is less than the total number of wells in the program.

Addresses of potential volunteers were queried in an ArcMap database containing residential address points within the study area (files provided by Lane Council of Governments). Those residing outside the study area were sent information describing the boundaries of the program, a schedule of upcoming OSU Extension Well Water Program events, a nitrate fact sheet, and contact information should they have further questions. Exceptions to the requirements that volunteers reside within the study area were made for individuals willing to serve as monitors, testing wells within the study area. The locations of the 118 volunteers in the program as of November 2006 are shown in Figure 5.

An additional site selection constraint was that the resident be dependent on their own private well for their drinking water supply. Exceptions were made for individuals receiving municipal water but willing to serve as a monitor, testing private drinking-water-supply wells other than their own irrigation well.

5.1.2 Sampling site access

Concern about access to sampling sites led to the decision that monitors should sample from an outdoor location at each home. There was some discussion of whether the nitrate concentration might differ between the outdoor sampling point and the indoor consumption point, due to a water treatment device installed at a point between the two faucets.

Monitors were asked to participate in evaluating this potential effect by taking samples of paired faucets (with and without water treatment) at a given residence. Their participation was solicited both because the tests needed to be conducted at a residence with a well, and because we wanted to give monitors an opportunity to practice using the test kit and provide input into the program design. Ten monitors expressed interest and were mailed protocol descriptions and data sheets. They were asked to conduct these tests in as many locations or as

many times as they liked, and then to return the completed data sheets. Only one monitor actually conducted this experiment and submitted results. While these data show a 1 ppm difference between the two sampled locations, it is difficult to draw conclusions from this small quantity of data (n=2).

5.2 Sampling Method Requirements (SAP B2)

5.2.1 Nitrate Collection

Well water samples for nitrate analysis were collected by monitors on or about the second Saturday of every month. Samples were usually collected at outdoor spigots, although monitors often sampled from an indoor tap when taking the sample at their home or that of a relative. Samples were collected in 120-mL plastic bottles with screw tops, following the protocol described in the Monitor Manual (SAP Section E3). Each monitor had a unique sample bottle for each well which was labeled with a unique identifying number corresponding to the well's location; this identifier was also recorded on the field data sheet with the nitrate reading. This number scheme was used to minimize association between the well owner, their location, and the nitrate reading.

5.2.2 Bacteria Sample Collection

Program coordinators tested every well in the program for total coliform bacteria and *E. coli* in November 2006. This sampling event was planned following volunteer recruitment, and occurred in the second month of volunteer sampling. It was thus considered burdensome to ask the volunteers to conduct the sampling, although volunteer assistance would have greatly facilitated the sample collection process. Materials necessary for the bacteria sample collection and analysis were provided by DEQ. Water samples of 100 mL volumes were collected in 120

mL sterile transparent nonfluorescent bottles. Samples were collected from the same outdoor tap from which nitrate samples are taken. Water was run for at least 3 minutes before each sample was taken, and care was taken not to contaminate the cap and neck of the bottle (DHS, 2006). Collected samples were labeled with the site's identifying number, date, time, and the sampler's name. Samples were stored in an iced cooler during the sampling day for a maximum of six hours before being transferred to a refrigerator at the laboratory, where they were stored for a maximum of two hours before being processed and incubated.

5.3 Analytical Methods Requirements (SAP B4)

Volunteer-collected samples were analyzed using color comparator field nitrate-nitrogen test kits, as discussed in Section 4.3. The samples were analyzed either at each well or at the monitor's home, following the protocol described in the Monitor Manual (SAP Section E3). Multiple test tubes and a test-tube rack were provided with the test kit to facilitate the simultaneous analysis of multiple samples.

The bacteria analysis procedure was selected after consideration of multiple alternatives. It was initially considered that collected bacteria samples would be sent to a professional lab to be analyzed. However, the cost to analyze 125 samples would have been roughly $2,800. These sums were beyond the project's scope, and thus alternative analysis facilities were considered, ranging from the OSU Department of Microbiology, the DEQ's mobile lab, or a municipal water quality testing facility. Instead, by writing up the bacteria sampling procedure in the SAP, we were able to obtain material support for the bacteria analysis from DEQ. In the description of the analysis protocol below, all necessary supplies were provided by DEQ, with the exception of the incubator which was located in the lab where analysis was conducted.

Bacteria samples were analyzed using the IDEXX Colilert® Quanti-Tray/2000 method (IDEXX Laboratories, Inc., Westbrook, ME). One packet of Colilert® reagent was added to each sample, mixed and dissolved. The sample was then poured into the Quanti-Tray/2000® pack. Packs were sealed using a Quanti-Tray® Sealer (IDEXX, Model 2x) following the IDEXX protocol. Sealed samples were placed in an incubator (Psychrotherm Controlled Environment Incubator Shaker, New Brunswick Scientific Co., Inc., New Brunswick, NJ) at 35°C for 24 hours. Between 24-28 hours following the initiation of incubation, samples were read for presence or absence of total coliform bacteria, as indicated by yellow-colored wells. Packs containing yellow wells were then placed under a 65 nm, long-wave UV lamp (Spectroline Fluorescence Analysis Cabinet, Model CM-10, Spectronics Corporation, Westbury, NY). Wells which fluoresced under the lamp indicated the presence of *E. coli* bacteria. All yellow wells and all fluorescing wells were counted following the Most Probable Number protocol.

5.4 Quality Control Requirements (SAP B5)

Quality control is "the operational techniques and the activities used to fulfill requirements of quality" (Shampine, 1993). Quality control for this program was designed largely to provide a check on the volunteer-conducted sampling protocol. There was also a quality control element to the bacteria sampling to check the bacteria analysis methodology. In both cases, duplicate samples were taken at 10% of the wells. Samples were collected as close to the volunteer sampling day as possible, with two samples taken four days following that day. Duplicate nitrate samples were analyzed by DEQ, while program coordinators analyzed the duplicate bacteria samples using the same method described above.

Samples were collected at fifteen randomly selected wells, representing roughly 10% of the wells to be sampled that weekend. Wells were selected using a stratified random sample to

ensure that the sampling of the maximum number of monitors was checked. Fifteen monitors were randomly selected, and then a single well was randomly selected from each monitor's list according to our records on October 30, 2006.

When possible, samples were collected from the same tap used by monitors. Nitrate samples were collected in reused, washed 500 mL polyethylene bottles supplied by DEQ, to which 12 drops of concentrated H_2SO_4 were added. Bottles were kept in a cooler on ice for up to 6 days until they were transported to the DEQ Water Quality Lab for analysis. Duplicate bacteria samples were collected following the previously-described technique. Because the presence of coliform bacteria in a drinking-supply well may require action, such as shock-chlorination, owners of wells in which coliforms were identified were referred to a certified water quality lab for further testing.

5.5 Data Acquisition Requirements (SAP B9)

In addition to the nitrate and bacteria data, certain auxiliary information was collected about each well to aid in the interpretation and reporting of results.

As discussed earlier, specific information regarding the characteristics and construction of wells is obtainable in Oregon in the form of well logs for most wells built beginning in the 1950s. Public access to these records is provided on the Oregon Department of Water Resources Well Log Query website[3]. This Well Log Query tool was used to search for well logs for the monitored wells. Parameters used in the search depended upon information provided by the well owner, and included owner name, township-range-section, tax lot, street address, well depth and age. Well logs were collected for as many wells as possible and were verified with the corresponding owner to ensure a match. The most important parameter to be extracted from

[3] http://apps2.wrd.state.or.us/apps/gw/well_log/Default.aspx

these logs was the well depth. The wells for which a well log could not be identified were scheduled to be measured in March 2007, following Oregon Water Resources Department recommendations.

Latitude and longitude information was obtained for each well. This information, along with the assigned program well ID number, was submitted to DEQ in order for them to assign their own identification number to the well for data reporting and sample analysis purposes. In most cases, address information was queried in the DEQ's on-line LASER database[4], which identifies latitude and longitude information for most address points within Oregon. In selected cases where addresses could not be identified, we took latitude/longitude readings at the residence using a hand-held GPS unit (Explorist 210, Magellan Navigation, Inc., San Dimas, CA).

5.6 Data Management (SAP B10)

The approach used in compiling and reporting data was the result of consultation with monitors, review of the relevant literature, and consideration of feasibility. Many researchers have found that web-based databases are an excellent method with which to present community-collected data, and many of the monitors were interested in the prospect of digitally reporting their results. However, developing a database which is both user-friendly and informative is a challenging task, and seemed to be beyond the scope of this program. Instead, we maintained an Excel database of nitrate and bacteria results, for annual submittal to the DEQ's web-based LASER database.

