Rogue Basin
Pesticide in Groundwater Data Evaluation

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1.0 INTRODUCTION

In February, March and October of 2015, the Oregon Department of Environmental Quality (DEQ) collected groundwater quality samples from 107 private drinking water wells in various locations throughout Jackson and Josephine Counties as part of their Statewide Groundwater Monitoring Program. In this study groundwater samples were analyzed for a range of pesticides in addition to nitrate, arsenic, coliform bacteria and other standard parameters. DEQ submitted its report for this project in December of 2016. It is available at www.deq.state.or.us/wq/groundwater/docs/midroguegwrep.pdf and attached as Appendix A.

Previous groundwater quality studies in the Rogue Basin by DEQ have been conducted in 1992, 1994 and 2011 and by the United States Geological Society (USGS) in 1971-73. A summary of the findings of these studies can be found in a 2013 report at http://www.deq.state.or.us/lab/techrpts/groundwater/2013RogueGWReport.pdf.

The Oregon Departments of Agriculture (ODA), DEQ, and other state agencies, tribal organizations, local landowners and organizations cooperate in a state program called the Pesticide Stewardship Partnership (PSP). This program's goals are to identify potential concerns and improve water quality affected by pesticide use in Oregon, to encourage voluntary changes in pesticide use and management practices, working toward safer waters for aquatic life and humans. The Interagency Water Quality Pesticide Management Team selected the Middle Rogue watershed as a PSP watershed in June of 2015. This priority designation provided funds to continue pesticide monitoring in surface water from 2014, into 2015 and 2016. Future monitoring will depend on continuation of DEQ's Statewide Toxics Monitoring Program funding.

Jackson Soil & Water Conservation District (JSWCD)contracted with Patton Environmental LLC to provide additional evaluation of the groundwater data collected by DEQ. The results of the evaluation would assist in the development of recommendations for future steps for education and outreach, and best management practice development related to pesticide occurrence in groundwater. The evaluation would also provide direction in the development of a groundwater quality monitoring network and set the stage for a better understanding of potential pesticide movement between ground and surface water.

It was agreed that the evaluation would include the following tasks:

1) Evaluation of potential relationship between nitrate concentrations and pesticide detections
2) Evaluation of pesticides detected in groundwater in relation to pesticides detected in surface water
3) Evaluation of pesticides detected in groundwater in relation to nearby land uses
4) Evaluation of pesticides detected in groundwater in relation to soil types

Patton Environmental LLC communicated with DEQ Laboratory Division staff and with DEQ hydrogeologists conducting well construction evaluation as needed to ensure that the evaluations of this study did not duplicate efforts. The intention of this study was to enhance and add to evaluations that DEQ could do within their current staffing limitations.

2.0 DEQ GROUNDWATER SAMPLING RESULTS 2015

Four hundred private well owners volunteered to have their wells tested as part of this study. DEQ selected 107 wells, ranging in location of west of Grants Pass to north Lost Creek Lake and south of Ashland. Both shallow and deep wells were selected, with and without known well construction records.

In February and March of 2015, sixty wells were sampled for 156 parameters including nitrate/nitrite as nitrogen (nitrate), coliform bacteria, current use and legacy pesticides, arsenic, common ions and common field parameters (see list in Appendix B). In October of 2015, forty-seven wells were tested in addition to the re-sampling of 13 wells sampled earlier.

2.1 Groundwater Quality Findings

The DEQ laboratory analyses of the well samples collected in 2015 showed:

Elevated nitrate concentrations (3 milligrams per liter (mg/L) or higher) were measured in 20.5% of wells tested.

In the area around Central Point, and north and west of Medford, 50% of wells tested had elevated nitrate concentrations (See Section 3.2.1 of Appendix A).

Nitrate Concentrations were above the drinking water standard in 4 wells (3.7%).

Coliform bacteria were detected in 43% of wells tested.

Pesticides were detected in 38% of wells tested (41/107), though at very low concentrations. 21.5% of wells tested had two or more pesticides present.

Of the 41 wells in which one or more pesticides were detected, a majority of the pesticides detected were from the triazine herbicide group, including atrazine and simazine and their breakdown products. The second most commonly detected pesticide was 2,6 Dichlorobenzamide, a breakdown product of dichlorbenil. Legacy, or banned pesticides were analyzed for only 43 well samples, and detected in almost 14% of the wells tested. The graph below shows the percent of wells in which different pesticides were detected (Figure 1).

A table of specific pesticides detected, concentrations of detection, and related health-based screening levels is available on page 11 of Appendix A.

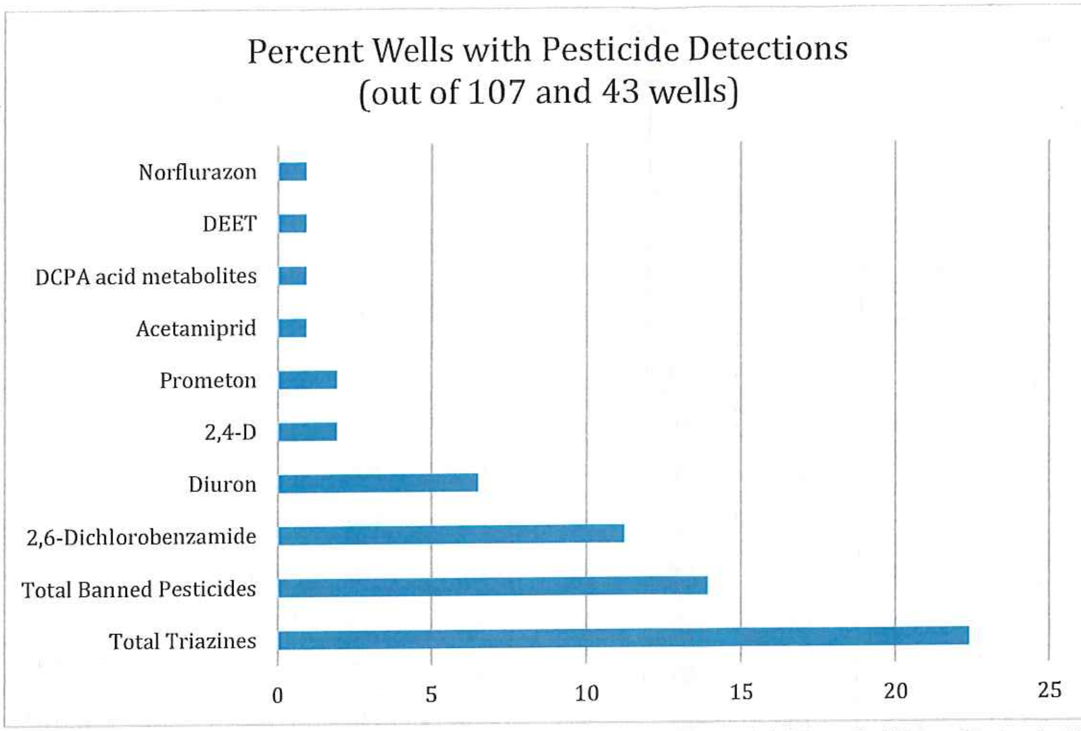

Figure 1 – Percent Wells with Pesticide Detections (out of 107 and 43* wells tested). *Only 47 wells were tested for banned pesticides such as DDT

Arsenic was detected in 24 wells (22.4%), with concentrations several times the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 10 micrograms per liter (ug/L) in 5 wells.

Low concentrations of uranium and vanadium were common.

Manganese was detected in 53% of wells, although only two wells had concentrations above the lifetime health advisory level of 300 mg/L.

2.2 Seasonal Fluctuations

No seasonal trends for nitrate or bacteria were detected.

A table of pesticide detections in the thirteen wells that were sampled in both spring and fall is below. No pesticides were detected in Well Number 132, 133, 157 or 166.

Pesticide detections and concentrations were slightly higher in February and March than in October for most re-sampled wells. In one well, number 126, the pesticide 2,6-Dichlorobenzamide was non-detectable in Feb/March and was detected in October. Figure 2 illustrates the change in Total Triazine concentrations for several wells from February/March to October. Additional graphs of seasonal variations can be found as Figures 10 and 11 in DEQ's report (Appendix A).

