Assessing Knowledge and Public Awareness of Nitrate Groundwater Pollution in the Southern Willamette Valley

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Water Resource Policy and Management
Oregon State University, 2009

Abstract

Nitrate inputs from agriculture, septic systems and animal waste in the Southern Willamette Valley led to the May, 2004 declaration of a Ground Water Management Area (GWMA) by the Department of Environmental Quality (DEQ). The DEQ, as the lead agency responsible for improving water quality in the area, is tasked with educating and organizing the affected population. The Southern Willamette Valley Groundwater Management Area Committee, a citizen's advisory committee made up of a group of stakeholders in the region overseen by the DEQ, developed an "Action Plan" to address education and outreach. The nitrate pollution is an anthropogenic problem and therefore, resolution is dependent upon mitigating contributive behaviors. Since knowledge of the problem is considered an essential precursor to mitigating contributive behaviors, a profile of knowledge was conducted.

In order to profile levels of policy relevant knowledge throughout the GWMA community, primary data were collected through a random mail survey of 454 GWMA residents. Statistical analysis using SPSS was used to create two scales of knowledge measurement using familiarity with groundwater terminology and self-assessed awareness of the issue. The survey also looked at knowledge gaps among the population using socio-demographic variables to predict and measure differences in knowledge. Results suggest that gaps in knowledge are differentiated by the predicted socio-economic indicators such as age, gender, education and income. In addition, variables such as well ownership and frequency of well testing were also found to be significant predictors of knowledge. The results also indicated that the GWMA population was generally unaware of the GWMA designation and its boundary.

Key Words: groundwater, nitrate, social capital, collective action, rational choice theory, policy relevant knowledge, common resource management

Introduction

"Without knowledge there is no (perceived) problem, no public awareness, and consequently no policy process…" (Janicke, 1997)

In May, 2004 the Oregon Department of Environmental Quality (DEQ) declared a portion of the Southern Willamette Valley a Groundwater Management Area (GWMA) due to groundwater nitrate levels that exceed federal (10 mg/L) and state (7 mg/L) Maximum Contaminant Level (MCL) standards (EPA, 2009). The standards are determined by the Environmental Protection Agency to protect human health based on epidemiological data of the impacts of exposure to nitrate via drinking water (EPA, 2009). As a result of the designation, several state agencies responsible for managing water quality such as the DEQ, Department of Agriculture, Water Resource Department, Department of Human Services, as well as others are required to work collaboratively to develop strategy and policy to improve water quality (DEQ, 2006). Current management approaches are voluntary.

Human activities at the ground level are responsible for affecting groundwater, the primary source of drinking water in the region. Elevated levels of nitrate pose a risk to human health and threaten the quality of the largest and most popular source of water in the region, the Willamette aquifer (Kim-Shaprio, 2005; Mueller, 2006; DEQ, 2006).

The DEQ made the GWMA designation based on four primary issues: 1) the severity and extent of documented non-point source groundwater contamination; 2) the vulnerability of shallow groundwater to adverse impacts from population growth; 3) the reliance of almost all residents of the valley on groundwater for drinking water; and 4) the need for integration of groundwater quality protection strategies (Kalakay, 2004). As a result of the designation, the DEQ formed the Southern Willamette Valley Groundwater

Management Area Committee, a citizen's advisory committee made up of a representative group of stakeholders from the GWMA area. The committee was tasked with developing a region-wide nitrate reduction strategy, or an "Action Plan," via the approval and oversight of the DEQ. Of the four overarching goals of the Action Plan, information dissemination and public education were primary interests (DEQ, 2006).

Research Problem

The resolution of the groundwater contamination problem is dependent upon the reduction of the human-caused inputs. Public knowledge of the problem is an important condition for the collective behavior change that is crucial to improving groundwater quality.

This research attempts to identify gaps in knowledge among the population and provide a general sense of knowledge and awareness regarding the groundwater contamination issue in the affected region. This information is critical to understanding and monitoring progress toward collective solutions.

Literature Review

This section discusses the literature relevant to comprehending the implications of the results of the survey. The theoretical component of this project is informed by political science theory. Theories of rational choice (Stone, 2002), bounded rationality (Simon, 1985), social capital (Anderson, Locker and Nugent, 2002) and collective action (Ostrom, 1991) are used to evaluate the implications of the results provided by survey data of the GWMA population.

Rational Choice Theory (RCT), as define by Stone (1997), asserts that rational individuals act to maximize their own self-interest. This theory is often applied to predict how individuals, or groups of individuals, will act in response to a given social dilemma. Collective action, or the pursuit of a goal or set of goals by more than one person, is central to addressing social dilemmas regarding common resources (Olson, 1965; Ostrom, 1990). The social dilemma presented here relates to a common good, groundwater, which GWMA residents are interdependent upon for drinking, irrigation and other uses. The desired collective action is mitigation of inputs (halting or modifying specific behaviors) of nitrate into the groundwater system.

Rational Choice Theory predicts that self-maximizing individuals will act in their own best interest in the short-term, rather than acting in the interest of the common good, particularly in the long-term (Stone, 1997). However, what is perceived by individuals to be in their own best interest is not static, but rather continually influenced by changes in knowledge. This concept is supported by the theory of bounded rationality, or the idea that individual rationality is limited by available information, individual cognitive limitations, and time limitations associated with decision-making (Simon, 1985). There has yet to be an established behavioral theory of boundedly rational behavior, but Ostrom (1998) argues that structural variables related to collective action, such as the size and heterogeneity of the group, monitoring techniques, and information available to the relevant stakeholders, affect behavior toward social dilemmas like common resource issues facing the GWMA population and similarly affected residents in the Southern Willamette Valley.

The goal of presenting these theories is to establish that behavior can be influenced by knowledge. More specifically, the success of collective action efforts is strongly dependent upon levels of policy relevant knowledge. Social capital, which encompasses knowledge, also incorporates the influential roles of norms and values on common resource stewardship. Research of social capital and common pool resources (Anderson et al., 2002) suggests that improving social capital can improve environmental outcomes. By definition, social capital is the shared knowledge, understandings, norms, rules, and expectations about patterns of interactions that groups of individuals bring to a recurrent activity (Coleman 1988; E. Ostrom 1990, 1992; Putnam, Leonardi, and Nanetti 1993). According to Ostrom, social capital is developed out of shared norms and conventions that develop common understanding (Ostrom, 1994). Knowledge and awareness are re-enforcing interdependent aspects of social capital, hence the importance of understanding these characteristics within a population (Aldridge, Halpern and Fitzpatrick, 2002). Social capital has been established as a key factor in building and maintaining collective action and it is considered fundamental to effective long-term changes in natural resource management. The work of Aldridge, et al. (2002) suggests that social capital is a key element of common resource management and that knowledge and public awareness, in particular, are primary components of social capital. It represents a potential link between policy level thinking and community level action (Pretty and Ward, 2001).