Community outreach objectives related to data management were met by regularly informing volunteers of the results of well tests. Each month, the monitor delivered a nitrate

[4] http://deq12.deq.state.or.us/lasar2/data.aspx?dt=0&mw=846&mh=330

results report to the owners of each well which had been tested that month. The format of this report included the nitrate-N level (in ppm), guidance on how to interpret that result, and OSU Extension Well Water Program contact information (SAP Section E3). Following the sampling for coliform bacteria in November, results were summarized for every volunteer in a standardized report which included interpretation guidelines and contact information for professional laboratories certified to conduct coliform tests. Finally, it was expected that at the end of the first year, a summary report would be issued that presented the nitrate trends throughout the region, with an insert describing the results at each volunteer's well.

The data for the summary report would be obtained from monitors, who submitted datasheets on a monthly basis after testing their wells (SAP, Section E2(ii)). These requirements were challenging in the beginning of the program. In the first month, only ten monitors submitted their datasheets within the first week, and by the time of the second sampling date, 20 out of 22 monitors had submitted data from their first monitoring. Submittal rates appeared to be improving in the second month, with fourteen datasheets received in the first week following sampling. It was expected that as monitors grew more familiar with the protocol, data submittal would occur more promptly. All available nitrate and bacteria data, including quality control data, were compiled and maintained at OSU with the intent of submittal to DEQ at the end of the first year.

CONCLUSION

Questions remain about the effectiveness of the volunteer monitoring program in changing participants' attitudes, behaviors, and involvement in proactive groundwater management. Many of these questions will be addressed in a forthcoming work (Moscowitz, unpublished). It is quite probable that well owners, when reviewing the results of monthly nitrate tests at their private well, will change their consumption of well water, their land management practices, or their well and septic system care. Whether the aggregated data will be used for any larger scale management purpose is less certain, and may be less a function of the data quality then of our current mechanisms to regulate private wells.

Residents in the Coburg area may be able to present the data from their wells, which in the first two months have shown high nitrate concentrations, as supporting evidence for the need to connect the area's residents to a wastewater treatment system. Residents in the Cheshire area may see increases in their nitrate concentrations as a new development is put in, and may be able to use these data in negotiating the terms of future developments. However, in light of the opinions of rural residents found by Kite-Powell and Harding (2006) that state and local regulation should assist in addressing groundwater pollution problems, there currently may not be much more that state or county agencies can or will do. The DEQ has already established a Groundwater Management Area in the Valley, and experience from the development of the GWMA Action Plan suggests that county governments may be very hesitant to impose new regulations on septic system type or to impose relevant zoning measures.

Another lingering question is how this experience translates into the likelihood of similar groundwater monitoring programs developing in other areas of the country. Certain assets of this program, such as the resources of a university and existing relationships with the DEQ, may

be more difficult for a strictly volunteer-based group to come by. It is unclear to what further degree groundwater contamination will need to enter public perception before volunteer-based groundwater monitoring can take off. The success of surface water monitoring programs may be attributed in part to two simple factors not found in groundwater monitoring. It is easy to see the effects of pollution in a river or lake; and it is enjoyable to visit a river or lake in order to take samples. In contrast, the effects of groundwater pollution may not be sensed in a person consuming the water for decades, if at all; while the act of visiting wells is less of an idealized Sunday excursion.

Given these caveats, it is important to note the successes of this program, which may be considered in three parts: the partnership with the DEQ, the successful first two months of monitoring, and the expected cost effectiveness of the program.

There was some initial concern that the DEQ would not consider supporting this program, given that the field test kit is less sophisticated than much of the equipment loaned to volunteer groups by the DEQ. However, our experience was that thorough documentation of the sampling protocol according to stated DEQ objectives and open communication with relevant staff at the DEQ were sufficient means to gain approval. This approval has thus far been of great benefit to the program both in terms of technical and material support and in facilitating careful consideration of the program's methodology. The DEQ has funded analysis of bacteria samples at all wells, plus quality control analysis of duplicate samples at 10% of the wells for both nitrate and bacteria. In addition, elements of the sampling protocol, data reporting, training and quality control/quality assurance were all informed by DEQ requirements and suggestions.

Secondly, the program does not appear to be cost-prohibitive. While conducting a cost-benefit analysis was not within the scope of this project, it is recommended for further

investigation. Although the start-up costs for this program were high, particularly in terms of project manager hours, we estimate that it will cost on the order of $20/year to monitor each well in the program for nitrate (monthly) and bacteria (annually).

Finally, the volunteers appear to be comfortable with managing their responsibilities. Indicators at this stage range from the number of neighbors which monitors recruited (and continue to recruit), the percentage of assigned wells which have been tested according to schedule, and the continued excitement and interest in groundwater which we have noticed when speaking with the participants. It is still possible that winter weather and additional commitments will cause volunteers to leave the program, however thus far we have found that monitors are handily taking on the job of sampling wells and reporting nitrate results.

Monitoring private residential wells is a different task than monitoring a local stream. At its most basic level, it is an examination of a quality at the center of a person's health and home - the water that people consume on a daily basis. Thanks are due to all of the volunteers for choosing to open their homes and lives to this project.

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SAMPLE & ANALYSIS PLAN

Volunteer Groundwater Quality Monitoring: Nitrate in the Southern Willamette Valley

DEQ##-LAB-####-SAP
Version 3.0 – August 24 2006

Well Water Program
116 Gilmore Hall
Corvallis, OR 97331
Phone: (541) 737-6295
Fax: (541) 737-2082
http://wellwater.oregonstate.edu/volunteer.php

Laila Parker / Laura Moscowitz Project Manager	Date
Steve Hanson / DEQ Volunteer Monitoring Specialist	Date
Chris Redman / DEQ Quality Assurance Officer (QAO)	Date

December 2004

A. Project Management

A1. Distribution List

Oregon Department of Environmental Quality (DEQ), Oregon State University (OSU).

A2. Project/Task Organization

Name	Project Title/Responsibility	Contact
Laila Parker	Project Manager	541-737-6311 or parkelai@onid.orst.edu
Laura Moscowitz	Project Manager	541-737-6311 or moscowil@onid.orst.edu
Gary Atwood	Sample collection & analysis	998-6139
Richard & Connie Burdick	"	richard.burdick@oregonstate.edu
Russ Carey	"	razoruss@hotmail.com
Nancy Corr	"	corrfranklin@aol.com
Pam & Dennis Fiske	"	dennispamfiske@aol.com
Katie Goldberg	"	katiejoshrose@earthlink.net
Diana Hollingshead	"	diana@eugeneskindivers.com
David Landrum	"	d.landrum@hughes.net
Kristin Lee	"	lee@eugene.econw.com
Susan Lorshbough	"	rslorshbough@highstream.com
Phil & Nancy McCullum	"	pmccullu@uoregon.edu,
Marler McGinnis	"	daydream@cpros.com
Yvonne Miller	"	davonearth@peoplepc.com
Don & Connie Pratt	"	donp@goodwill-oregon.org
Chris Percival	"	crispy@cswinet.com
Jenny & Ed Rogers	"	jenedr@juno.com
Samantha Rounsavell	"	zanesr@centurytel.net
Rob Silbernagel	"	silbernagel.rl@juno.com
Maryanne Smith	"	coburghills@msn.com
Mindi & Neill Thornton	"	mindithornton@yahoo.com
Hilary White	"	pup@comcast.net
Emily Williams	"	sub_13_lime@yahoo.com
Laila Parker	Data Management & Analysis	541-737-6311 or parkelai@onid.orst.edu
Laura Moscowitz	Report Writing & Data Presentation	541-737-6311 or moscowil@onid.orst.edu
Steve Hanson	DEQ Volunteer Monitoring Specialist	503.229.5449

A3. Purpose Statement/Problem Definition/Background

The purpose of this project is to create a groundwater monitoring network in the Southern Willamette Valley in which volunteers will monitor their own and their neighbors' wells for nitrate. A secondary purpose is to increase awareness of local groundwater issues and improve public involvement in management efforts through community participation, outreach, and education. While this is expected to be a one-year pilot project examining the feasibility of using volunteer monitors to identify regional and temporal trends in groundwater nitrate, ideally monitoring would continue past the first year. The project is designed to involve minimal outside administration, in the hopes that volunteer monitors will eventually take ownership of the project and it will be self-sustaining. The data will be primarily used as a screening tool for the community to identify regions at high risk for nitrate contamination and to identify times of the year at which nitrate levels are highest in each locale. We would like for the data to be used by Oregon DEQ or another agency to look for regional and temporal trends in nitrate across the valley.