Table 1 - Changes in Pesticide Concentrations from February to October 2015

	Triazines		2,6 DCB		DDTs		Acetamiprid		Diuron	
Well #	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
66	21.45	16.31	ND	ND	ND	ND	ND	ND	ND	ND
117	4.53	0	ND	ND	ND	ND	ND	ND	ND	ND
120	31.73	31.33	ND	ND	ND	ND	ND	ND	10.3	9.31
126	ND	ND	ND	32.7	ND	ND	ND	ND	ND	ND
127	12	8.81	ND	ND	ND	ND	ND	ND	ND	ND
132	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
133	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
138	81.2	43.9	90.9	67.8	ND	ND	ND	ND	12.8	11.7
139	127.32	111.76	ND	ND	0.417	ND	ND	ND	ND	ND
141	61	36.4	ND	ND	ND	ND	5.96	ND	ND	ND
150	17.34	12.51	ND	ND	ND	ND	ND	ND	ND	ND
157	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
166	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = Not Detectable at laboratory method detection limits

2.3 Well Characteristics

Well construction records (well logs) were located for 48 of the 107 wells sampled. A DEQ hydrogeologist concluded the following from review of the well logs:

All but two of the wells with logs have conditions suggesting the well water source is from a confined or semi-confined aquifer. This condition may protect the well water from surface contamination sources.

The depth of the top of the water bearing zone was determined for 41 wells and ranged from 23 to 890 feet below ground surface. There seemed to be a strong correlation between the presence of nitrate and the top of the water bearing zone recorded in the well logs (see Figure 3 in DEQ report, Appendix A). Elevated nitrate concentrations were primarily found in shallow wells (of those wells for which well depth could be determined).

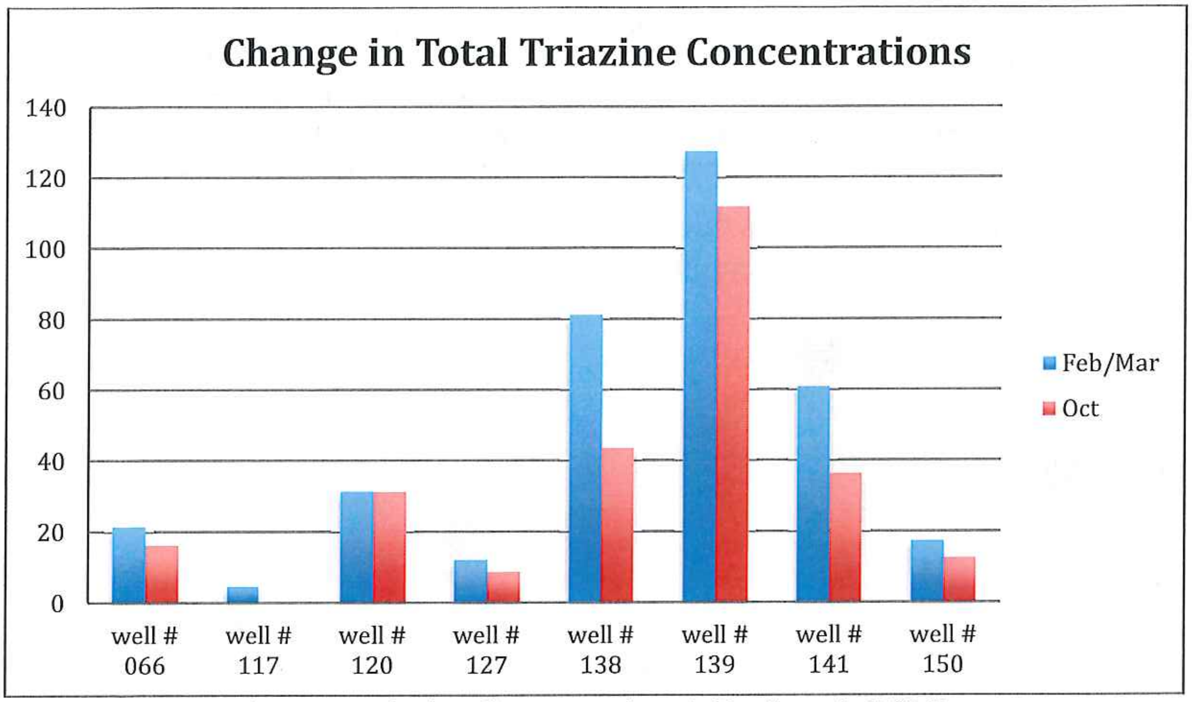

Figure 2– Change in Total Triazine Concentrations in Re-Sampled Wells

Poorly constructed wells may allow contaminants to travel along the borehole from the surface to the water bearing zone. Thirty-nine wells were determined by DEQ Hydrogeologist Matt Kohlbecker to have a high relative potential for vertical fluid migration *below the well seal* based on geologic material in which the well is located. Forty-four percent (18/41) of wells (with sufficient well construction information for evaluation) were considered by DEQ Hydrogeologist Paul Measles to have poor sanitary seals, possibly allowing contamination from surface activities to migrate to groundwater along the well casing. This indicates that more attention should be given to proper well construction in areas of elevated nitrate to avoid contamination and cross contamination of aquifers.

3.0 ADDITIONAL EVALUATION OF GROUNDWATER QUALITY DATA

Data from the 2015 study was compared with data from previous Rogue Basin studies and evaluated for correlations with surface water, land uses and soil types.

3.1 Comparison of 2015 Data with Previous Study Data

3.1.1 Nitrate – Nitrate concentrations in Rogue Basin wells have been measured several times over the past decades, and show a variety of results, related primarily to sampling design (see Figure 3, below). In 1992, DEQ attempted to collect samples only from wells with well construction records. As a result, the wells sampled were generally newer and deeper than wells sampled in previous and subsequent studies. Fewer of the wells sampled in 1992 had nitrate contamination. In 1994, DEQ attempted to evaluate more of the shallow groundwater in the Rogue Basin, and consequently found many more wells with nitrate contamination. The 2011 and 2015 DEQ studies represent a more balanced approach, with sampling conducted at both well-constructed, deeper wells and shallow, older wells. Data from wells tested at public education and outreach events in 2015 (Vol Data) and 2016 (Vol Data), represent field nitrate test results from well owners voluntarily offering samples for testing. The Real Estate Transaction (RET) data, collected at property transfer from 1989 through the present, is the largest data base and therefore perhaps most representative of area-wide conditions.

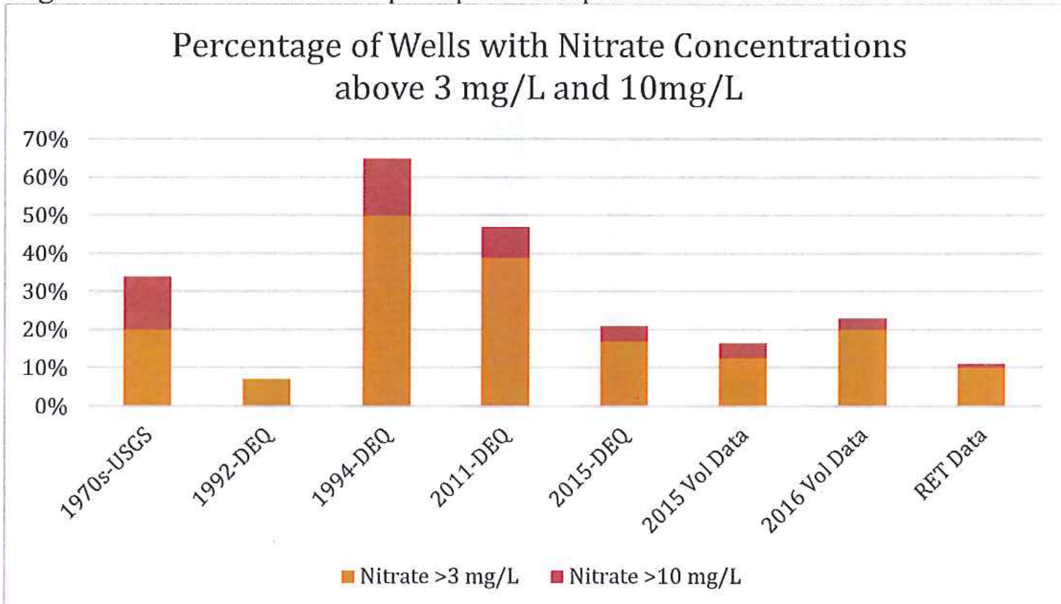

Figure 3 – Nitrate Concentrations Above 3 mg/L and Above 10 mg/L in Various Rogue Basin Studies

Perhaps the most important conclusion to draw from this set of study results is that there are certain types and locations of wells in the valley which are more heavily contaminated by nitrate than others.

<u>3.1.2 Pesticides</u> - In the 1994 DEQ Groundwater Quality Investigation, water samples were analyzed for a few select pesticides and some Volatile Organic Compounds (VOCs). The laboratory technology available at that date was much less sensitive, however, and many of the contaminants detected in 2015 may have been present, but would not have been detected in 1994. Constituents that were detected in 1994 included pentachlorophenol and dacthal acid, in one well each.