Aldridge et al. (2002) suggest that economic disadvantage and social class correlate with social capital. That is, "low social capital reduces the ability of a community to develop a shared social vision or build commitment to common welfare" (p.3). According to research, the distribution of knowledge within communities is divided by socio-economic status. Those with low socio-economic status tend to have less policy relevant knowledge than those with high status (Pierce, J. C., Lovrich, N. P., Tsurutani, T.

Abe, T., 1989, Pierce, J. C., Steger, M. A., Steel, B. S. Lovrich, N. P., 1992; Delli Carpini and Keeter, 1996; Steel, B., Lovrich, N., Lach, D., Fomenko, V., 2005). To explain knowledge gaps, research indicates that variables such as income and education correlate with environmental knowledge (Pierce et al.,1992, 1989; Delli Carpini and Keeter, 1996; Pierce, J. C., Lovrich, N., Steel, B.S., Steger, M. A. Tennert, J., 2000) and variables such as age and gender are important predictors of levels of knowledge, with older groups and men tending to have higher levels of knowledge than younger groups and women (Steel, Soden, and Warner, 1990; Delli Carpini and Keeter, 1996; Jamieson, 2000;).

Environmental Value Orientations

The following section includes a discussion of environmental value orientations as an independent variable potentially associated with levels of policy relevant knowledge. The New Environmental Paradigm (Dunlap and Van Liere, 1978) is used as a predictive measure of pro-environmental behavior. A study of the relationship between environmental attitudes and environmental knowledge using the New Environmental Paradigm subscales found environmental knowledge to be consistently and positively related to environmental attitudes, suggesting that individuals who care more about environmental issues have higher levels of related knowledge (Arcury, 1990.) Studies of environmental value orientations suggest that those with more biocentric points of view will engage in pro-environmental behaviors (Cardano, Welcomer and Scherer, 2003).

According to theory, an anthropocentric value orientation represents a human-centered view of the nonhuman world (Pinchot, 1910; Eckersley, 1992). This assumes that human uses and benefits are the primary purposes of natural resources and their use. The environment is seen as "material to be used by humans as they see fit" (Scherer and Attig, 1983; Vaske, 2008: p.25). A biocentric value orientation is labeled as naturecentered or eco-centered. This assumes that environmental objects have inherent as well as instrumental worth, and that human economic uses and benefits are not necessarily the most important uses of natural resources. Inherent value as well as instrumental worth is considered and economic benefit is not the most important consideration in managing natural resources (Thompson and Barton, 1994; Vaske, 2008).

Study Site and Methods

The GWMA boundary encompasses approximately 230 square miles of land within the Southern Willamette Valley. The boundary extends from the northern edge of the Eugene urban growth boundary, and extends 50 miles north to include a small portion of the city of Corvallis. The cities of Harrisburg, Coburg, Junction City, and Monroe also lie within the GWMA. Portions of Lane, Linn, and Benton counties are included within the boundary. The population density per square mile is greatest in the Lane County portion of the GWMA (see figure 1). Almost half of the GWMA population is concentrated in this area, while the remaining portion of the population is spread out over the region in a rural setting (DEQ, 2006). There are close to 21,200 residents in the GWMA, and approximately 80% of these residents rely on groundwater as their only source of drinking water (DEQ, 2006). Public systems supply water to some 12,500 urban residents, while the remaining 8,700 residents rely on household and community wells (DEQ, 2006).

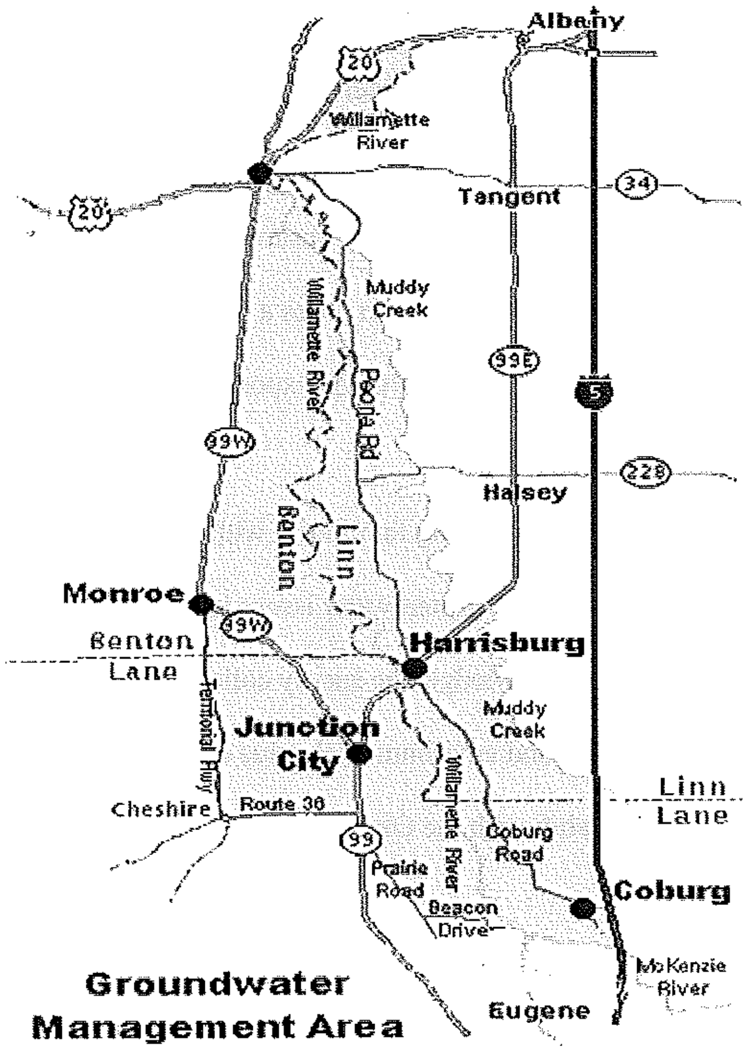

Figure. 1 Groundwater Management Area Map (DEQ, 2006)

The Willamette Aquifer is the primary source of drinking water for the region. Recent US Geological Survey studies of the Willamette Basin suggest that "more than 80 percent of the groundwater use in the Willamette Basin is pumped from the alluvial aquifer" (Hinkle, 1997). The zone west of the Willamette River is considered to be shallow, with an average thickness of about 20 feet. The shallow nature of this zone, as well as high soil permeability, facilitates a rapid hydrological link between the land surface and groundwater (DEQ, 2006). Coupled with high rainfall in the area, high soil permeability leads to susceptibility to contamination from surface activities. The unconfined portion of the aquifer zone is heavily used and therefore particularly vulnerable to human activities. The activities indentified as potential point and non point sources of nitrate are: fertilizers, animal waste, septic systems, wastewater, and unused or poorly constructed wells (DEQ, 2006). Nitrate contamination poses a threat to all uses of groundwater in the area and may pose a risk to human health via exposure through drinking water (Mueller, 2001; Kim-Shaprio, 2005).