This monitoring program is one of many actions in response to the DEQ's declaration of the Southern Willamette Valley Groundwater Management Area (SWVGWMA). The SWVGWMA was designated as a result of evidence of high nitrate levels within the valley's groundwater, which supplies the majority of the drinking water in the region. The hydrogeology of the valley is complex, with good connections in some areas between the shallow and deeper zones of the aquifer, and confining layers in other areas which may restrict contaminated groundwater from moving directly into the deeper aquifer zones. In some areas of the Valley, the Willamette Silt Unit may offer some protection to underlying aquifers due both to its low permeability and its tendency to facilitate reduction of nitrate to nitrogen gas. As a result of this hydrogeologic complexity, and of the wide variety of land-use activities which may contribute nitrogen at the surface, the distribution of nitrate in the region's groundwater is highly variable. It is hoped that this monitoring project will help to clarify that variability for both residents and decision-makers.

A4. Project Task/Description

Residential drinking wells will be sampled for nitrate-nitrogen. Sampling will be conducted by 22 volunteer monitors, or pairs of monitors, who will each be responsible for testing 1-10 wells including their own. Monitors will recruit neighbors to participate in the program, and will be paired with neighboring well-owners who have expressed interest in the program. It is expected that no monitor will need to travel more than 2 miles from their home when conducting sampling, however some have agreed to travel longer distances. On the second Saturday of each month, monitors will collect water samples at each home from an outdoor spigot. Monitors will either analyze each sample in the field, or bring all the samples home and conduct the analysis there. If sample analysis is to occur later than one hour following sample collection, monitors will store the samples in a cooler or refrigerator, however analysis will occur that same day. Samples will be tested using a color comparator field nitrate-nitrogen test kit (#3354, LaMotte Co., Chestertown, MD). Readings will be recorded on a form to be given to the homeowner and on a datasheet either in electronic or paper format, which will be submitted to the data manager. Bacteria samples will also be taken in November 2006 both as an indicator of well condition and

as a screening for the well owners. Bacteria samples will be collected by the project managers, with the help of interested volunteers, and will be analyzed using the Colilert® test (IDEXX Laboratories, Westbrook, ME) in a lab volunteered by John Selker at OSU. Nitrate data will be summarized using descriptive statistics in a report to be sent out to interested parties. Recipients will include participating well owners, who will also receive a detailed description of their own well's data. Data will also be analyzed for seasonal and spatial trends following the methods used by Mutti (2006), and/or recommendations from the OSU Student Statistical Consulting Service.

Project Timetable:

Tasks to be completed	Months for year 2006 - 2007											
	8	9	10	11	12	1	2	3	4	5	6	7
Sampling planning and revision	x	x	x									
Quality control tests	x	x										
Duplicate sampling & testing				x								
Monthly nitrate testing			x	x	x	x	x	x	x	x	x	x
Data entry			x	x	x	x	x	x	x	x	x	x
Developing data analysis method		x	x	x	x							
Seeking additional funding and support	x	x	x	x	x	x	x	x	x	x	x	x

The major constraint on completing this program is that funding and logistical support do not exist beyond June 2007. This presents a challenge even to completing the one-year pilot study. Beyond that, in order for the program to produce meaningful long-term results, it must either become entirely volunteer-run or it must be taken under the wing of another OSU graduate student or another agency. Currently we are developing a 319 grant proposal to seek further funding. As the monitoring program gets underway, we will look for particularly committed volunteers and speak with them about potentially taking a larger role in keeping the program running.

A5. Measurement Quality Objectives

The project is designed primarily to screen residential wells for high nitrate levels to aid rural residents in making management decisions regarding drinking water safety. Our sampling will characterize the ambient nitrate levels in residential drinking water from wells. Sampling is designed based on some assumptions that nitrate levels can be measured without accounting for diurnal fluctuations or drawdown. As this project is focused on characterization of the nitrate levels in residents' drinking water, it is important to note that people often consume water from the tap at times when the well has not been 'purged' by water-demanding activities such as showers. The drawdown assumption is supported by Mutti's (2006) findings of a minimal difference in nitrate levels from wells which were purged for 6.5, 9, 15 and 18 minutes. The assumption that any diurnal fluctuation effect can be ignored was tested by a group of three volunteer monitors, for a total of 14 morning/evening data points. On average, a difference of 0.3 ppm nitrate was detected between morning and evening readings, with a standard error of

35%. While these data are not conclusive, they suggest that if diurnal fluctuation does exist, it is not strong enough to be detected by these kits.

Other programs have required monitored wells to be constructed according to established standards, however as this program is designed to describe the quality of water which residents are consuming, similar constraints were not used in recruiting volunteers. Attempts will be made to correlate the data with relevant well information. When possible, well logs will be obtained from the Oregon Department of Water Resources Well Log Query website (http://apps2.wrd.state.or.us/apps/gw/well_log/Default.aspx), however well logs are often unavailable or do not contain adequate information to easily match them to existing wells. We will be conducting bacteria tests for every well in the program in November 2006 which should assist in determining whether there is a surface water contribution to the well, thus providing some information about well construction. Additionally, we plan to take depth measurements of wells for which well logs have not been obtained. These data on well depth, age and surface water contribution may be used in interpreting the nitrate data.

Given the limitations of the color reader in the nitrate field test kit, a lower level of accuracy and precision is expected than if the water samples were tested for nitrate in a laboratory. We do not expect to generate "A" level nitrate data as defined by the DEQ's field data quality matrix. The grade of the data quality will be determined following quality control checks which will be made at 15 sampling stations, as described in Section B5. We do, however, expect to generate "A" level bacteria data as defined by the DEQ's field data quality matrix. Bacteria tests will be conducted following DEQ-recommended protocols, using the recommended Coliliert® test kit.

Our understanding is that no comparable volunteer monitoring programs exist in which volunteers take and measure nitrate samples from wells using field kits. As a result, we do not expect comparability with other programs. The Draft Southern Willamette Valley Groundwater Management Area Action Plan calls for this program to sample at least 50 wells. Currently we estimate that 150 wells will be sampled monthly under the program.

Table 2: Accuracy and Precision Targets

Matrix	Parameter	Precision	Accuracy	Measurement Range
Water	Nitrate-Nitrogen	0.6 ppm ± 0.2 ppm*	1.9 ppm ± 0.2 ppm (or 35% error ± 3 %)	1 ppm to 15 ppm
Water	Total coliform, *E. coli*	± 0.6 log	NA	0 to >2419

*see Section B6

A6. Training Requirements and Certification

By the beginning of the program, all monitors will have participated in at least one training session in the use of the field kit and in sampling protocol; most monitors will have attended two training sessions. Training sessions include the Well Water Training held at Oregon State University on June 22; Community Orientation Meetings held in Junction City, Coburg, Corvallis, Monroe and Harrisburg during the week of July 17;, and two regional training and organizational sessions held October 4 in Junction City and October 11 in Corvallis. Training sessions are run by project managers Laila Parker and Laura Moscowitz. Four volunteer

monitors (including one monitor pair) came to the Well Water Training, with an additional 22 volunteer monitors (including three monitor pairs) coming to the regional meetings in July. All monitors with the exception of one attended either the Junction City or Corvallis meeting in October. All volunteers who came to training meetings were given a nitrate test kit in order to familiarize themselves with the method before beginning sampling.

The October trainings were designed to assign volunteered wells to neighboring monitors, to distribute additional testing materials (sample bottles, manual, etc.), and to review the testing protocol. As part of the protocol review, all volunteers were given two unlabeled water samples of nitrate concentrations 2 ppm and 6 ppm, which they tested independently using the provided manual (see Appendix E3). Each volunteer entered their results into a data form similar to that which they will use during sampling. Volunteers were then asked for their feedback on using the manual and the data form, and their datasheets were collected at the end of the program. Overall, the mean difference between the lab values and the values read using the kit was 0.8 ppm ± 0.2 ppm, while the mean percent error was 23% ± 5%. Comparing these results to those obtained by a group of OSU students and described in Section B6 suggests that the experience gained by the volunteers in using the kits over the course of the summer made a positive impact on their accuracy using the kits.

A7. Documentation and Records

Document or Record Name and Description	Storage Location	Storage Time
Volunteer Groundwater Quality Monitoring Sampling Analysis Plan	DEQ Laboratory & Department of Biological and Ecological Engineering (BIOE), OSU	5 years
Community Well Water Testing Program Manual Methods manual, developed at OSU	Monitors' test kits & BIOE, OSU	5 years
Monitor Datasheets	Monitors' homes (folder or hard drive) & BIOE, OSU	5 years
Quality Control record notebook	BIOE, OSU	5 years

B. Data Generation and Acquisition

B1. Sampling Process Design

The project extent is determined by previously designated boundaries drawn by DEQ, and includes the overlay of the areas described by both the DEQ's initial Southern Willamette Valley study area and the current Southern Willamette Valley Groundwater Management Area (SWVGWMA). The initial study area is being used as it was drawn to encompass an area within which nitrate was expected to be a contaminant of concern, based on topography and soils.