In 2015, 17 different pesticides were detected in Rogue Valley groundwater, though at low concentrations. One or more pesticides were detected in 41 of the 107 wells tested (38%). Some wells had 4 to 7 pesticides present in drinking water supplies.

<u>3.1.3 Arsenic</u> - Very high concentrations of arsenic were detected in 3 wells of the 2015 study (38.8, 107, and 452 ug/L) versus a high of 32.1 ug/L in 2011. Due to a lower laboratory detection limit used in 2011, the percentage of wells with detected arsenic was much higher in the 2011 DEQ Rogue Basin study than in 2015 (see Figure 4). The 2011 data is consistent with the much larger database of the Oregon Health Authority's Real Estate Transaction testing -

showing approximately 44% of wells with some arsenic. Adjusted to compare to the 2015 detection level of 2 ug/L, the 2011 detection level would be reduced to 13%.

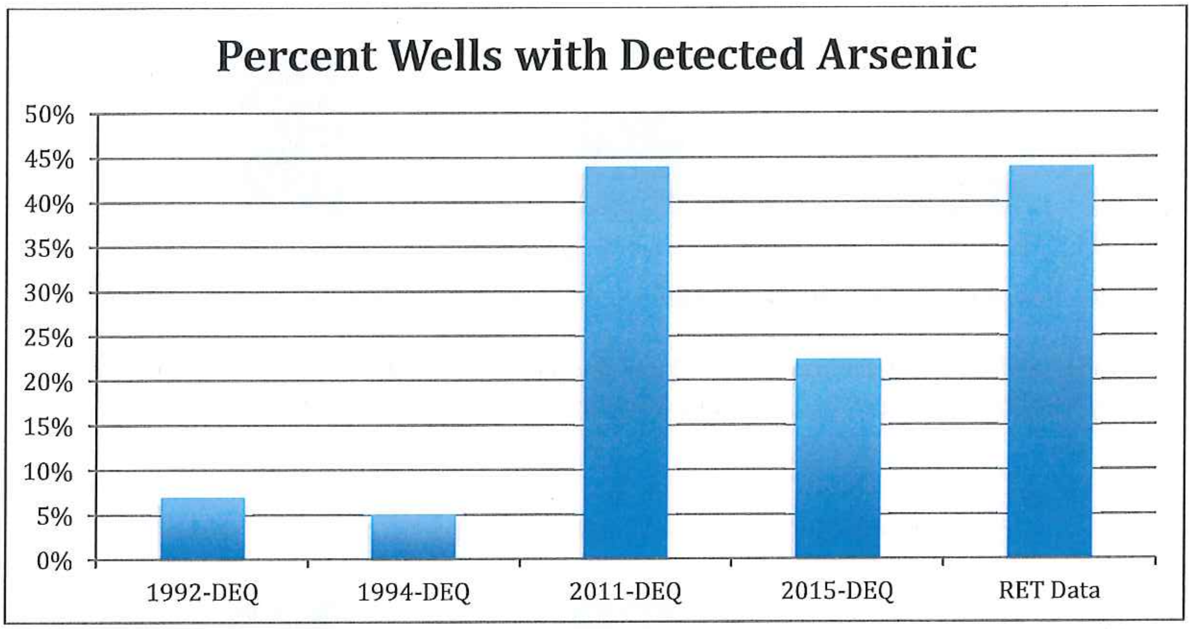

Figure 4– Percent of wells with detected arsenic in various DEQ studies and in Real Estate Transaction data collected by the Oregon Health Authority

EPA's Maximum Contaminant Level Goal (MCLG) for Arsenic is 0 ug/L. The MCLG is the concentration below which there is no known or expected health risks. The MCL of 10 ug/L, considered the drinking water standard, is set based on feasibility of treatment considering technology and cost for public water suppliers as well as health considerations.

3.2 Relationship between Pesticide Detections and Nitrate Concentration

Nitrate in groundwater is generally the result of either fertilizer, manure applications to surface soils, drainage from manure or compost piles, or the result of poorly treated septic system drainage. Similarly, pesticide contamination of groundwater is likely due to surface applications or spills that have seeped through the soils into groundwater, or otherwise entered a well through a poor seal or improper well construction. Thus, there is reason to expect a correlation between findings of elevated nitrate and pesticide detections in domestic wells.

The number of pesticides detected per well was compared to the nitrate concentrations in those wells to evaluate this relationship. The bar chart in Figure 5 shows a strong positive correlation between the average number of pesticide detections per well and nitrate concentrations above 1 mg/L and above 3 mg/L in wells tested. Calculations show the correlation to be statistically significant ($p<0.01$).

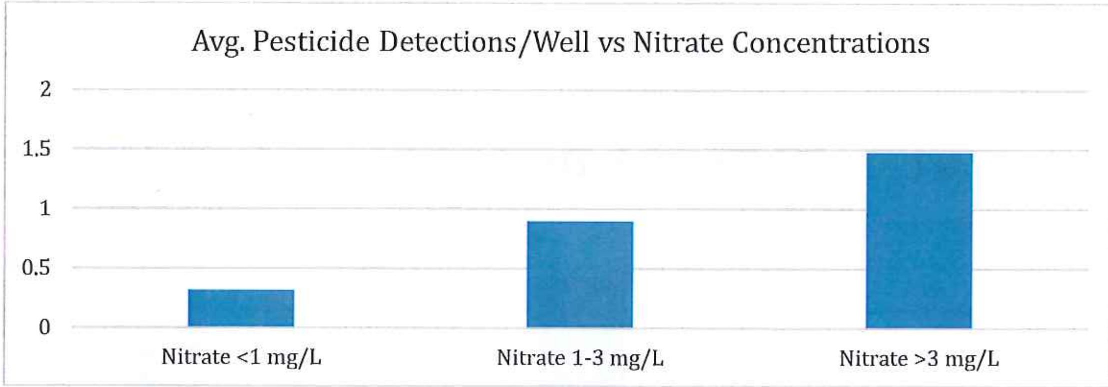

Figure 5 – Number of Pesticide Detections vs. Average Nitrate Concentration in Wells

The number of Triazine detections per well and the number of DDT detections per well also increased as nitrate concentrations increased above 1 mg/L (see Figure 6).

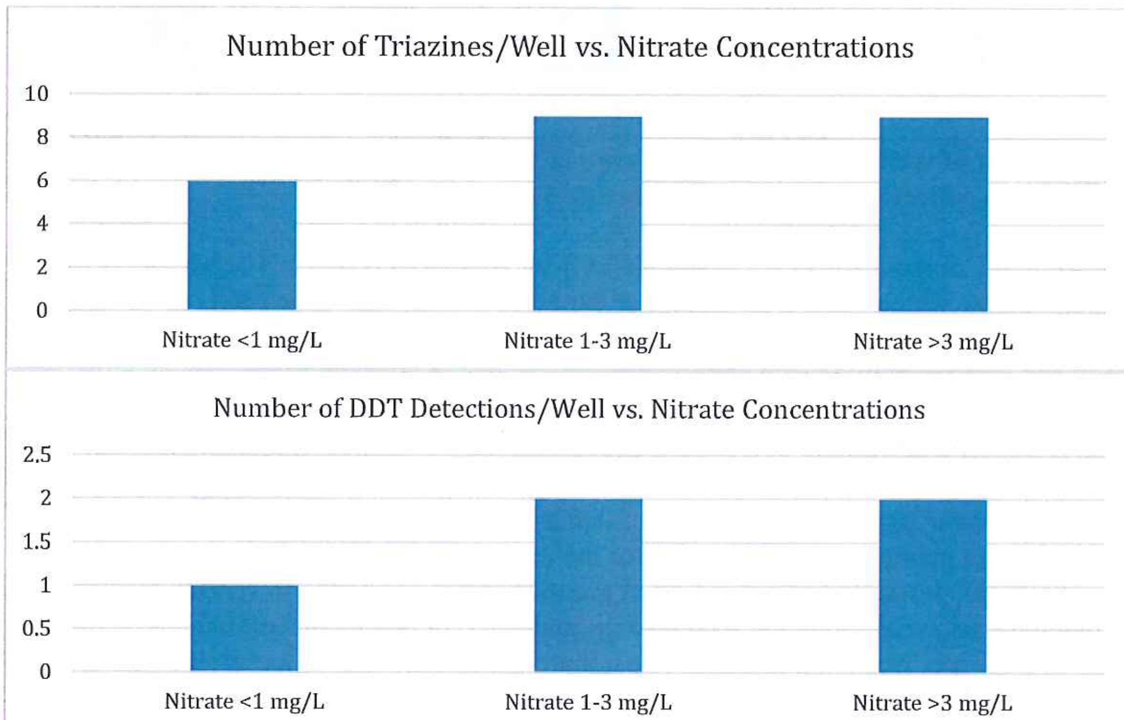

Figure 6 – Number of Triazine and DDT Detections per Well vs. Nitrate Concentrations

These results, and the results in Figure 3 of the DEQ report attached, raise the question as to whether more attention should be paid to wells with nitrate concentrations less than 1 mg/L, 1-3 mg/L and above 3 mg/L.