This research attempts to assess knowledge using familiarity with groundwater-related terminology and self-assessed awareness of groundwater issues in the GWMA as dependent variables. In addition to assessing knowledge, the survey collected data on preferred information sources, demographics, and environmental value orientations. The survey research project was done in partnership with the Oregon Department of Environmental Quality (DEQ).

Research Question and Hypotheses

The objective of this research is to evaluate awareness and knowledge of groundwater issues in the Southern Willamette Valley Groundwater Management Area. The main research question asks: Who has (and does not have) knowledge in the GWMA? It is predicted that knowledge gaps exist in the GWMA population, and that these gaps are consistent with indicators of socio-economic disadvantage. The following hypotheses are tested to address this research question:

Hypothesis 1: Biocentric attitudes are associated with higher levels of knowledge.

Hypothesis 2: Higher levels of income are associated with higher levels of knowledge.

Hypothesis 3: Older cohorts are associated with higher levels of knowledge.

Hypothesis 4: Men will have higher levels of policy relevant knowledge when compared to women.

Hypothesis 5: Higher levels of education are associated with higher levels of knowledge.

Hypothesis 6: Longer residency is associated with higher levels of knowledge.

Hypothesis 7: Well ownership is associated with higher levels of knowledge.

Hypothesis 8: Frequent well testing is associated with higher levels of knowledge.

Significance of Research

This research was done in coordination with the DEQ and the GWMA Committee as a key piece in the effort to meet the goals and strategies set forth in the 2006 Southern Willamette Valley Groundwater Management Area Action Plan (DEQ, 2006). Survey research of the GWMA population provides baseline data for the affected region. This research provides the only available demographic data specific to the GWMA population and the first population-wide evaluation of public awareness and knowledge of the groundwater issues in the area. Additionally, this research provides needed data regarding the nature of the distribution of knowledge across the population.

An evaluation of the levels of knowledge regarding the nitrate groundwater problem is an important initial evaluation step, not only to gauge the progress of previous education and outreach efforts, but also to get a sense of the progress made toward developing the precursors to collective action, such as social capital. This information may help managers, like the DEQ, design efficient targeted education efforts that pinpoint segments of the population where past efforts have not been successful. Additionally, survey data can be used for future comparison to evaluate progress over time.

Methods

The survey design was informed by a previous study conducted by Steel, Lovrich, Lach and Fomenko (2005) and their survey of public knowledge of ocean fisheries management issues. Members of the GWMA Committee were consulted for input on question formulation. The survey design was completed in July, 2008 and the survey and study protocol were reviewed and passed by the Oregon State University Institutional Review Board in August, 2008.

The mail survey was sent to 923 randomly selected residents of the Southern Willamette Valley Groundwater Management Area (GWMA). The random sample of households within the GWMA was generated by Survey Sampling International (SSI), a national sampling service. Surveys were mailed in September and October, 2008 and returned via mail through December, 2008. SSI also provided address labels corresponding to the randomly selected households. A majority of the labels were addressed to male heads of household. To avoid gender bias, the cover letter sent with each survey requested that the person in the household who most recently celebrated a birthday, and is at least 18 years of age, complete the survey. Two waves of surveys were sent, preceded by an initial postcard informing recipients of the survey. Return envelopes with postage were included with each survey wave. Recipients were asked to return uncompleted surveys if they wished not to participate. The survey generated a 49% response rate (451 surveys returned).

To assess overall knowledge of groundwater issues, two scales measuring knowledge were created. The first knowledge scale was derived from familiarity with groundwater related terminology (see Table 1). A second scale was derived from self-assessed awareness regarding groundwater issues. The survey asked respondents "In general, how well informed do you consider yourself to be concerning groundwater quality in your community?" and "In general, how well informed do you consider yourself to be about where your drinking water comes from." Each question was answered on a scale from 1 = "not informed" or 4 = "very well informed." These variables were tested for statistical reliability using SPSS and computed into a single dependent variable.

The independent variables used in analysis were predominantly socio-economic indicators gauging income, education, gender, and age (see Table 2). Additional control variables such as well ownership, frequency of well testing (for those who indicated owning a well), environmental value orientations (NEP), and residence time in the GWMA community were also addressed and evaluated.

Table 1. Term Familiarity

Term	Percent who "know" term
Nitrate	73 n = 312
Aquifer	69 n = 291
Non point-sources pollution	29 n = 120
Watershed	83 n = 353

Term familiarity: For the following terms, please indicate if you. 1 = know what the term means, 2 = have heard of the term but don't know it's meaning, or 3 = have not heard the term at all. Percent say "know" term

Table 2. Independent Variables[1]

Variable name	Variable description	Frequency
Age	Dummy variable, 0 = < 60 years, 1= 60+	n = 427
Gender	Dummy variable, 0 = male, 1= female	n = 432
Education	Dummy variable, 0 = no college, 1 = college+	n = 432
Income	Dummy variable, 0 = < 75K, 1= 75K+	n = 383
Residency	Dummy variable, 0 = < 40 years, 1= 40+	n = 430
Well ownership	Dummy variable, 0 = no well, 1= well	n = 434
Well testing	Dummy variable, 0 = male, 1= female	n = 223 (of 231)
NEP	0= anthropocentric 1= mixed 2= biocentric	n = 416

[1] Cut point for dummy variables determined by respective mean values

Results

Several survey questions asked respondents to indicate their level of awareness regarding groundwater in the GWMA. Survey recipients were asked, "In general, how well informed do you consider yourself to be concerning groundwater quality in your community?" Only 22% of respondents indicated that they were "informed" or "very well informed" (see Table 3).