There is a small region of the SWVGWMA in South Corvallis which is not included in the initial study area but is included in this project as the project was designed to target the SWVGWMA.

As sampling occurs on private property, sites will be selected based on residential interest in response to newspaper articles, flyers, and conversations with neighbors who may already have volunteered for the program. Nitrate levels will be assessed at each site, using a field nitrate-nitrogen kit, on the second Saturday of every month. Coliform bacteria assays will be conducted on a one-time basis (with potential to conduct once a year if funding exists) in the second weekend of November, when it is assumed that there will have been adequate rainfall to assess surface water contributions.

If there are resources to expand the project, it is presumed that a new outreach campaign will recruit new volunteers. It is expected that the project boundaries will remain constant, but that decision may be reversed by future managers of the project.

Ideally, as each well owner has agreed to participate in the program, each monitor will have complete access to the sampling sites he or she is responsible for. In order to minimize imposition on well-owners, monitors will take their readings at outdoor spigots. Well owners will be expected to show monitors the location of such spigots and otherwise facilitate the sampling process as needed. A small project to test for a measurable difference in nitrate between indoor and outdoor faucets (which might be caused by water treatment devices) was designed, but only carried out by one monitor (total of two indoor/outdoor data points). However we do not expect water softeners to affect nitrate levels (ODEQ, 2004). Appendix E1 contains a map of all sampling stations, and a table showing station ID numbers. See Section B9 for further discussion of these data.

B2. Sampling Method Requirements

B2.1 Nitrate

As discussed above, nitrate samples will be collected at outdoor spigots on the designated sampling day. Monitors will follow a protocol in a manual produced by OSU Extension (Section E3), which will include the basic steps as follows:

1. A 5-mL sample of water is added to a test tube
2. Tablet #1 is added to the test tube and dissolved.
3. Tablet #2 is added to the test tube and dissolved.
4. After 5 minutes, the test tube is inserted into a color comparator reader and the nitrate concentration in the tube is read.

Initially we had intended to give all monitors a bottle of a known nitrate concentration, which they could analyze each month and use as a visual standard against which to compare their samples. However, both our own experimentation and the experience of others (e.g. Katznelson, 1997) suggest that using such a standard does not improve the accuracy of the readings, and for this reason we decided not to use a standard.

The split samples taken by project managers for quality control in November will use the sample collection containers, holding times and preservation specified in Table 4 of the QAPP

DEQ04-LAB-0047-QAPP. Samples will be collected from the same outdoor tap from which volunteer samples are taken, just after the monitor collects his/her sample. 500 mL samples will be collected in reused, washed 500 mL polyethelyne bottles supplied by DEQ, to which 12 drops of concentrated H2SO4 will be added. Bottles will be kept in a cooler and then transferred to a refrigerator at the OSU Selker Lab until they can be transported to the DEQ Water Quality Lab.

B2.2 Bacteria

100 mL water samples will be collected in 120 mL sterile transparent nonfluorescent bottles. Samples will be collected from the same outdoor tap from which nitrate samples are taken. Water will be run for at least 3 minutes before samples are taken, and care will be taken to ensure that the cap and neck of the bottle are not contaminated as the sample is taken. Samples will be stored in an iced cooler during the sampling day for a maximum of 6 hours before being transferred to a refrigerator in the OSU Selker Laboratory.

B3. Sample Handling and Custody Procedures

B3.1 Nitrate

Monitors may either read each sample at the sampling station (well) or they may collect all their samples and do the testing at home. Each monitor will have a sample bottle for each well which is labeled with a unique identifying number corresponding to the well's location (see Appendix E1). A list of these numbers and the locations to which they correspond will be maintained at OSU Extension and each monitor will have a list of the sites for which they are responsible. This number scheme will be used to minimize association between the well owner and the nitrate reading. The protocol for sample labeling is discussed in the monitors' manual (Appendix E3). Monitors will also record this information on the field data sheet shown in Appendix E2.

During the split sampling field trip, collected samples will be labeled with the site's identifying number, date, time, and the sampler's name. As described above, samples will be transferred to a refrigerator at the OSU Selker Lab until they can be transported to the DEQ Water Quality Lab. Samples will either be driven to the Water Quality Lab in Portland by one of the project managers on the following Tuesday morning when the lab is open, or will be shipped by Greyhound as specified in the DEQ's Watershed Assessment Mode of Operations Manual (03-LAB-0036-SOP).

B3.2 Bacteria

Collected samples will be labeled with the site's identifying number, date, time, and the sampler's name. Samples will be stored in an iced cooler during the sampling day, for a maximum of 6 hours before being transferred to a refrigerator in the OSU Selker Laboratory. Samples will be processed and incubated within 8 hours of arriving at the laboratory.

B4. Analytical Methods Requirements

B4.1 Nitrate

Monitor-collected samples will be analyzed using the LaMotte Nitrate-Nitrogen test kit (#3354, LaMotte Co., Chestertown, MD). This kit was chosen based on its being relatively easy to use, non-toxic, and inexpensive. The kit uses zinc to reduce nitrate to nitrite, which then undergoes diazotization/coupling to form a pink color, with darker colors indicating higher nitrate levels. The color of the sample is then matched to a color standard using a slide viewer system, and an approximate nitrate-nitrogen level (ppm) is read. Monitors will either analyze each sample in the field, or bring all the samples home and conduct the analysis there. Sample analysis will occur no later than one hour following sample collection. Processed samples will be poured down the drain. Details of the methods are attached in the manual in Appendix E3.

Split samples will be collected and transported as described in Sections B2 and B3. They will be analyzed using standard methods for nitrate-nitrite at the DEQ Water Quality Laboratory.

B4.2 Bacteria

Bacteria samples will be collected, transported and stored as described in Sections B2 and B3. Upon their arrival at the OSU Selker Laboratory, they will be analyzed using the IDEXX Colilert® Quanti-Tray/2000 method by the project managers. One packet of Colilert reagent will be added to each sample, mixed and dissolved. The sample will then be poured into the Quanti-Tray pack and sealed following the IDEXX protocol. Sealed samples will then be placed in an incubator at 35°C for 24 hours. At the end of this period, but before 28 hours have passed, samples will be read following the Most Probable Number protocol. Data will be recorded into a datasheet and subsequently entered into the master database. Waste will be disposed of in the garbage without sterilization.

B5. Quality Control Requirements

B5.1 Nitrate

During the second sampling day (November), project managers will accompany randomly selected volunteer monitors on their sampling trips, collecting simultaneous samples at stations sampled by the monitor. A total of fifteen samples will be collected, representing roughly 10% of the stations to be sampled that month. The split samples will be sent to DEQ's Water Quality lab for analysis. Resultant values will be compared with the monitors' values to determine the accuracy of the monitors' sampling results.

Monitors' accuracy with the field kit alone will be assessed during the training to be held October 4, at which time the volunteers will be given unidentified samples of a known concentration to read using the kit, as described in Section A8.

We had originally planned to also take routine ambient monitoring samples, through coordination with the DEQ's GWMA monitoring plan. However, there is only one well within the volunteer monitoring network which is also being monitoring by the DEQ, and their monitoring schedule does not appear to coincide with ours. They are sampling quarterly, and sampling in the month of November will be at the end of the month. Thus the utility of this approach for data quality control is up for debate.

If quality control results show a sampling problem with the LaMotte test kits, we will contact the manufacturer and look into using an alternate field test kit. If the results show monitor error,

we will either conduct refresher training sessions and/or accompany monitors on upcoming sampling days.

B5.2 Bacteria

The bacteria sampling will occur only once during the sampling year. If the DEQ would like this sampling event to include side-by-side sampling as a quality check, we can arrange for samples to be provided to the DEQ Water Quality Laboratory according to the time requirements set forth in the DEQ04-LAB-0047-QAPP. Alternatively, we could conduct duplicate samples at 10% of the wells, and examine the duplicate results to determine our accuracy. We plan to refer any residents in whose well water we identify coliforms to a certified water quality lab for further testing, thus the function of this sampling is more as a screening than as a definitive test.

B6. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

B6.1 Nitrate

Before each sampling day, monitors will inspect their test kit to ensure that sampling tubes and bottles are clean and dry, supplies of chemical tablets are adequate for the number of samples to be taken, and all the contents of the kit are present. When chemistry tablets are low, monitors will request an additional supply from project managers. Project managers will be responsible for testing each new batch of tablets as it is received from LaMotte before distributing the tablets to monitors.

Before each sample is taken, monitors will rinse the relevant equipment (sample bottle, test tube, beaker, syringe) with the water to be sampled. All materials will be rinsed with tap water after sampling is finished to remove any reagent residue. Given the level of precision afforded by this method, we are not concerned about nitrate residues on the equipment. All materials will be air-dried before being stored.