Another indicator of the correlation of pesticide detections to nitrate concentrations can be found through a comparison of two maps provided in the attached DEQ report, Figure 7, Number of parent pesticides detected in sampled wells and Figure 1, Nitrate concentration in sampled wells (Appendix A).

3.3 Pesticide Detections in Groundwater versus Surface Water

The Oregon Department of Environmental Quality, in partnership with the Oregon Department of Agriculture, the Jackson Soil & Water Conservation District and other state and local agencies have collected surface water samples for analysis of pesticides and other constituents as part of the Pesticide Stewardship Partnership and Toxics Monitoring Programs. Surface water samples were collected from 2 locations along Jackson and Griffin Creeks in 2014-2015 and 2 locations in 2015-2016, from 2 locations along Payne and Coleman Creeks in 2014-2015, and from 1 location along Wagner Creek in 2014-2015 and 3 locations in 2015-2016. Maps of the surface water sampling locations in relation to wells sampled by DEQ in 2015 are included in Appendix B.

It is beyond the scope of this report to present or analyze the results of the surface water study. However, a brief comparison of pesticide detections in surface water and groundwater was conducted.

The table in Appendix B presents the list of analytes tested for groundwater and for surface water samples in the various studies. It is important to note that not every sample collected was tested for the same suite of analytes. In particular, only a few of the surface water samples and none of the groundwater samples were tested for the commonly used pesticide glyphosate (Round Up) or for AMPA (a glyphosate degradate).

In both the Payne/Coleman Creek areas and the Wagner Creek areas, there were no obvious correlations between surface and groundwater testing results. This is mainly due to the long distances between surface water and groundwater sampling sites (most much more than a mile apart) (see maps in Appendix B).

In the Wagner Creek watershed, no similar pesticides were detected in surface and groundwater.

In the Payne/Coleman watershed, legacy (banned) pesticide constituents 4,4-DDD were detected in groundwater and 4,4-DDE was detected in surface water.

In the Jackson and Griffin Creek Watersheds, there were several correlations between test results of surface and groundwater samples. Atrazine, 2,4-D, 2,6-Dichlorobenzamide, Acetamiprid, Triazines, Diuron, and Prometon were all found in both water bodies.

The large distance between most of the groundwater wells and the surface water sampling locations make a direct surface water-groundwater connection between these sampling locations unlikely. It is more likely that the chemicals found in both water bodies in these watersheds are the result of common use of those chemicals in this area.

3.4 Pesticide Detections in Groundwater versus Land Uses

For this evaluation, only those 41 wells with pesticide detections were used. Land uses for areas around the wells were determined based on visual observation of probable irrigation methods, density of housing and evidence of agricultural activities using Google Earth images in a method similar to that used by Jackson Soil & Water Conservation District on a 2015 project: Groundwater Nitrate Education in Rogue Basin Drinking Water Areas, funded by the Oregon Department of Environmental Quality. Nitrate Leaching Potential from land use for that project and this were divided as follows:

Low Leach Potential: *Commercial, Concentrated Urban, Dryland Crop, Dryland Livestock, Forest, Orchard, Riparian, Rural Open Space, Rural Residential, Urban Open Space, Urban Residential*

Medium Nitrate Leaching Potential: *Golf Course, Industrial, Sprinkler Irrigation Crop, Sprinkler Irrigation Livestock*

High Nitrate Leaching Potential: *Concentrated Rural, Flood Irrigation Crop, Flood Irrigation Livestock*

Low Leach Potential land uses were assigned a number 1, Medium Leach Potential land uses a 2, and High Leach Potential land uses a 3. The numbers were then compared to nitrate concentrations and to numbers of pesticides detected. There was no statistically significant correlation of nitrate concentrations to Nitrate Leach Potential or of pesticide detection to Nitrate Leach Potential. This result does not mean that there is no correlation between land use and either nitrate or pesticide detections. It may mean that there is more than one factor that influence groundwater contamination in areas of specific land uses – such as well construction, aquifer types, best management practices in the area of the well, etc. In addition, a better result might be achieved if the method of evaluation of land uses was conducted in a more accurate, ground-truthed, manner.

3.5 Pesticide Detections in Groundwater versus Soil Types

Soil types were identified in the vicinity of each of the 41 wells where pesticides were detected. Soil characteristics were evaluated in relation to the detection of pesticides and nitrate in groundwater to determine any relationship. Soil types and characteristics were obtained from the Natural Resource Conservation Service (NRCS) soil survey information at http://nrcs.usda.gov. It is important to recognize that NRCS soils classifications are created on a broad scale and may not be accurate for specific locations. In addition, there were sometimes two or three soil types around each well. Only the predominant soil type was selected for use in this analysis.

Twenty soils are listed in Table 2. Pesticides were detected in wells near each of these soil types. Interestingly, 31 of the 41 wells with pesticide detections were located within 10 soil types, whereas the remaining 10 wells with pesticide detections were in 10 other, separate soil types. In addition, the number of pesticide detections per well were generally greater in the 10 most frequent soil types and fewer detections were found in the other soil types.

Table 2 presents data regarding the number of total pesticide detections per soil type, the number of detections per well per soil type, and the average nitrate concentration in groundwater per soil type. This evaluation shows the highest pesticide detections (in total and per well) are in the following soil types: the Agate-Winlow Complex, the Barron Coarse Sandy Loam, the Kubli Loam, the Medford Silty Clay Loam, the Central Point Sandy Loam, and the Ruch Silt Loam and Gravelly Silt Loam. Nitrate concentrations in groundwater were also generally higher in wells located around those soil types.

NRCS soil descriptions offer a range of permeability and clay content for soil types identified. Ideally, site specific testing should be conducted to determine a more precise soil quality. Any evaluation conducted using this data has the potential for misleading results.

Of the various soil characteristics recorded by NRCS, permeability and percent clay content were considered most relevant to this study. Although soil type and characteristics generally relate only to the first few feet of the material through which a domestic well is drilled, and well water is generally drawn from rock formations sixty to hundreds of feet deep, soil characteristics could influence the probability of surface contamination such as nitrate or pesticides reaching deeper groundwater through filtration – a factor related to permeability - or through contaminant adsorption – a factor related to clay content.

3.5.1 – Permeability - Permeability is a measure of the ability of a soil to allow fluids to pass through. The NRCS permeability ratings for the top soil layers were used for this study. They ranged from 0.2<0.6, 0.6<2, and 2<6 inches per hour. These ranges were averaged to rates of 0.4, 1.3 and 4 inches per hour and plotted against the number of pesticides detected per well for 41 wells with at least one detection. Theoretically, a more permeable soil would have a greater potential to allow contaminants to pass through it because of the shorter retention time and therefore less opportunity for contaminants to adhere to soil particles. A scatter plot of this data showed a very slight positive correlation between the number of pesticides detected and the permeability of the soil, as expected. The correlation was not statistically significant, however.

3.5.2 – Percent Clay Content - The NRCS identifies percentage clay content in soils in ranges of 0-5, 5-10, 8-12, 8-15, 8-18, 12-18, 15-22, 18-25, 18-27, 18-35, 12-35, 15-35, 18-35, 27-35, 20-40, 30-40, 40-50 and 60-70. These were translated into averages of 2.5, 7.5, 10, 11.5, 13, 15, 18.5, 21.5, 22.5, 23.5, 25, 26.5, 28.15, 30, 35, 45 and 65 to create scatter plots. Increased percentages of clay in soils will reduce soil permeability, so it was not surprising to find a slight negative correlation between the number of pesticides detected per well and soils with higher clay content. The other benefit of clay in soil is that it provides a large volume of surface area onto which contaminants such as pesticides can adhere. This feature would theoretically reduce the ability of pesticides to pass through a soil with high clay content to reach groundwater. The correlation between the number of pesticides detected per well and percent clay content was not statistically significant, however, and therefore not conclusive. This is perhaps because a source of pesticides must also be present for pesticides to be detected and this factor was not universal in this study.