Table 3. Level of awareness regarding groundwater in the GWMA

In general, how well informed do you consider yourself to be concerning groundwater quality in your community?	n = 434	In general, how well informed do you consider yourself to be about where your drinking water comes from?	n = 433
Not informed	23.3%	Not informed	9.9%
Somewhat informed	54.6%	Somewhat informed	31.4%
Informed	17.7%	Informed	33%
Very well informed	4.4%	Very well informed	25.6%

Over 60% of respondents indicated that they were "somewhat informed," or "informed" about the source of their drinking water. Approximately 52% indicated that their source was a domestic well, while 42% selected municipal water as their drinking water source. The majority of respondents rated the quality of their drinking water as "good" (45%) or "excellent" (37%). The quality of the groundwater was rated "fair" (23%) and "good" (40%) (table 3) .

Table 4. Groundwater and drinking water ratings

How would you rate the quality of your drinking water?	n = 436	How would you rate the current groundwater quality in your community?	n = 431
Poor	3.4%	Poor	4.2%
Fair	12.8%	Fair	23%
Good	44.7%	Good	39.7%
Excellent	37.4%	Excellent	8.3%
Don't know	1.6%	Don't know	23.4%

Those who indicated that their drinking water source was a well were asked how often, if ever, they tested their well. The majority of respondents (49%) indicated that they tested "rarely," or once during ownership, while 31% indicated that they "occasionally" tested (specified as once a year), and 11% never tested their well. More than half (61%) of respondents indicated that their home used a septic system (see Table 5 and 6).

Table 5. Well ownership and testing

Where does your drinking water come from?	n = 434	If your drinking water comes from a well, how often (if ever) do you test the quality of your well?	n = 223 of 231
A domestic well	51.6%	Never	11.3%
The city/municipal water	41.9%	Rarely (once during ownership)	48.9%
Bottled water	2.1%	Occasionally (once a year)	30.7%
Don't know	0.5%	Somewhat frequently (twice a year)	4.8%
		Very frequently (more than twice a year)	4.3%

In addition, 80% of the respondents indicated that they had never heard of the Southern Willamette Valley Groundwater Management Area. Of those who had heard of the GWMA, 56% indicated they did not know whether or not they lived within the boundary, despite the fact that all recipients of the survey were GWMA residents (see Table 6).

Table. 6 Awareness of GWMA, designated boundary, and septic system ownership

Have you ever heard of the Southern Willamette Valley Groundwater Management Area?	n = 430	Do you know if you live within the boundary of the Southern Willamette Groundwater Management Area?	n = 313	Does your home use a septic system?	n = 435
Yes	16%	Yes	34%	Yes	60.9%
No	80%	No	10%	No	38.4%
Don't know	4%	Don't know	56%	Don't know	0.7%

When asked to indicate the possible threats to groundwater quality (more than one choice was possible), fertilizer application was the most commonly identified threat

(81%), followed by septic systems (57%) and animal waste (45%). When asked if respondents ever used fertilizer 77% indicated "yes" and the majority (65%) applied it to their lawns (see Table 7).

Table 7. Listed possible threats to groundwater

Which of the following do you consider possible threats to groundwater pollution in your community?	n = 430	Where do you use fertilizer?	n = 434
Fertilizer application (lawns, gardens, agricultural crops, etc.)	80.9%	Lawn	64.5%
Septic systems	57.4%	Garden	45.6%
Animal waste (dogs and larger animals)	44.9%	Agriculture/crops	10.6%

Respondents were asked to indicate which information sources they currently use, or would use to learn more about groundwater issues. Watershed councils and state elected officials were the least popular sources of information, while television and Oregon Public Broadcasting (OPB) were the two most popular sources of information. It is not known whether the preferred OPB source is radio or television, however radio programs in general were the fourth most popular source behind "other" local newspapers (not including the Register Guard). The DEQ, as a source of information, was a preferred over local community leaders, state elected officials, watershed councils, and environmental groups. Utilities were equal in popularity with the internet (see Table 8).

Table 8. Information sources GWMA residents currently use, or would use to learn more about groundwater issues.[1]

Information Source	Never	Infrequently	Frequently	Very Frequently	N
Television news programs and specials	8.9%	31.6%	41.7%	17.8%	n = 415
Oregon Public Broadcasting	16.7%	38%	31.9%	13.5%	n = 408
Radio programs	27%	37.4%	27.5%	8.2%	n = 404
The *Register Guard* newspaper	46.8%	18.5%	17.7%	17%	n = 406
Other local newspapers	36.5%	26.5%	21.8%	15.2%	n = 408
Local community leaders	42.9%	45.2%	10.2%	1.7%	n = 403
Watershed councils	66.3%	26.6%	6%	1.2%	n = 403
State elected officials	52.3%	41.5%	4.8%	1.5%	n = 398
Oregon Department of Environmental Quality	44.1%	37.2%	15.8%	3%	n = 406
Universities and colleges	40.1	37.2%	18.2%	4.4%	n = 406
Utilities	30.2%	42.1%	22.4%	5.2%	n = 401
Environmental groups	50.7%	34.1%	12.7%	2.5%	n = 402
Information available on the Internet	43.3%	28.6%	18.7%	9.5%	n = 402

[1]Percentages indicate frequency of use

Dependent Variables: Familiarity with groundwater related terms was computed into a scale reflecting groundwater related knowledge. On average, the population had heard of the terms, but did not know their meaning. The term "watershed" was best understood, followed by the term "nitrate." The term understood the least (not heard of "at all") was "non point-source pollution" (see Table 1).

Reliability for the "knowledge" scale was tested to see how well familiarity with a given set of groundwater terms measured knowledge as a latent construct. The reliability analysis for the five groundwater terms supported the use of the scale as a measure. A Cronbach alpha coefficient of α = 0.73 indicated that items are measuring the same concept and justified combining them into a single index. Deletion of any of the groundwater terms did not improve reliability of the scale (Cortina, 1993; Nunnally and Bernstein, 1994) (see Table 9).

Table 9. Reliability analysis of knowledge scale[1]

Survey Item[2]	Mean	Standard Deviation	Item total correlation	Cronbach alpha if item deleted	Cronbach alpha
Watershed	2.8	0.4	0.47	0.70	0.73
Nitrate	2.7	0.5	0.56	0.66	
Clean Water Act	2.4	0.6	0.51	0.67	
Nonpoint source pollution	1.2	0.9	0.46	0.71	
Aquifer	2.6	0.7	0.53	0.66	

[1]Familiarity with groundwater terminology is used as a measure of knowledge regarding groundwater
[2]Variables were coded on a 3-point scale from 1=have not heard of the term at all 2= have heard of the term but don't know its meaning 3=know what the term mean.
[3] Measure of strength of association when one measure is categorical and one is continuous.