Accuracy and precision of the nitrate test kit was evaluated through an experiment conducted in September 2006. Twelve graduate students/research assistants in the Department of Biological & Ecological Engineering volunteered to participate. Each participant was given eight nitrate samples (two sets of four concentrations) to read using the LaMotte kit. The samples were donated by Pacific Analytical Lab in Corvallis, and were all residential well water samples which had been analyzed by the lab and then stored for a required period of 30 days before being donated to our program. After reading the first set of four samples, half of the participants were given a reference 4.0 ppm nitrate standard made from nitric acid buffered with NaOH to be at pH 5.5. These six participants were asked to read the standard before reading each sample. Results indicated no significant difference between accuracy and precision in readings conducted with or without the standard. Overall, the mean difference between the lab values and the values assigned using the kit was 1.9 ppm ± 0.2 ppm, while the mean percent error was 35% ± 3%. The mean difference between values read for subsequent samples was 0.6 ppm ± 0.2 ppm.

B6.2 Bacteria

As the incubator in the Selker lab at OSU has not been used recently, we will inspect it before use and check that all parts are working and that its temperature reading is accurate. If we

find any problems with the incubator, we will seek out another incubator (this should be relatively easy to find).

B7. Instrument Calibration and Frequency

Nitrate test kit instrumentation will not be subject to calibration. However, if the program lasts for more than the initial year, monitors will be expected to participate in refresher training sessions.

B8. Inspection/Acceptance Requirements

Each monitor will be responsible for storing his or her equipment in a cool and dry place, protected from freezing, direct sunlight, and extreme temperatures. Monitors will be responsible for ensuring that kits are adequately supplied, and will contact project managers if any additional supplies are required. Bacteria sampling equipment will be handled as specified.

B9. Data Acquisition Requirements

All wells have been assigned an ID #, recorded by the responsible volunteer monitor and the project managers, however we are still lacking street addresses for some wells, which we expect to receive in the coming month as new volunteers complete and return their application materials. Latitude and longitude has been identified for a majority of the wells using the LASER website; additional information will be added as we receive the addresses, although for some cases we expect to need to take location data with a GPS unit during the bacteria sampling in November. During the process of obtaining latitude and longitude data, each well was checked for correspondence to an existing LASER identification number; in cases where such a number did already exist it was recorded in Appendix E1.Source of latitude and longitude for each site will be noted in the database.

Whenever possible, well logs will be obtained from the Oregon Department of Water Resources Well Log Query website (http://apps2.wrd.state.or.us/apps/gw/well_log/Default.aspx). These logs will be found using address, tax lot, previous owner, well depth and well age information provided by volunteers. As well logs often do not exist for existing wells or do not contain adequate information to easily match them to existing wells, we do not expect to find logs for every well in the program. Currently, well logs have been found for only 27% of the 65 participants for whom well logs were sought. Thus we plan to supplement this data for wells for which we have not located well logs by taking well depth measurements over the course of the following months, using two well depth probes owned by OSU Extension.

B10. Data Management

Data will be stored electronically, in field data sheets, and in postcards sent to well owners. Monitors will have the option of recording their data in paper or electronic format. The paper field data sheets are printed in a duplicate form. Monitors will keep the lower sheet and mail the upper sheet to the Data Manager. The electronic forms can be download from the volunteer website (http://wellwater.oregonstate.edu/volunteer.php) and mailed to the Data Manager; a copy will be stored on the monitor's computer. Monitors will also be responsible for mailing well

owners monthly postcards with their nitrate reading and some information about interpreting that reading. Well-owners may decide to store these postcards in a long-term, retrievable manner. Monitors will be provided with all the necessary postage for mailing both postcards and field data sheets. The Data Manager (this role may be taken by an eager volunteer) will be responsible for entering the data on-line into a database established at OSU. Each year, the project manager will also be responsible for entering the year's accumulated data into DEQ's LASAR database according to the normal grab water quality submittal format. Data will be submitted in Excel spreadsheets. The first data submission will occur at the end of the pilot study or when funding expires, but not longer than a year following the beginning of the project (e.g. October 2007).

A description of the data fields used in the field data sheet are shown in the list in Appendix E2. These data fields are a modification of the ODEQ grab data submittal procedure for the 2004 303(d) list. Also to be found in this Appendix are two sample data sheets – one blank and one filled-in, as well as the postcard which monitors will send to their respective well owners. Project managers will be responsible for monthly checks of the on-line database for completeness and reasonableness. If any station is missing data or if the data seems unreasonable, the project manager will contact the appropriate monitor to discuss the issue.

Software will be selected to present the data spatially and to conduct the statistics discussed in section A6. Results will be presented on the volunteer website and in an annual report to be sent to volunteers and other interested parties.

C. Assessment and Oversight

C1. Assessment and Response Actions

Following the receipt of analytical results from split sampling field trips, results from the laboratory and the monitors' analysis will be compared. Volunteer data will be considered to be adequate if the difference between volunteer and laboratory results is within 2 standard deviations of the mean difference between duplicate samples using the kit (0.6 ppm ± 1.7 ppm). Data beyond this action level will prompt review of the sampling methodology, the test kit, and the volunteers' ability to use the kit.

The project managers will be responsible for training the volunteers before the monitoring program begins, and for conducting refresher training courses as necessary. The need for refresher training courses may be determined based on review of the correlation between split samples or feedback from monitors. Project managers will stay abreast of developments in test kits and may determine that an alternate test kit should be used if it is deemed to be more accurate or easy to use.

C2. Reports to Management

Quality control tests will be conducted by the project managers, who will take action if necessary. Monitors will report their sampling results monthly, including duplicate samples when necessary, and project managers will review that information.

D. Data Validation and Usability

D1. Data Review, Validation, and Verification

Data result values will be classified based on standards determined by the project managers in consultation with the DEQ Volunteer Monitoring Specialist Steve Hanson. Determination of whether collected data meets the plan's objectives will be conducted as described in section D1 of the QAPP DEQ04-LAB-0047-QAPP

D2. Validation and Verification Methods

Data validation and verification will proceed as set forth in section D2 of the QAPP DEQ04-LAB-0047-QAPP. Monitors will be responsible for reviewing field data sheets at the end of each sampling day for completeness and reasonableness. After entering the data into the database, the data manager will review entries for transcription errors. Following data entry, project managers will review the database for reasonableness and completeness, and will respond as necessary as described in section B10. Project managers will also be responsible for reviewing laboratory results from split sampling trips, and comparing the results with the relevant monitor-collected data. Data quality levels will be determined following the split sampling trip in November through consultation with the DEQ Volunteer Monitoring Specialist Steve Hanson

D3. Reconciliation with Data Quality Objectives

Reconciliation with data quality objectives will proceed as described in section D3 of the ODEQ QAPP DEQ04-LAB-0047-QAPP, although re-sampling is not expected to occur if data quality indicators do not meet the project's specifications. Instead, the focus will be on retraining volunteers and improving the sampling plan if necessary.

E. Appendices

E1. Well Locations

E1.1 List of wells.