Table 2: Soil Types and Corresponding Numbers of Pesticides and Nitrate Concentrations

Soil Type	Number of Pesticides per Soil Type	Number of Wells per Soil Type	Number of Pesticides per Well per Soil Type	Average Nitrate Concentration per well per Soil Type
100A and 100B, Kubli loam	10	3	3.33	1.61
6B, Agate-Winlo complex 0-5	19	6	3.17	3.17
10B, Barron coarse sandy loam, 0-7	12	4	3	1.49
31A, Central Point sandy loam 0-3	6	3	3	4.65
127A , Medford silty clay loam 0-3	9	4	2.25	4.23
157B Ruch silt loam 2-7	6	3	2	2.79
34 Evans loam	2	1	2	0
163A Sevenoaks loamy sand 0-3	2	1	2	1.71
158D Ruch gravelly silt loam	5	3	1.67	1.69
113E McMullin-rock outcrop complex 3-35	3	2	1.5	0.79
164D Shefflein loam	2	2	1	0
108E Manita loam 7-20	2	2	1	1.87
98B &102B, Kerby loam & Langellain-Brader loams	1	1	1	2.52
5b Barron coarse sandy loam 2-7	1	1	1	0.52
43D Darow silty clay loam 5-20	1	1	1	0.08
35A Cove clay 0-3	1	1	1	3
22A Camas gravelly sandy loam 0-3	1	1	1	1.09
196E Vannoy silt loam 12-35	1	1	1	0.25
189E Tallowbox gravelly sandy loam, 20-35	1	1	1	0
141A Phoenix clay 0-3	1	1	1	0.17

A graph of Concentration of Nitrate in Groundwater vs. Percent Clay in Soils (Figure 7) shows an apparent connection between elevated nitrate and soils with 20 to 30 percent clay content. Only five wells had elevated nitrate in areas of soils outside of that clay content. It would be interesting to test for nitrogen concentrations in soils with 20-30 percent clay and see if they relate to groundwater results.

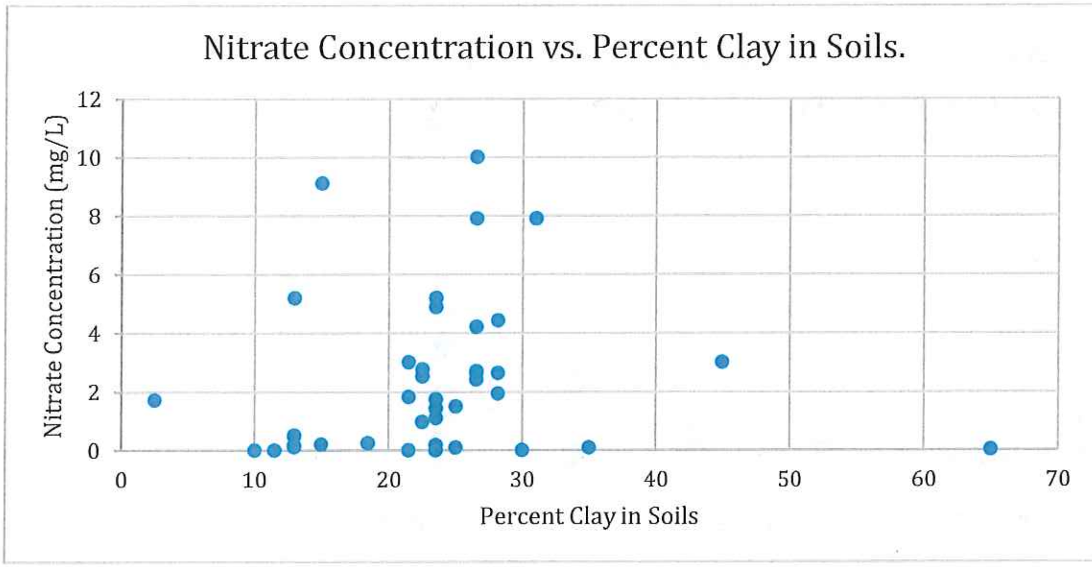

Figure 7 – Nitrate Concentration vs. Percent Clay in Soils for 30 wells with Pesticides

3.6 Pesticide Detections in Groundwater versus Well Construction

Some discussion about well construction impacts on water quality is presented in Section 2.3 of this report and in the DEQ report. It is important to remember that well logs were only available for 46 wells of the 107 wells sampled. In addition, most wells for which well logs were available were newer wells, and probably better constructed (deeper, better seals) than the other wells, making them less susceptible to contamination from nitrate or pesticides.

Using DEQ data for top of water bearing zone, wells were assigned the following ratings based on their depth to first water:

0-50 ft. = 5
51-100 ft. = 4
101-150 ft. = 3
151 – 200 ft. = 2
201 – 300 ft. = 1
301 – 1000 ft. =0

A rating of 5 is considered more sensitive to groundwater contamination due to the shallow distance between the possible source of nitrate and pesticides and the top of the water bearing zone of the well. Ratings of 4 to 0 reflect increasingly reduced sensitivity to contamination.

A comparison of nitrate concentrations to top of the water bearing zone is shown in Figure 8 to have a strong positive correlation which calculated to be statistically significant ($p<0.01$). Comparison of pesticide detections to the top of the water bearing zone is shown in Figure 9 to also have a positive correlation, though less strong. This correlation was not found to be statistically significant ($p>0.01$).

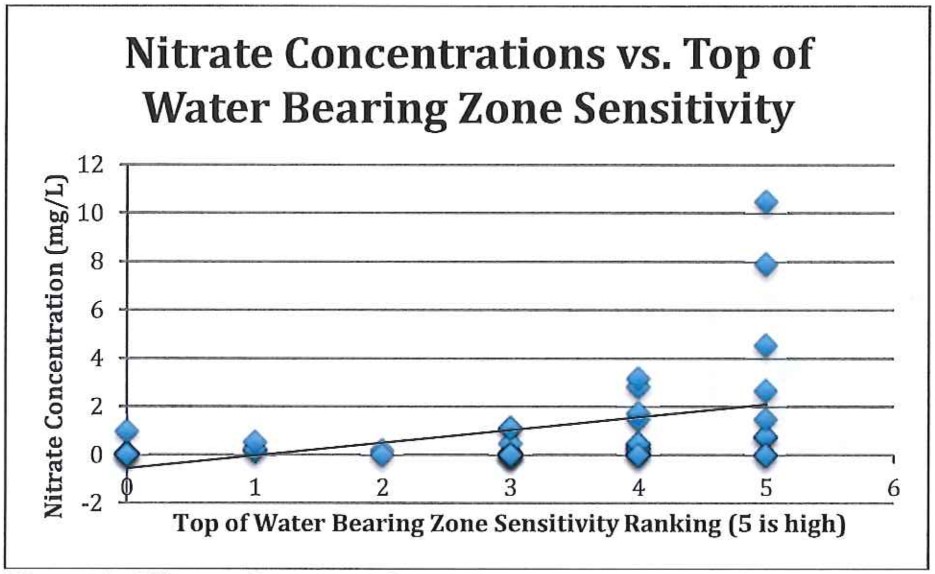

Figure 8 –Nitrate Concentrations vs. Top of Water Bearing Zone

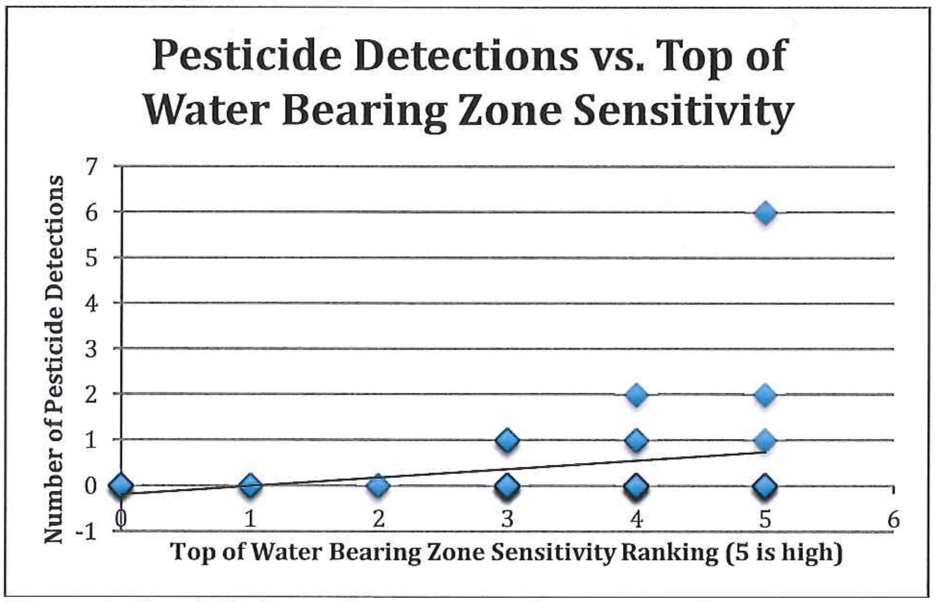

Figure 9 –Pesticide Detections vs. Top of Water Bearing Zone

4.0 CONCLUSIONS

Key findings from this study include:

Pesticides were detected in 38% of wells tested. Legacy pesticides were detected in 14% of wells tested.