Reliability for the "awareness" scale was tested to see how well a set of two questions surveying self-determined "informedness" regarding groundwater in the GWMA measure knowledge as a latent construct. The reliability analysis for the questions had a Cronbach alpha coefficient of α = .61. A Cronbach alpha coefficient of α =0.65 is the typical benchmark used to justify combining items into a single index; however, Cortina (1993) and Nunnally and Bernstein (1994) contend that this range is inclusive of numbers as low as α = 0.60. Therefore, the Cronbach alpha of α = .61 supports combining the items into an awareness scale index (see Table 10). The total item correlation was above .40, which further justified the index (Howard and Forehand, 1962).

Table 10. Reliability Analysis of Self-assessed Awareness

Survey Item[1]	**Mean**	**Standard Deviation**	**Item total correlation**	**Cronbach alpha**
How informed are you on groundwater quality in your community?	2.0	0.8	0.44	0.61
How informed are you about where your drinking water comes from?	2.7	1.0	0.44	

[1] Cell entries are means.
[2] Variables were coded on a 4-point scale from 1=Not informed to 9= Very well informed

On average, respondents indicated that they were less aware, or "somewhat informed" about groundwater quality in their community (55%).

New Environmental Paradigm Index: Reliability for the New Environmental Paradigm (NEP) index was tested to see how well each set of directed biocentric and anthropocentric questions measure environmental value orientations within the study population. A reliability analysis of the anthropocentric-oriented question set had a Cronbach alpha coefficient of α = 0.68, and the biocentric questions yielded a Cronbach alpha coefficient of α = 0.70. Deleting any of the anthropocentric or biocentric terms did not improve reliability of the scale. The respective Cronbach alpha coefficients of α = 0.68 and α = 0.70 indicated that items were measuring the same concept, and justified combining the items into a single index (Cortina 1993; Nunnally and Bernstein, 1994).

Table 11. Reliability analysis of Environmental Value Orientations using the New Environmental Paradigm (NEP) Analysis[1]

Value Orientation, Survey Item[2]	Mean	Standard deviation	Item-total correlation	Cronbach alpha if item deleted	Cronbach alpha
Anthropocentric					0.68
Humans have the right to modify the natural environment to suit their needs	3.3	1.2	0.48	0.62	
The so-called "ecological crisis" facing humankind has been greatly exaggerated	3.3	1.4	0.46	0.64	
Humans were meant to rule over the rest of nature	3.2	1.4	0.56	0.50	
Biocentric					0.70
The balance of nature is very delicate and easily upset by human activities.	3.9	1.2	0.57	0.55	
We are approaching the limit of people the earth can support.	3.3	1.4	0.48	0.66	
Plants and animals have as much right as humans to exist.	3.5	1.4	0.51	0.62	

[1] Variables coded on a 5-point scale from 1 "strongly disagree" to 5 "strongly agree"
[2] Variables reverse coded

A K- means cluster analysis of the environmental value orientations revealed three environmental value orientation groups: anthropocentric (22%), biocentric (38%), and mixed (40%). A K-means cluster analysis is used to determine if responses are patterned in more than two categories, that is, if averages within responses more closely fit (cluster around) a tertiary (or higher) response pattern reflected by their mean. The cluster analysis does not assume that value orientations co-vary and is used as an empirical multivariate analysis tool used to parse out groups of value orientations (McFarlane, 1994; Scott, D., Ditton, R.B., Stoll, J.R., Eubanks Jr., T.L., 2005; Needham, M., Vaske, J., Donnelly, M., Manfredo, M., 2007).

An ANOVA test was run to determine if there were differences in measurements of knowledge and environmental value orientations. It was predicted that those with a more biocentric point of view would have more knowledge (both measures) than those with an anthropocentric or mixed point of view.

On average, all three environmental orientation groups indicated having similar "somewhat informed" levels of knowledge. Statistically, respondents with anthropocentric environmental value orientations had the highest levels of knowledge, followed by those with biocentric value orientations and those with mixed values (M= 2.56 to 2.39) (see Table 11). The strength of this relationship was "minimal" (Vaske et al., 2002) or "weak" (Cohen, 1988) ($\eta = .15$). This result is counter to the hypothesis that biocentric points of view would result in higher levels of knowledge about environmental issues.

Table 12. Differences in knowledge and awareness with environmental value orientations (NEP)

Measures of Knowledge	NEP Value Orientations[1]					
	Anthropocentric	Mixed	Biocentric	F	p	Eta (η)
Awareness[2]	2.51	2.33	2.38	1.80	0.17	0.09
Knowledge[3]	2.56^{a}	2.39^{b}	2.49^{ab}	4.40	0.01	0.15

[1]scale 0= anthropocentric 1= mixed 2= biocentric
[2]scale from 1 "not informed" to 4 "very well informed"
[3]scale from 1 "have not heard of the term at all" to 3 "know what the term means
Means with different superscripts are significant at $p < .05$ based on Scheffe post-hoc tests for equal variances tests

Socio-demographic Variables and Knowledge: A t-test was run to determine differences in measures of knowledge and income. Income was converted to a dummy variable (coded 0 = < $75K, 1 = $75K+) using the median income as the arbitrary cut point. Based on previous study (Pierce et al., 1992, 1989; Delli Carpini and Keeter, 1996; Steel et al., 2005), it was expected that those with lower levels of income would have less awareness and knowledge of groundwater issues than those with higher income in the GWMA. The results were mixed. There was no statistical relationship between awareness and income. The relationship between knowledge and income was statistically significant, indicating that those with higher levels of income had higher levels of knowledge (see Table 13). A point biserial correlation indicated that the strength of this relationship "minimally" supports the hypothesis ($r_{pb} = 0.12$) (Vaske et al., 2002).

Table 13. Differences in knowledge and awareness with income level

Measures of Knowledge		Income				
	< $75,000	$75,000 +	*t*	df	*p*	r_{pb}
[1]Awareness	2.39	2.37	0.29	380	0.773	0.02
[2]Knowledge	2.43	2.54	2.33	375	0.021	0.12

[1]scale from 1 "not informed" to 4 "very well informed"
[2]scale from 1 "have not heard of the term at all" to 3 "know what the term means

An independent t-test was conducted to determine if there were differences in levels of knowledge when age was considered. The arbitrary cut point for age groups (< 60 years and 60+ years) was determined based on the median (M = 60 years old). The hypothesis was that the older population group (60 +) would have more knowledge and awareness than the younger population group (< 60). On average the population, regardless of age, indicated being "somewhat informed." The results show that older respondents had higher levels of awareness than younger respondents (M = 2.46 to 2.3) (see Table 14).