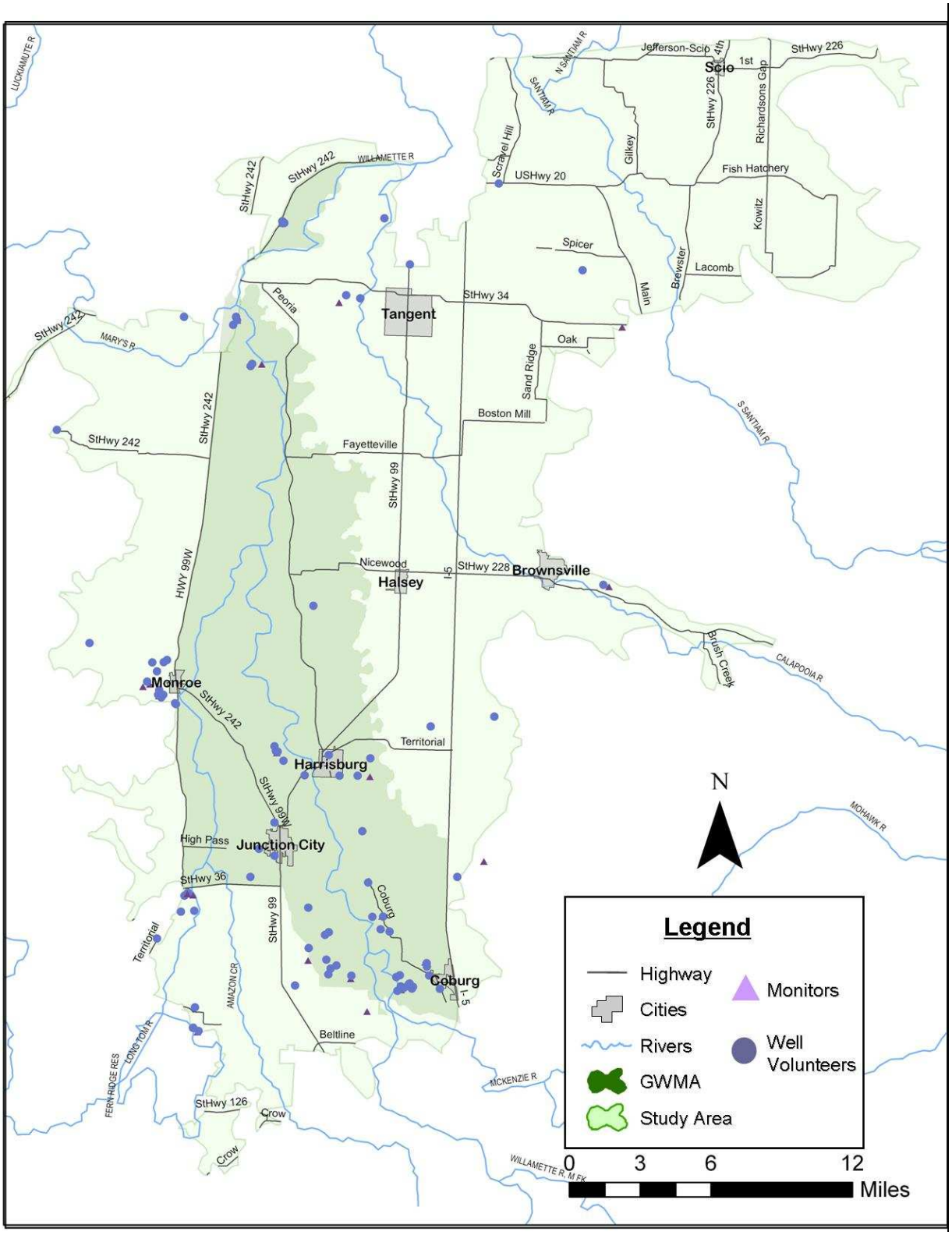
Well ID numbers are assigned based on the monitor's kit number: if the monitor's kit number is 1, their well ID # will be SWV1.0, and the wells they test will be SWV1.1, SWV1.2, etc. Address gaps will be filled as applications are received and missing latitude/longitude data will be collected by GPS if necessary over the months of October/November. LASER #s are provided when found to exist for that well.

Name	City	Latitude	Longitude	Well ID #	LASER #
Jenny & Ed Rogers	Junction City	44.1895	-123.2784	SWV1.0	
Chad Garner	Junction City	44.1866	-123.2755	SWV1.2	
Dana & Denise Garner	Junction City	44.1898	-123.2786	SWV1.3	
Matt (Garner rental)	Junction City	44.1874	-123.2763	SWV1.4	
Jim (Garner rental)	Junction City	44.1892	-123.2781	SWV1.5	
Diana Hollingshead	Eugene	44.1012	-123.2699	SWV2.0	
Candi Outka	Eugene	44.1012	-123.2699	SWV2.1	
Nova Hollingshead	Eugene	44.1044	-123.2729	SWV2.2	
Donnie Marguess	Eugene	44.104	-123.2726	SWV2.3	
Art Nersecien	Junction City	44.1179	-123.2739	SWV2.4	
Kristin Lee	Junction City	44.1378	-123.1435	SWV3.0	
Miriam Reinhart	Junction City	44.1378	-123.1434	SWV3.1	
Jean Phifer	Junction City	44.1653	-123.1623	SWV3.2	
Kathryn Sampson	Junction City	44.1653	-123.1664	SWV3.3	
Laura & Dave Pimentel	Junction City	44.1574	-123.1798	SWV3.4	
Tiffany & Tad Lueck	Junction City	44.1709	-123.1482	SWV3.5	
Emily Williams	Brownsville	44.3847	-122.9335	SWV4.0	
Ron Bonham	Halsey	44.3711	-123.1906	SWV4.1	
Winnie Baron	Brownsville	44.3847	-122.1906	SWV4.2	
Marler McGinnis	Junction City	44.2623	-123.1292	SWV5.0	
Bob & Joan Franz	Junction City	44.2621	-123.1409	SWV5.1	
Roger Bristol	Harrisburg	44.2741	-123.1261	SWV5.2	
Ken & Kim Morrison	Harrisburg	44.2332	-123.1367	SWV5.3	
Lou & Lin Wilcox	Harrisburg	44.274	-123.1397	SWV5.4	
Maryanne & Dan Smith	Eugene	44.1487	-123.0757	SWV6.0	
John Critelli	Eugene	44.1463	-123.0757	SWV6.1	
Brad Chvatal	Eugene	44.1333	-123.0638	SWV6.2	
Dyane Mclmgren	Eugene	44.1477	-123.0757	SWV6.3	
Walker	Eugene	44.1465	-123.0757	SWV6.4	
Segebert	Eugene	44.1418	-123.0736	SWV6.5	
Gary Atwood	Junction City	44.2767	-123.2106	SWV7.0	
Rachael Feuerstein	Junction City	44.2768	-123.2078	SWV7.1	
Judith Ridge	Harrisburg			SWV7.2	

Name	City	Latitude	Longitude	Well ID #	LASER #
Al Beaser	Junction City	44.2323	-123.2092	SWV7.3	
Ed England	Junction City	44.2761	-123.2106	SWV7.4	
Curtis Griffith	Harrisburg	44.275	-123.1648	SWV7.5	
Jim Suess	Junction City	44.2803	-123.2106	SWV7.6	
Kathy Smith	Junction City	44.277	-123.2081	SWV7.7	
Russ & Kim Carey	Eugene	44.1178	-123.1259	SWV8.0	
Lonnie Ballard	Coburg	44.1348	-123.0916	SWV9.1	
Kellie Shelton	Coburg	44.1348	-123.0936	SWV9.2	
Richard Murphy	Coburg	44.1348	-123.0904	SWV9.4	
Neil Murphy	Coburg	44.1342	-123.0825	SWV9.5	24884
Robert Rust	Coburg	44.1348	-123.0898	SWV9.6	
Sam & Katy	Coburg	44.1348	-123.0899	SWV9.7	
Pam & Dennis Fiske	Junction City	44.1487	-123.1765	SWV10.0	
Julian & Debbie Brailsford	Junction City	44.1482	-123.1762	SWV10.1	
Doug & Brenda Lane	Junction City	44.1463	-123.1584	SWV10.2	
Lance & Loreis Evenson	Junction City	44.1807	-123.1779	SWV10.3	
Phil Collins	Eugene	44.1319	-123.1859	SWV10.4	
Tim & Lyn Cogswell	Junction City	44.1463	-123.1517	SWV10.5	
Pat Bohanan	Junction City	44.1463	-123.1556	SWV10.6	
David Landrum	Coburg	44.1771	-123.116	SWV11.0	16648
Mel & Lori Blank	Coburg	44.1765	-123.115	SWV11.1	
Tiffany Blank	Coburg	44.1765	-123.115	SWV11.2	
Robert & Catherine Cook	Eugene	44.1962	-123.1265	SWV11.3	
Chase (house water)	Coburg	44.1646	-123.1077	SWV11.4	
Chase (yard)	Coburg	44.1646	-123.1077	SWV11.5	
Richard & Connie Burdick	Albany	44.5532	-123.1671	SWV12.0	
Helen Sprig	Tangent	44.5776	-123.1078	SWV12.1	
Mike Garner	Albany	44.6063	-123.1319	SWV12.2	
Orville "Swede" Ohling	Albany	44.5544	-123.1636	SWV12.3	24698
Bill Alden	Albany	44.5643	-123.1533	SWV12.4	
Katie Goldberg	Corvallis	44.5397	-123.2558	SWV13.0	
Laura Pagano	Corvallis	44.5425	-123.2558	SWV13.1	
Janet & Ed Starkey	Corvallis	44.5369	-123.2588	SWV13.2	
Carrie Kart	Corvallis	44.5451	-123.2562	SWV13.3	
Rob Silbernagel	Monroe	44.3151	-123.32	SWV14.0	
Annie Ingersoll	Monroe	44.3382	-123.372	SWV14.1	
Mike & Nikki Louie	Monroe	44.3151	-123.3196	SWV14.2	
Morgan & Jessica Bradley	Monroe	44.3218	-123.313	SWV14.3	
Mike & Amy Bodi	Monroe	44.3297	-123.3107	SWV14.4	
Mindi & Neill Thornton	Corvallis	44.519	-123.2362	SWV15.0	
Nancy Newcomb	Corvallis	44.5451	-123.3013	SWV15.1	
Dena Alexander	Corvallis	44.4684	-123.4045	SWV15.2	
Carol Finley	Corvallis	44.5117	-123.2464	SWV15.3	
Bette Lenehan	Corvallis	44.5148	-123.2465	SWV15.4	
Hilary & Robert White	Corvallis	44.6018	-123.2191	SWV16.0	