The area where most pesticides were detected coincided with the areas of highest nitrate concentrations.

Pesticide detections were generally lower in the spring (Feb, Mar) than in the fall (Oct), with some concentrations moving to non-detectable in October.

For those pesticides with available drinking water standards or health based screening levels, the pesticide detections were far below those concentrations. There is little research, however, about how multiple pesticides in one well might influence human health.

4.1 Comparison of 2015 Data with Previous Studies

The most concentrated area of nitrate contamination in drinking water wells is in the rural areas around Central Point and north and west of Medford. Depending on the depth, construction, and location of drinking water wells tested, researchers have found differing percentages and concentrations of nitrate contamination in well water in the Rogue Basin in the 1970s, from 7% to 65%.

The percentage of wells with arsenic detections above 1 ug/L in DEQ's 2011 study is consistent with the percentage of wells with arsenic detections reported to the Oregon Health Authority through the Real Estate Testing program. (DEQ's 2015 study had a higher detection level for arsenic, reducing the numbers of detections). Very high concentrations of arsenic were detected in some of the 2015 wells.

4.2 Correlations between nitrate concentrations and pesticide detections

A positive, statistically significant correlation was found between nitrate concentrations and pesticides in those wells with pesticide detections. This was not surprising since both nitrate and pesticide contamination of groundwater is likely to occur from similar sources and through similar mechanisms (either leaching through the shallow soils to groundwater or migrating along a pathway such as a failed well seal).

The correlation is true for wells with over 1 mg/L nitrate as well as for those wells above 3 mg/L. This result suggests that more attention should be paid to nitrate concentrations below 3 mg/L as well as those over. In the past, nitrate concentrations below 3 mg/L were not considered significant.

4.3 Correlations between pesticides in groundwater and surface water

There were no obvious correlations between surface and groundwater testing results. This is mainly due to the long distances between surface water and groundwater sampling locations.

No similar pesticides were detected in surface water and groundwater in the Wagner Creek watershed. Some similar pesticides were detected in surface water and groundwater in the Payne/Coleman Creek watersheds and particularly in the Jackson/Griffin Creek watersheds. This is likely a result of use of those pesticides in the watershed, rather than a result of any surface water/groundwater connection.

4.4 Correlations between groundwater quality and nearby land uses

Insufficient data were available to adequately evaluate nitrate concentrations or pesticide detections and land uses. More specific evaluation in this area is needed.

4.5 Correlations between groundwater quality and soil types

Seventy-five percent of the wells with pesticide detections were located near ten soil types, possibly indicating increased contaminant sensitivity for those soils. More research is needed to determine the strength of the correlations between pesticide and nitrate contamination in groundwater and soil types such as the Agate-Winlo complex, Barron coarse sandy loam, Kubli loam, Medford silty clay loam, Central Point sandy loam and the Ruch silt loam or gravelly silt loam.

Insufficient data were available to adequately evaluate soil characteristics such as permeability and clay content in relation to contaminant sensitivity. There was some correlation between clay content of 20-30% and elevated nitrate in groundwater, however.

4.6 Correlations between groundwater quality and well construction

Forty-four percent of wells with well construction records were considered by DEQ to have been constructed with poor well seals. Wells with poor well seals had higher nitrate concentrations than those with good well seals, indicating a need for improved well seal construction.

As expected, wells receiving water from shallow aquifers were more likely to have both nitrate and pesticide contamination (top of water-bearing zone sensitivity).

5.0 RECOMMENDATIONS

5.1 Education and Outreach

Provide improved well construction education of well owners and drillers if needed, particularly concerning placement of well seals.

Focus education and outreach efforts in areas of known contamination, offer free well water testing for nitrate to homeowners in that area (use post cards or door hangers, make it convenient). Identify neighborhood centers or community organizers and ask them how best to reach people in their community.

Provide education and outreach through schools with large rural populations, offer free nitrate testing, community meetings, continue to support OSU Master Gardener Fair Outreach. Publicize free nitrate testing on Tuesday mornings at JSWCD.

Provide information to landlords and to rural tenants about the new legislation (if it passes) that requires landlords to inform tenants of drinking well water quality prior to lease. Provide information about how low income rural residents can access funding for septic or well repairs.

Continue public education about naturally occurring arsenic in Rogue Basin well water.

5.2 Best Management Practices

Work with OSU Extension and Experiment Stations and ODA to evaluate current irrigation and fertilization practices in the valley and to promote best management practices to growers and ranchers. Access funding to conduct experiments to develop best management practices specific to the Rogue Basin at OSU's Southern Oregon Research and Extension Center in Central Point.

BMP resources for reduction of nitrate contamination of groundwater are available from research conducted in California, the Willamette Valley, Eastern Oregon and elsewhere.

5.3 Further Assessment

DEQ's report suggests establishing a set of wells for long term assessment and evaluation of seasonal variation. These wells should be selected from wells know to have some contamination or no changes will be apparent from year to year.

Attempt to collect surface and groundwater samples in adjacent locations, preferably with a shallow well for the groundwater sample, to better evaluate surface water and groundwater connection. A stronger study would be to first locate a portion of the stream that is gaining water from groundwater and sample in that area to determine if the groundwater is contributing to poor stream quality, including temperature. If a connection is discovered, contamination prevention best management practices could be developed that benefit both water bodies.

A more thorough, accurate evaluation of land uses and agricultural management practices could be conducted in areas where elevated nitrate and pesticides have been detected to better determine any correlation between potential sources and documented contamination. This effort would greatly benefit any determination of best management practices for groundwater quality protection.

A more thorough analysis could be conducted to further evaluate any correlations between nitrate and pesticide contamination of groundwater and particular soil types in the Rogue Basin.

Appendix A

DEQ Report-Statewide Groundwater Monitoring: Mid-Rogue Basin 2015

Statewide Groundwater Monitoring Program: Mid-Rogue Basin 2015

December 2016

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DEQ is a leader in restoring, maintaining and enhancing the quality of Oregon's air, land and water.

State of Oregon
Department of Environmental Quality

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Documents can be provided upon request in an alternate format for individuals with disabilities or in a language other than English for people with limited English skills. To request a document in another format or language, call DEQ in Portland at 503-229-5696, or toll-free in Oregon at 1-800-452-4011, ext. 5696; or email deqinfo@deq.state.or.us.

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Executive Summary

Oregon's goal is "to prevent contamination of Oregon's groundwater resource while striving to conserve and restore this resource and to maintain the high quality of Oregon's groundwater resource for present and future uses (ORS 468B.155)." To understand how Oregon is doing in meeting this goal, the Statewide Groundwater Monitoring Program began collecting water quality data in 2015 to establish the status of ambient groundwater conditions, identify emerging groundwater quality problems and inform groundwater users of potential risks from contamination. To implement this work, two regional groundwater studies are conducted annually with the goal of monitoring Oregon's vulnerable aquifers over a 10-year period. Regional study areas are selected based on previously identified groundwater vulnerabilities, nitrate data collected during real estate transactions as required by statute (ORS 448.271), time elapsed since water quality data were collected, analysis of potential contamination sources and community interest to help with recruitment of volunteer participants. All studies include analysis of nitrate, arsenic, bacteria, pesticides and common ions in 60 to 100 wells. Additional analyses are added based on local risk factors and program capacity.

In 2015, the Statewide Groundwater Monitoring Program conducted a groundwater study in the mid-Rogue Basin. Objectives of the study were:

1. To collect high-quality data on nitrate, arsenic, coliform bacteria and pesticide concentrations in groundwater throughout the study area;
2. To identify areas of groundwater contamination related to these parameters;
3. To inform well water users of the results of this study and provide information regarding potential risks to human health;
4. To identify areas needing additional investigation in order to describe the extent of contamination and help focus efforts to prevent further contamination.