Table 14. Differences in knowledge and awareness with age

Measures of Knowledge		Age				
	< 60	60+	*t*	df	*p*	r_{pb}
[1]Awareness	2.3	2.46	2.163	424	< .001	0.10
[2]Knowledge	2.45	2.43	1.64	401	0.103	0.08

[1]scale from 1 "not informed" to 4 "very well informed"

[2]scale from 1 "have not heard of the term at all" to 3 "know what the term means

The relationship between awareness and age "minimally" supports the hypothesis (r_{pb} = 0.1) (Vaske et al., 2002). There was no statistically significant relationship between knowledge and age.

To determine if there were differences in measurements of knowledge among the sexes, an independent t-test was conducted (see Table 15). In accordance with the literature, the results show that male respondents had higher levels of both awareness and knowledge than females. The differences in both knowledge and awareness between males and females were statistically significant ($p < .001$ to .031). The point biserial correlation effect sizes suggested that that the relationships were "typical" and "minimal" (r_{pb} =.23 to .1) (Vaske et al., 2002).

Table 15. Differences in measurements of knowledge and Sex

Measures of Knowledge		Sex				
	Male	Female	t	df	p	r_{pb}
[1]Awareness	2.44	2.27	2.167	429	0.031	0.10
[2]Knowledge	2.53	2.31	4.56	211	< .001	0.23

[1]scale from 1 "not informed" to 4 "very well informed"
[2]scale from 1 "have not heard of the term at all" to 3 "know what the term means

A t-test was conducted to determine differences in measures of awareness and knowledge when education level was considered. Education was recoded as a dummy variable (0 = no college, 1 = college) using the average response as a cut point. Respondents with higher levels of education indicated having higher levels of knowledge. The differences in knowledge between those with and without a college education were statistically significant ($p < .001$) (see Table 16). The point biserial correlation effect size suggested that the relationship was "minimal" to "typical" (r_{pb} =.23) (Vaske et al., 2002).

No relationship between awareness and education level could be concluded as the means did not differ statistically.

Table 16. Differences in measures of knowledge and Educational Attainment

Measures of Knowledge		[1]Educational attainment				
	College	No College	t-value	df	*p*-value	r_{pb}
[2]Awareness	2.43	2.32	1.59	423	0.113	0.10
[3]Knowledge	2.56	2.35	4.78	396	< .001	0.23

[1]some college or less = no college, college degree and advanced = college
[2]scale from 1 "not informed" to 4 "very well informed"
[3]scale from 1 "have not heard of the term at all" to 3 "know what the term means

The purpose of the analysis was to determine if the length of time living in the area could be related to levels of knowledge regarding groundwater issues. Reason implies that the longer one lives in an area, the more one might know about it. In this case, the hypothesis was that a longer residence time would result in higher levels of both awareness and knowledge. A t-test was run to determine if there were differences in measurements when residence time is considered. Results show that longer residency (40 + years) indicated higher levels of awareness (see Table 17).

Table 17. Differences in Measures of Knowledge and Residency Time

Measures of Knowledge		[1]Residence Time				
	< 40 years	40 + years	t-value	df	*p*-value	r_{pb}
[2]Awareness	2.25	2.51	3.8	427	< .001	0.20
[3]Knowledge	2.47	2.46	0.157	420	0.876	0.01

[1]residence time = 0-39 years and 40+ years
[2]scale from 1 "not informed" to 4 "very well informed"
[3]scale from 1 "have not heard of the term at all" to 3 "know what the term mean

The difference in means was statistically significant ($p < .001$) and the point-biserial correlation effect size suggests that the strength of this relationship was "minimal" to "typical" ($r_{pb} = .21$) (Vaske, 2002). The differences in knowledge were not statistically significant.

Well Ownership: An independent t-test was used to determine the differences in measurements of knowledge and well ownership. The prediction was that those who owned wells would have higher levels of awareness and knowledge. Self-interest justified the assumption that those who derived their drinking water from groundwater (and indicated that they knew it) would have more knowledge about issues relating to groundwater issues in their community. On average, regardless of well ownership, respondents indicated being "somewhat informed" about groundwater issues. As predicted, those who owned a well reported higher levels of awareness than those who did not own a well. The relationships were statistically significant ($p < .001$ to .005) (see Table 18) and the point biserial correlation effect size measure indicated that the relationship between well ownership and awareness was "typical," while the relationship between knowledge and well ownership was "minimal" ($r_{pb} = .21$ to .14) (Vaske et al., 2002).

Table 18. Differences in knowledge and awareness and well ownership[1]

Measures of Knowledge		Well Ownership				
	Yes	No	t	df	p	r_{pb}
[2]Awareness	2.54	2.23	4.52	432	< .001	0.21
[3]Knowledge	2.52	2.4	2.8	425	0.005	0.14

[1]prospective respondents were asked where their drinking water comes from 0= no well, 1 = well
[3]scale from 1 "have not heard of the term at all" to 3 "know what the term means

Well Testing: A t-test was run to determine if there were differences in measurements of knowledge and awareness and the frequency of well tests. Reason suggested that those who test their wells would have higher levels of awareness and knowledge regarding groundwater issues than those who rarely or never tested their wells. On average, those who had wells, regardless of their testing frequency, indicated similar levels of awareness ("somewhat informed"). The results show that those who regularly tested their wells had statistically higher levels of both awareness and knowledge than those who to did not test their wells. The relationship between the frequency of well tests and knowledge were significant for both measures ($p < .001$ to .05) (see Table 19). The point biserial correlation effect sizes suggested that the strength of the relationship between awareness and testing was "typical" to "substantial," while the relationship with the knowledge variable was "minimal" (r_{pb} =.3 to .13) (Vaske et al., 2002).