Name	City	Latitude	Longitude	Well ID #	LASER #
Julie O'Briant	Corvallis	44.6004	-123.2197	SWV16.1	
Michelle Lovrich	Corvallis	44.6007	-123.2196	SWV16.2	
Michelle Lovrich (rental)	Corvallis	44.6009	-123.2195	SWV16.3	
Ali	Corvallis	44.6001	-123.2199	SWV16.4	
Mark Merklein	Corvallis	44.6009	-123.2195	SWV16.5	
Mark Merklein (rental)	Corvallis	44.6016	-123.2192	SWV16.6	
Phil & Nancy McCullum	Monroe	44.3186	-123.329	SWV17.0	
Ron Tippetts Sr.	Monroe	44.2938	-123.2954	SWV17.1	
Yvonne Miller	Monroe	44.3104	-123.3068	SWV18.0	
Catherine Utter	Monroe	44.3283	-123.3162	SWV18.1	
Bob Zysett	Monroe	44.3288	-123.3099	SWV18.2	
Dave Crosby	Monroe	44.3097	-123.3096	SWV18.3	
Mike Stoffel	Monroe	44.3106	-123.3068	SWV18.4	
Roger King	Monroe	44.3088	-123.3145	SWV18.5	
Suzanne Vasquez	Monroe	44.2937	-123.2954	SWV18.6	
Cindy Darling	Veneta	44.0616	-123.3717	SWV18.7	
J Stanley Davidson	Harrisburg	44.2944	-123.0865	SWV19.1	
Mary Jarvis	Harrisburg	44.297	-123.0142	SWV19.2	
Lynn Tanantell	Harrisburg	44.2034	-123.0455	SWV19.3	
Susan Lorshbough	Junction City	44.1861	-123.2811	SWV20.0	
James Pitney	Junction City	44.198	-123.2189	SWV20.1	
Virgy Burkhard	Junction City			SWV20.2	
Elaine Payne	Junction City	44.2165	-123.2217	SWV20.3	
Carl & Enola Nielsen	Junction City	44.2117	-123.2089	SWV20.4	
Virginia Siewart	Junction City	44.1749	-123.286	SWV20.5	
Barbara Marra	Junction City	44.1867	-123.2808	SWV20.6	
Ronald Schmitt	Junction City	44.359	-123.168	SWV20.7	
Chris Percival (well 1)	Eugene	44.1317	-123.097	SWV21.0	
Chris Percival (well 2)	Eugene	44.1317	-123.097	SWV21.1	16659
Kurt & Barbara Wuest	Eugene	44.1322	-123.0872	SWV21.2	
Shannon Gray	Coburg	44.1337	-123.0868	SWV21.3	
John McBeath	Coburg	44.1342	-123.0969	SWV21.4	
Alan Schacher	Eugene	44.1311	-123.0971	SWV21.5	
Ed Brown	Eugene	44.1312	-123.0969	SWV21.6	
Sam Rounsavell	Lebanon	44.5428	-122.9249	SWV22.0	
Donald Rounsavell	Lebanon	44.5764	-122.9673	SWV22.1	
Carrie Lovell	Albany	44.6296	-123.0352	SWV22.2	

E1.2 Map of Study Area.



E2. Data Forms

E2.1 Description of Data Fields

These fields are to be included for each station in the database, with notation as to whether they will be recorded on the monthly datasheet, are constants to be maintained in the database, or will be entered by the database manager.

ORGANIZATION: Southern Willamette Valley Community Well Water Testing Program, always in database

SITE DESCRIPTION: identifying information entered by monitor each time data is recorded, serves as a check on Station ID

POINT OF SAMPLE COLLECTION: description of location from which well water sample is obtained

WELL DEPTH: from well log, if possible, always in database

WELL AGE: from well log, if possible, always in database
WELL CONSTRUCTION: from well log, if possible, always in database
ELEVATION: in feet, of the sample site, always in database

LATITUDE - in decimal degrees, always in database

LONGITUDE - in decimal degrees, always in database

SOURCE. source of latitude and longitude is GPS data from bacteria sampling, always in database

STATION ID: A unique number will been assigned to each sampling site and recorded each time data is reported. *Example:* SWV1.0

DATE of Collection: The date the sample was taken in MM/DD/YYYY format. *Example:*10/14/2006.

TIME of Collection: Use the 24 hour clock and HH:MM format. *Example:* 14:35 to designate 2:35 p.m.

NITRATE SAMPLE RESULT: The nitrate value of the water sample in ppm

DUPLICATES: Nitrate measurements of duplicate samples will be taken at a minimum of 10% of the total number of monitoring sites during the first sampling period.

EQUIPMENT USED: LaMotte kit #, will be recorded at each sampling.

CHEMISTRY BATCH NUMBER: Information to be provided to monitors, will be recorded at each sampling
MONITOR: The person(s) who collected the data, with contact information (full name and phone number), to be recorded at each sampling

CHECKED TRANSCRIPTION ERRORS: Data managers should always enter ‘yes’ here after entering data.

DATA REVIEW DATE: The date that the data was reviewed to ensure accuracy and completeness of all data points, entered by database manager

DATA REVIEW CONTACT: Name and contact information for the data reviewer, entered by database manager.

LAB CONTACT: If samples were analyzed by a laboratory, provide contact information (full name and phone contact).

QA/QC PROTOCOL FOLLOWED: "Volunteer Groundwater Quality Monitoring: Nitrate in the Southern Willamette Valley"

QA/QC PLAN AVAILABLE: Answer yes and provide contact information (full name and phone number).

COMMENTS: Any comments if appropriate.

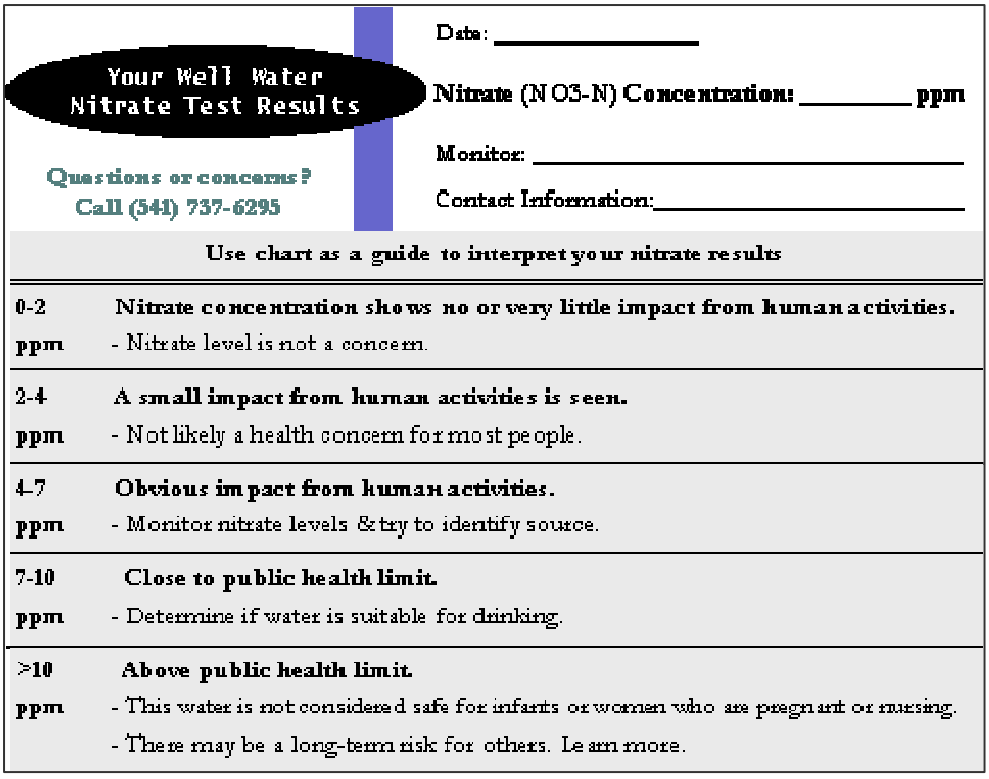
E2.2 Sample Datasheet

Sampling date:_____ Time: _____Weather: _____
Kit #:_____ Reagent 1 Batch #:_____ Reagent 2 Batch #:_____
Monitor name(s): _____ Contact info:_____

Well ID #	Site Description	Point of Sample Collection	Nitrate Sample Result	Comments
			ppm	
			ppm	
			ppm	
			ppm	
			ppm	

E2.3 Sample Postcard

(front)



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E3.Manual

Community Well Water Testing Program

Manual

This manual was developed by the
OSU Extension Well Water Team.
116 Gilmore Hall, Corvallis, OR 97331-3906
541-737-6294, well.water@oregonstate.edu
http://wellwater.oregonstate.edu

OSU Oregon State University Extension Service

Table of Contents by Topic

Introduction

As a volunteer well monitor, you play a key role in assessing and managing groundwater quality in the Willamette Valley. Maybe you became a volunteer because you are concerned about nitrate levels in your own well, or maybe you are interested in protecting groundwater quality across the Willamette Valley. By becoming a well monitor, you are helping to collect region-wide information about well-water nitrate levels, and raising awareness about well water issues. This manual is designed to help with your monthly sampling and data reporting. Resources for more information about groundwater issues can be found on page 10. You may always contact the OSU Well Water Extension program with any questions you may have about groundwater, well water, septic systems or monitoring.