Outside the scope of this study and report:
- Hydrogeologic characterization of the study area and contamination
- Investigation of the sources of contamination
- Health risk assessments

The study area spanned Jackson and Josephine counties, including the communities of Grants Pass, Shady Cove, Central Point, Medford and Ashland. DEQ staff sampled 107 private, mostly domestic, wells for nitrate, arsenic, bacteria, pesticides, metals, and common ions over two sampling events in February and October 2015. These domestic wells serve as sources of drinking water, along with other household uses such as for farm animals, outdoor garden and lawn irrigation, etc.

Key findings include:
- Elevated nitrate levels [3 milligrams per liter (mg/L) or higher] in the area around Central Point and north and west of Medford. For the limited data set of wells with well logs, elevated nitrate concentrations were found only in wells with shallow water bearing zones. Four wells had nitrate concentrations above the maximum contaminant level (10 mg/L) set by the U.S. Environmental Protection Agency for public water systems
- High arsenic [above the maximum contaminant level of 10 micrograms per liter (µg/L)] was measured in six wells. Lack of well logs for many of the wells with high arsenic results limited the interpretation of this data
- Coliform bacteria detected in 43 percent of wells tested
- At least one pesticide or pesticide breakdown product in 41 of the 107 wells tested. Twenty-three wells had two or more pesticide-related chemicals detected. All pesticide detections were well below their associated screening levels. However, very little research has been done on the effect of multiple chemicals on human health. Pesticide mixtures found in wells included up to four different "parent" pesticides

- Manganese was detected in 57 of the study wells, with two of the wells above the Lifetime Health Advisory level of 300 µg/L. While low concentrations are likely due to natural geochemical processes, further investigation is necessary to determine the sources of manganese in the wells with very high concentrations
- Low concentrations of uranium and vanadium were common
- No seasonal trend was detected in nitrate or bacteria results. Pesticide detections and concentrations were slightly higher in the winter than the fall

The results of this study can be used to focus outreach and education activities that encourage private well owners to routinely test wells for nitrate, bacteria and arsenic and encourage well protection and maintenance best practices to protect the aquifer. Further analysis is needed to delineate the extent of nitrate contamination in several parts of the study area, particularly around Central Point and north and west of Medford. Long-term monitoring of nitrate and pesticides is recommended, especially in the area north and west of Medford. A network of wells should be established and monitored to detect any changes over time.

1. Background

Groundwater is a vital resource in Oregon. Over 600,000 Oregonians rely on private wells for their drinking water (Maupin et al. 2014). Public water systems, the agricultural community and industry also rely on groundwater to meet their operational needs. In addition, Oregon's rivers and streams depend on groundwater for the maintenance of adequate summer flows to sustain fish populations and for recreational opportunities. Groundwater is a critical water reserve that can be used when available surface water is inadequate to meet demands.

Oregon's goal is "to prevent contamination of Oregon's groundwater resource while striving to conserve and restore this resource and to maintain the high quality of Oregon's groundwater resource for present and future uses (ORS 468B.155)." To understand how Oregon is doing in meeting this goal, the Statewide Groundwater Monitoring Program began collecting water quality data in 2015 to establish the status of ambient groundwater conditions, identify emerging groundwater quality problems and inform groundwater users of potential risks from contamination. To implement this work, two regional groundwater studies are conducted annually with the goal of monitoring Oregon's vulnerable aquifers over a 10-year period. Regional study areas are selected based on previously identified groundwater vulnerabilities, nitrate data collected during real estate transactions as required by statute (ORS 448.271), time elapsed since water quality data were collected, analysis of potential contamination sources and community interest to help with recruitment of volunteer participants. All studies include analysis of nitrate, arsenic, bacteria, pesticides and common ions in 60 to 100 wells. Additional analyses are added based on local risk factors and program capacity.

In 2015, the Statewide Groundwater Monitoring Program collected groundwater quality data in the mid-Rogue basin. Data from the 2011 Rogue Basin Groundwater Investigation, which includes a comprehensive review of the Basin's groundwater data since the 1970s (Patton and Eldridge 2013), and the Oregon Health Authority's Real Estate Transaction Act (ORS 448.271) indicated some elevated nitrate concentrations in the region, particularly the Central Point area. Data collected by DEQ for the Rogue Basin Groundwater Investigation in 2011 showed elevated nitrate concentrations (3 mg/L or higher) in 35 percent of the wells tested (18 of 52 wells), including all the wells tested in Central Point and north and west of Medford. The 2011 study also investigated arsenic, fluoride, boron and vanadium concentrations (Patton and Eldridge 2013).

Using information learned from the 2011 study and guided by the objectives of the Statewide Groundwater Monitoring Program, the goals of the 2015 mid-Rogue basin groundwater study were:

1. To collect high-quality data on nitrate, arsenic, coliform bacteria and pesticide concentrations in groundwater throughout the study area;
2. To identify areas of groundwater contamination related to these parameters;
3. To inform well water users of the results of this study and provide information regarding potential risks to human health;
4. To identify areas needing additional investigation in order to describe the extent of contamination and help focus efforts to prevent further contamination.

Outside the scope of this study and report:
- Hydrogeologic characterization of the study area and contamination
- Investigation of the sources of contamination
- Health risk assessments

2. Study Design and Methods

2.1 Study Design

The study area included the communities of Grants Pass, Shady Cove, Central Point, Medford and Ashland. The boundary was within the Rogue River watershed and included the area surrounding Lost Creek Lake. Our study focused primarily on private, domestic wells and relied on homeowners who volunteered to have their wells tested in exchange for a complete report of the analytical results from their well. Volunteers were recruited using flyers, emails, and other announcements with the help of the Jackson County Soil and Water Conservation District, staff from the DEQ office in Medford, and others. Over 400 individuals expressed interest in having their well tested. From these 400 plus volunteers, 150 potential wells were randomly selected as candidates for sampling. Of these 150 candidate wells, 107 wells were sampled as a part of the study based on location, availability of a well log and known or suspected depth of the well. Known depths were based on a confirmed well log. Suspected depths were based on conversations with the homeowner.

Previous DEQ groundwater studies tried to only include wells with well logs and it is unknown if this introduced a bias in the dataset. Older wells are more likely to not have well logs. These wells may also be more vulnerable to contamination due to poor construction or location in areas that have a longer history of agricultural activity, a known risk factor for groundwater contamination. This study did not require all study site wells to have a well log in an effort to see if there is an increased risk of contamination in this population, which has not been included in previous studies. A full site list including information on presence or absence of a well log can be found in Appendix A. Figure 1 shows the locations of the wells selected for this study and the location of water table aquifers as described by Sweet et al. (1980). A water table aquifer, also known as an unconfined aquifer, is groundwater that is overlain by permeable material (i.e., sand) and therefore, is expected to be more vulnerable to contamination from surface activities.

DEQ collected samples during two events, each lasting three weeks. The first 60 wells were sampled between Feb. 9 and March 4, 2015. Another 47 wells, along with a resampling of 13 wells from the first event, occurred between Oct. 12 and Oct. 28, 2015. Wells were resampled to capture potential seasonal variability. Of the wells selected to be resampled, eight were selected based on results from the first event; the rest were selected based on location and the existence of a well log. All resampled wells were shallow wells (chosen as less than 100 feet below ground surface), as they are most likely to be affected by seasonal differences in precipitation or land use practices. Due to limitations of the study design and inclusion of wells without well logs, results from this study represent the conditions in the well sampled and not the broader aquifer. Additional hydrogeologic analysis is outside the scope of this report.

2.2 Methods

2.2.1 Sampling Methods

DEQ water quality monitoring staff collected and processed samples according to standard procedures found in the Manual of Methods, Sampling and Analysis Plan and Quality Assurance Project Plan. (DEQ03-LAB-0036-SOP_V3, DEQ11-LAB-0043-SAP, DEQ93-LAB-0024-QAPP). Samples were collected from an outdoor spigot closest to the well head, whenever possible, and always before any water filtration or treatment. Some samples were collected from a pressure tank or large storage reservoir when access to water directly from the well was not available. Wells were purged for at least five minutes and until field readings of conductivity, temperature and dissolved oxygen stabilized. Bacteria samples were collected last, after the sample point was disinfected with isopropyl alcohol.