Table 19. Differences in knowledge and awareness and frequency of well tests

Measures of Knowledge		Well testing frequency				
	Regularly	Rarely or Never	*t*	df	*p*	r_{pb}
[2]Awareness	2.78	2.38	4.22	229	< .001	0.27
[3]Knowledge	2.59	2.48	2.02	210	0.05	0.13

[1]prospective respondents who indicated that their drinking water came from a private well were asked how often they test their well 0= rarely or never, 1 = regularly
[2]scale from 1 "not informed" to 4 "very well informed"
[3]scale from 1 "have not heard of the term at all" to 3 "know what the term means

Regression Analysis: A multi-variate dummy variable regression of several independent variables representing socio-demographic indicators, as well as key behaviors, was conducted to determine the relative strength of the predictive ability (linear relationship) regarding knowledge and awareness. A regression analysis of knowledge indicated that, of the independent variables, well testing frequency, gender and education predicted 17.2% of the knowledge variable ($R^2 = .172$). The relative standardized coefficients (b = -.204 to .118) were statistically significant ($p = .003$ to

.046) and indicated that gender was the strongest predictor of knowledge, followed by educational attainment and frequency of well testing (see Table 20).

Table 20. Regression analysis predicting survey respondent's "knowledge" of groundwater issues; dependent variable: Knowledge scale[1]

Independent Dummy Variables	Standardized Coefficient (B)	SE	Unstandardized Coefficient	*p*
If your water comes from a well, how often do you test for quality?	.118	.059	.140	0.046
Gender	-.204	.068	-.218	0.003
Education	.170	.061	.206	0.006

[1] $R^2 = .172$, F = (9, 180) 4.142, $p < .001$. Knowledge scale was computed using familiarity with groundwater related terms (Q15, 1-3).
[2] Independent variables are dummy variables (coded 0, 1)

Regression analysis of awareness revealed that frequency of well testing as well as environmental value orientations were the strongest predictors of awareness. These independent variables predicted 17.4% of the dependent variable ($R^2 = .174$). The relative unstandardized coefficients (b = .271 to -.226) were statistically significant (p = <.001 and .002) (see Table 21).

Table 21. Regression analysis predicting survey respondent's "awareness" of groundwater issues; dependent variable: Awareness scale[1]

Independent Dummy Variables	Standardized Coefficient (B)	SE	Unstandardized Coefficient	*p*
If your water comes from a well, how often do you test for quality?	.393	.100	.271	< .001
NEP Scale	-.154	.004	-.226	0.002

[1] $R^2 = .174$, F = (9, 182) 4.261, $p < .001$. Awareness scale was computed using self-assessed awareness (Q1, 6)
[2] NEP- reverse coding accounts for negative coefficient values

For all regression analyses, all independent variables were considered in the calculation simultaneously using the "enter" method to ensure that the theoretical rather than empirical strength of the variables was considered (Vaske, 2008). Tables 20 and 21 show a final model, with all insignificant predictors dropped.

Discussion and Recommendations

The results indicated by the descriptive statistics showed a general lack of knowledge among the population. These results suggest that the GWMA population is relatively uninformed of their groundwater quality, the Groundwater Management Area designation, and their inclusion within this boundary. Data from the DEQ indicates that the majority of residents in the GWMA derive their drinking water from a well (DEQ, 2006) and this majority is reflected by the survey results. It is important to note that those with wells tend to test their well at least once during ownership, followed closely in numbers by those who test about once a year. This outcome shows a mixed result, so it is therefore difficult to determine whether or not well owners have accurate or updated information on their well water quality, including levels of nitrate in their drinking water.

The sources of nitrate appear to be well understood among the population, with fertilizer application perceived as a primary contributor to nitrate in groundwater; however, the application of fertilizer to lawns in the GWMA is practiced by the majority of the population. Alternatives to nitrate fertilizers should be encouraged, and proper application should be included and emphasized in outreach efforts.

Information Sources: The data suggest that television and Oregon Public Broadcasting are the two information sources that GWMA residents use, or would use, to learn more about groundwater related issues. As a result, education outreach efforts should focus on both of these venues to better reach the population with educational information. Televised public service announcements and commercials, as well as informational radio segments are potential options to be considered. Local newspapers (not including the Register Guard), the radio, and utilities were also identified as popular sources of information, suggesting that feature articles, editorials, and op-ed pieces may be effective in spreading knowledge. The internet was less popular than might be expected, which may be the result of the age of survey respondents and the rural setting. Older generations (the mean age was 59 years) and rural populations may have less access to the internet and tend to use it less as an information source than younger generations and urban populations. Newsprint was a preferred source of information, but, despite its widespread circulation in the region, the Register Guard was not the preferred source in the area. Also of note is that the DEQ was a favored source of information over local community leaders, state elected officials, watershed councils, and environmental groups. Curiously, utilities were equal in popularity with the internet (see Figure 2), a consideration that should be approached in education and outreach efforts.

In response to these results, it is recommended that the DEQ and similarly concerned organizations focus their outreach efforts on these preferred sources, taking into consideration the nuances within the population that may result in successful outreach through local television and radio marketing rather than internet sources.

Knowledge Gaps: The parametric statistical analyses indicated a general lack of understanding across the population regarding the GWMA designation and its boundaries. These knowledge deficits were marked by gaps that coincide with socio-economic indicators often indicative of disadvantage (Steel, et al., 2005). The gaps were punctuated by several factors, including: income, age, gender, and education. Other factors such as residence time, well ownership, frequency of well testing, and environmental value orientations were addressed as well. The following is a discussion of the research and hypotheses tested to determine the relationships between these variables and knowledge of groundwater issues in the GWMA. The hypotheses are discussed in the order in which they were presented, including relevant recommendations.

Hypothesis 1: Biocentric attitudes are associated with higher levels of knowledge. The hypothesis was not supported. The New Environmental Paradigm question set was used to measure environmental value orientations within the population. The results indicated that those with anthropocentric environmental value orientations had higher average levels of awareness than those with biocentric orientations, and the difference in means (anthropocentric vs biocentric) for the knowledge variable was statistically significant. This result raises the question of whether or not the strong male response had an influence on this outcome, since the analysis established that male survey respondents had higher levels of knowledge than females. Previous study of gender differences and environmental value orientations suggests that males tend to have more anthropocentric trending orientations, while women tend to have more biocentric orientations (Zelezney, L., Chua, P., and Aldrich, C., 2000).

The literature regarding environmental orientations argues that those with more biocentric orientations are more likely to cooperate and get involved in pro-environmental efforts (Cardano, et al., 2003). The cluster analysis helped to characterize the values of the population as a whole and revealed that, across the surveyed population, a "mixed" environmental orientation was dominant. About 40% of the population indicated a "mixed" value orientation, followed by 38% identifying with biocentric orientations, and 22% with anthropocentric orientations. This may indicate that the GWMA population as a whole would be willing to engage in pro-environmental behaviors associated with mitigating nitrate groundwater pollution. This outcome is consistent with the research of Cardano, et al. (2003).