Thanks for volunteering!

Map of Well Locations in the Program

Each month, the nitrate level at each of the wells marked on the map will be tested by a volunteer. The grey region encompasses the geographic extent of the community well water testing program. The darker region within the project boundaries is the Southern Willamette Valley Groundwater Management Area (GWMA) – see the related website on page 9. Locations will be added as wells are volunteered.

Sampling Day Overview

- ❖ Visit the wells on your list and collect a sample at each, using a labeled sample bottle, as described on page 3.
- ❖ Analyze each sample using the nitrate test kit following the protocol on pages 5-6.
- ❖ After sampling, follow the clean-up procedure on page 9.
- ❖ Report your results to the well owner and to the project managers as described on pages 7 & 8.

Before heading out, check your kit to make sure that you have:

- ○ Sampling bottles, labeled with station ID#
- ○ Test tubes, labeled with station ID#
- ○ Test tube rack
- ○ Syringe
- ○ LaMotte nitrate test kit with:
  - ▪ Reader
  - ▪ Adequate reagents (Nitrate 1 & 2)
- ○ Datasheet
- ○ Pen or pencil
- ○ Watch or timer
- ○ Umbrella for rainy days
- ○ Clipboard (optional)
- ○ Safety glasses (optional)
- ○ Gloves (optional)

Sampling Day Calendar for 2006-2007

October

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

November

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

December

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

January

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

March

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

April

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

May

S	M	T	W	T	F	S
	1	2	3	4	5	
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

June

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

July

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

August

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

September

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Southern Willamette Valley Community Well Water Testing Program

If you cannot sample on the designated day, please try to sample on the day before or after.

Thank you for volunteering!

9 Easy Steps for Nitrate Testing

1. Turn on the tap and fill the sample bottle. Use a different (labeled) sample bottle for each house. If it is raining, take precautions to ensure that no rainwater enters the sample.

2. Draw up 5 mL (cc) of each sample using the syringe.

3. Add the 5 mL from the syringe to the test tube.

4. Add one tablet of Nitrate #1 reagent (labeled on back of packet) to the test tube. Insert the rubber stopper.

5. Invert or shake the test tube to dissolve the tablet.

6. Add one tablet of Nitrate #2 reagent (labeled on back of packet) to the test tube. Insert the rubber stopper.

7. Invert or shake the test tube to dissolve the tablet.

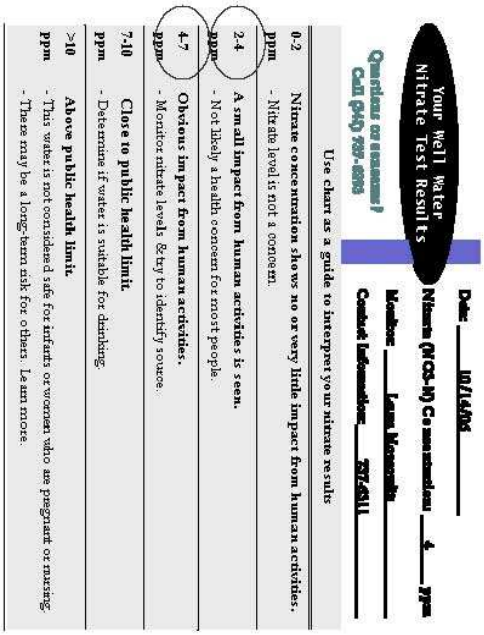
8. Wait five minutes.

9. Insert the test tube into the reader. Hold the reader so that a light-colored surface like a wall is behind it, but do not hold it to a light source. Match the color in the test tube to the closest color on the color slide. If the color in the test tube is between two colors on the slide (for example, 6 and 8 ppm), record the number which falls in between (in this case, 7 ppm).

Reporting your results

You'll need to record each reading on two forms: a postcard and a data sheet.

Postcards (sample below) should be mailed or delivered to each well owner every month. The side shown is where you will enter your information and the monthly reading. Each month's postcard has a different groundwater protection tip on the reverse (mailing) side. If a well's nitrate reading intersects two categories, fill out the postcard as shown below.



A sample datasheet is shown on page 8. Always fill out the datasheet completely. Readings of less than 1 ppm nitrate are still interesting, and the accompanying information (weather, reagent batch number) may help in interpreting the results. You may submit your datasheet using either U.S. mail or e-mail (see page 9).

Sample Datasheet

Sampling date: 10/4/06 Time: 2:00 pm Weather: partly cloudy, no rain
Monitor name(s): Laila Parker Kit #: 12
Contact info: 541-737-6311 Reagent 1 Batch # 2345A Reagent 2 Batch #: 4798

Well ID #	Site Description	Point of Sample Collection	Sample Result	Comments
SWV12.2	Green house with blueberries	spigot next to garage	5 ppm	water cloudy
			ppm	

ID numbers will be assigned before the first sampling date. These will be used to protect each person's privacy.

Back-up anonymous identification which will jog your memory, such as house color, in case the ID # is unclear or incorrect.

Should be the same at each house every time.

Record in whole numbers. For example, 5, not 5.3.

Anything unusual about the sample or sampling process, such as a downpour during sampling, or if you waited more than 5 minutes to read the sample.

Always fill out the datasheet completely, and save a copy of the data form in case it gets lost in transit. Digital forms can be saved on your hard drive, paper forms in the envelope in your kit. Digital forms may be downloaded from: http://wellwater.oregonstate.edu/volunteer.php

After Sampling

DISPOSING OF WASTE

You may pour any and all wastes produced during the sampling process down your sink or on the ground, as the test kit reagents are non-toxic.

CLEANING YOUR EQUIPMENT

Clean your equipment between samples and after the entire sampling process to improve the accuracy of your readings.

- Before collecting each sample:
  - Triple rinse the sample bottle with the water to be collected
- Before analyzing each sample:
  - Triple rinse the test tube and the syringe (pull up and squirt out water) with the collected water.
- After sampling:
  - Rinse everything with tap water and air dry.

STORING YOUR EQUIPMENT

Once all of your equipment is dry, store it in the provided box in a cool dry place (e.g. not in your car). Reagents in the test kit may be damaged if exposed to prolonged light, heat or cold.

MAILING YOUR DATA

Regular mail (using provided postage & envelopes):
Well Water Monitoring Program
116 Gilmore Hall , OSU
Corvallis, OR 97333
E-mail: well.water@oregonstate.edu.

Please save a copy of each completed data form in the envelope in your monitoring kit or on your hard drive.

Internet Resources & Contact Information

Groundwater-specific resources:

S. Willamette Valley Groundwater Management Area:
http://groundwater.oregonstate.edu/willamette/

The Oregon Well Water Program:
http://wellwater.oregonstate.edu/

Oregon Water Resources – Well Log Look-up page:
http://apps2.wrd.state.or.us/apps/gw/well_log/Default.aspx

Oregon Department of Environmental Quality – Groundwater:
http://www.deq.state.or.us/wq/groundwa/wqgw.htm

Volunteer programs:

This program:
http://wellwater.oregonstate.edu/volunteer.php

Volunteer Water Quality Monitoring:
http://www.usawaterquality.org/volunteer/

U.S. Environmental Protection Agency Volunteer Monitors:
http://www.epa.gov/ow_ow/monitoring/volunteer/

Groundwater Guardian:
http://www.groundwater.org/gg/learnmore.html

No web access? Call Gail Glick Andrews for a wealth of groundwater-related information: 541-737-6295

Run out of postage? Datasheets? Questions? Concerns? Call Laura Moscowitz at 541-737-6294.

This manual was developed by the Oregon State University Extension Well Water Team. Thanks to the 2005 Weeds Watch Out! Manual (Oswego River Basin, NY) which was used for guidance.

E4. Literature Cited

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Mutti, J. G. 2006. Temporal and Spatial Variability of Groundwater Nitrate in the Southern Willamette Valley of Oregon. M.S. Thesis, Oregon State University, Corvallis, OR.

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