Hypothesis 2: Higher levels of income are associated with higher levels of knowledge.

The hypothesis was supported. Those who earned an income of $75,000 or more had higher levels of knowledge. It can be interpreted from this result that higher income is an indicator of higher knowledge levels (although the significance is minimal) in the GWMA population. The $75,000 threshold was determined by the population's indicated median income. This income level does not imply that those making less are socio-economically disadvantaged (though many likely are), what it does suggest is that those with economic advantage (making $75,000 or more) benefit from the advantage of higher levels of relevant knowledge. This is an important factor when considering the disadvantages (including health related consequences to exposure) to incomplete information regarding the myriad consequences of groundwater nitrate pollution.

In an effort to increase knowledge of groundwater issues among the GWMA population it is suggested that the DEQ and related organizations consider socio-economic divisions in the formulation and targeting of education and outreach programs.

Hypothesis 3: Older age is associated with higher levels of knowledge.

The hypothesis was supported by the awareness variable, where age was found to be a significant indicator of higher levels of knowledge. However, the strength of this relationship is weak. The knowledge variable indicated that there was no statistical difference between younger and older age groups. Though the relationship is not strong, it can be concluded that knowledge levels may differ by age, such that focusing education efforts on younger populations may be a beneficial strategy.

Hypothesis 4: The male gender is associated with higher levels of knowledge.

Differences in both awareness and knowledge supported the hypothesis. The significance of the statistical difference in levels of knowledge between men and women was moderate in strength, while the difference in awareness only weakly supported the hypothesis. This result suggests that efforts to further educate the community should focus on increasing knowledge among women, particularly because current studies suggest that exposure to nitrate through drinking water may have significant negative consequences on the health of women and young children under their care.

Hypothesis 5: Higher levels of education are associated with higher levels of knowledge.

The hypothesis was supported by the statistically higher levels of knowledge among those with a college education than those with lower levels of attainment. The moderate strength in the statistical significance lends strength to the support of the hypothesis and points to a target group that may benefit from strategic outreach efforts.

Hypothesis 6: Longer residency time is associated with higher levels of knowledge.

The hypothesis was supported by the higher levels of awareness exhibited by those living in the area for 40 or more years. That is, those living in the GWMA for 40 or more years perceived themselves to be more aware than those who have lived in the area for a shorter period of time. The strength of the relationship supports a strategy for a focused effort to educate newer GWMA residents of the groundwater issues in the area.

Hypothesis 7: Well ownership is associated with higher levels of knowledge.

The hypothesis was supported by differences in both awareness and knowledge between well owners and non-owners, and the strength of the results justify a focused effort on educating those who do not derive their water from a well, or do not know that they depend on well water as a source of drinking water. It should be considered that the results include only those who knew that they used a well. The result is encouraging and suggests, as predicted, that those who were aware of their dependence on groundwater were more informed about it. It is therefore important that outreach efforts continue to inform well owners, but it is also crucial that non-owners become more aware of the role they play in the maintenance of groundwater quality.

Hypothesis 8: Frequent well testing is associated with higher levels of knowledge.

The hypothesis was supported by the difference in awareness between those who do and those who do not test their wells. The knowledge variable was on the cusp of statistical significance, but indicated that 5 times out of 100 differences in knowledge would occur out of chance, which was not statistically significant enough to warrant consideration. The result indicated that those who know that they have a well and test it regularly were more aware than those who rarely or never tested. The reasons for regular well testing are not known, but it may indicate that those who were more aware of groundwater issues were more motivated to test the quality of their water, or that the results of water quality testing have signified the need to continually monitor quality. Encouraging regular testing may be an important strategy for monitoring and maintaining drinking water quality. Changes in well water quality may help residents better understand the connections between surface activity and groundwater quality, and therefore help to encourage accountability and cooperation aimed at mitigating nitrate inputs.

Discussion Summary: Collecting socio-demographic information of the population made it possible to detect inequities in knowledge and awareness that appear to indicate that socio-economically "disadvantaged" groups have the lowest levels of knowledge and awareness in the community. Specifically, within the GWMA population these were women, those with lower educational attainment, lower income, and those who were younger in age. In sum, those who had lived in the community for forty or more years, who were male, who owned and tested their wells frequently, who were at least 60 years old, who had a college education, and who earned an income of $75,000 or more, had the highest levels of knowledge and awareness of groundwater issues in the GWMA. Alternatively, the analysis suggests that women with lower levels of education (no college degree) may have the lowest levels of knowledge and awareness among the population (see Table 16).

Table 16. Results Summary

Those With "Awareness"	Those with "Knowledge"
Residence Time (40+ years)	Education (college +)
Males	Males
Regular well testing	Regular well testing
Well ownership	Well ownership
Age (60+)	Income (75K+)

Implications of Results

The results have broad policy implications that call for targeted education and outreach to specific vulnerable populations highlighted by knowledge gaps. Indeed, socio-economic factors within the GWMA population are predictors of policy-relevant knowledge, which may be a useful tool when efficiently targeting outreach and education efforts. While the DEQ should put particular focus on reaching women with lower educational attainment, as they appear to be a key target group, it is also clear that the population as whole needs further exposure to information regarding groundwater nitrate pollution in the area. Collective action focused on mitigating behaviors that contribute to non point-source nitrate pollution is needed to accomplish the goal of improving groundwater quality and drinking water safety. Building social capital and, in particular, increasing knowledge and public awareness of groundwater issues in the GWMA is necessary to inform and incite behavior change. Because the Willamette Valley is experiencing one of Oregon's most rapid growth rates (ODLCD, 1999), and because the area currently depends primarily upon groundwater for private wells, public drinking water, irrigation, industry and other "beneficial" uses, it is imperative that current and future residents become aware of the role they play in maintaining groundwater quality in the region.

In addition to environmental repercussions of groundwater contamination in the short and long-term, nitrate exposure through contamination of drinking water sources may harm health. Cancers, reproductive complications, and Blue Baby Syndrome have all been attributed to nitrate exposure through drinking water (Mueller, 2001; Kim-Shaprio, 2005). The results may suggest that the more disadvantaged segments of the population, due to lower levels of policy relevant knowledge, are at greater risk to the negative health impacts of nitrate exposure. Women and children are particularly vulnerable to these health impacts, and as the data reveal, women are the least knowledgeable and least aware of groundwater issues. It is therefore in the best interest of female GWMA residents and the children they care for that women be a primary focus of education and outreach efforts.

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