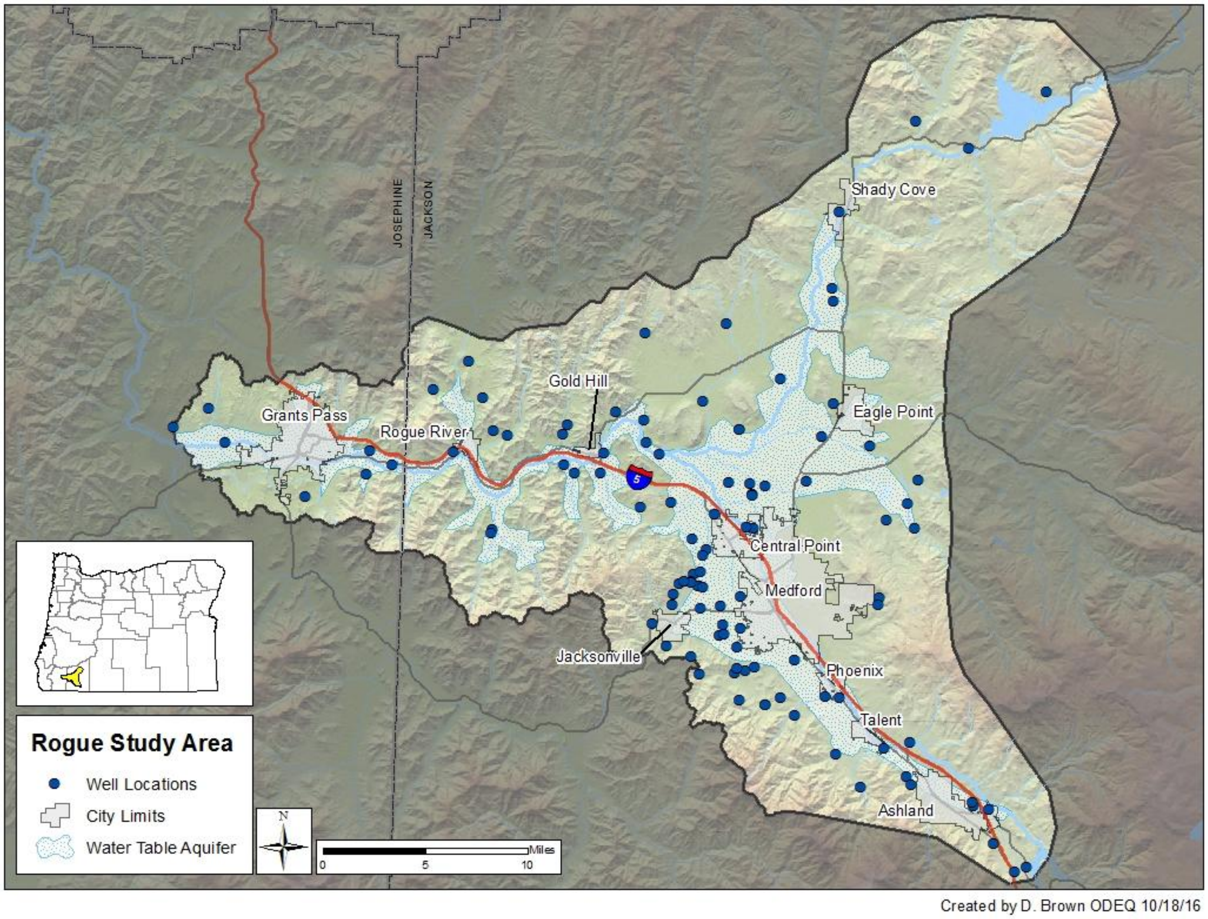

Figure 1. Study area and sample locations (Water table aquifer from Sweet et al. 1980).

Sample analyses included nitrate/nitrite as N (henceforth referred to as nitrate), total coliform bacteria, *E. coli* bacteria, current use and legacy chlorinated pesticides, total recoverable arsenic, common ions and common field parameters. A complete analyte list can be found in Appendix B and the corresponding laboratory methods can be found in the Sampling and Analysis Plan (DEQ11-LAB-0043-SAP). Due to project capacity limits, legacy chlorinated pesticides were only analyzed on samples from known or suspected shallow wells during each sampling event (n=43 wells). These pesticides are highlighted in green in Appendix B.

2.2.2 Context for Data Interpretation

The results from this study can be interpreted in two different contexts: the impacts of human activities on groundwater quality and the potential for human health impacts when the groundwater is used for drinking water. Many of the chemicals analyzed in this study are not found naturally in groundwater (e.g., pesticides), or have very low natural concentrations (e.g., nitrate). Detection of these chemicals indicates an influence from human activities such as leaching from agricultural or residential use of fertilizers and pesticides, improperly designed or maintained septic systems or poor well construction. These contaminants, along with some naturally occurring minerals such as arsenic, may be harmful to human health when present in drinking water above certain levels.

In Oregon, there are no regulatory criteria that apply to water from private, domestic wells. However, it can be useful to compare water quality results to the criteria set by EPA for public water systems. EPA sets a maximum contaminant level goal at the concentration of a contaminant below which there is no known or expected health risk. The EPA then sets the maximum contaminant level as close to the maximum contaminant goal as feasible considering treatment technologies and cost. Maximum contaminant levels are enforceable water quality criteria for public water systems (U.S. EPA 2014).

Many of the chemicals measured in this study do not have a maximum contaminant level. There are several other sources of health risk information, such as the lists of Health Advisories, Human Health Benchmarks for Pesticides, and Regional Screening Levels developed by EPA (U.S. EPA 2012, U.S. EPA 2013 and U.S. EPA 2016) and the Health-Based Screening Levels developed by the United States Geological Survey (Toccalino et al., 2014). These non-regulatory screening values are based on the available toxicological research and can be used to determine whether the concentration of a contaminant in drinking water may pose a risk to human health. In this report, results are compared to maximum contaminant level goal and maximum contaminant levels when available. If no maximum contaminant level is available, the result is compared to the lowest value of the current Health Advisories, Human Health Benchmarks for Pesticides, Regional Screening Levels, or Health-Based Screening Levels.

3. Results and Discussion

3.1 Well Characteristics

Of the 107 wells sampled in this study, 48 had a verified well log. A DEQ hydrogeologist evaluated wells logs for aquifer confinement[1], depth of water bearing interval, and potential for vertical fluid migration below the well seal (Appendix A):

- **Aquifer Confinement.** All but two of the wells with well logs suggest that the water is being withdrawn from a confined or semi-confined aquifer. Existence of a confining or semi-confining layer may protect the aquifer from surface contamination.
- **Depth of Water Bearing Interval.** Depth of the water bearing interval may be related to the presence of contamination. Contamination may come from surface activities such as fertilizer or pesticide application, which may impact shallow waters (less than 100 feet below ground surface), or dissolution of geologic minerals in deeper, and likely older, waters. Depth to top of the water bearing zone was determined for 41 wells and ranged from 23 to 890 feet below ground surface.
- **Potential for Vertical Fluid Migration.** Poorly constructed wells may allow water to travel along the borehole, introducing contaminants into deep aquifers. Thirty-nine wells have a high relative potential for vertical fluid migration below the seal based on the geologic material in which the well is located.

The differences between the wells sampled in this study include the following variables: depth the well was drilled, age of the well, well construction or alterations/deepenings, land use around the well, the geology of the land and aquifer, how frequently the well is used, distance of transport piping and piping material between well and faucet, whether an inline filter system needed to be removed to take the sample, the type of faucet the sample was collected from and the presence of and/or the size of holding tank or pressure tank connected to system.

3.2 Water Quality

The following sections discuss results for analytes that indicate contamination due to human activities, or present a potential health risk for people drinking the water. Comprehensive analytical reports may be obtained by contacting the DEQ Laboratory and Environmental Assessment Program.

[1] A confined aquifer occurs when the aquifer (for example, a permeable sand) is capped by an impermeable layer (for example, an impermeable silt). A confined aquifer does not connect with shallow groundwater. Aquifers can also be semi-confined, which means that an aquifer has limited connection with shallow groundwater. An aquifer is confined or semi-confined if the static water level in the well is higher than the water-bearing zone.

3.2.1 Nitrate

While nitrate is a natural and necessary nutrient found in soil and surface water, human activities can enrich the level of nitrate found in the environment. Nitrate enriched water can leach into aquifers from areas of fertilizer use, manure storage or application or improperly designed or maintained septic systems (Powers and Schepers, 1989). While background concentrations of nitrate in groundwater may only be up to 1 mg/L (Nolan and Hitt, 2003), this report will consider values of 3 mg/L or greater as elevated. This is consistent with the previous report (Patton and Eldridge, 2013) and represents a level sufficiently above background to indicate an impact from human activities on groundwater quality. Drinking water with high nitrate may cause serious health problems for infants, pregnant women and nursing mothers. To protect the public from these health risks, the EPA has set the maximum contaminant level for nitrate (as N) at 10 mg/L. As mentioned previously, nitrate in this study was measured as nitrate/nitrite as N. While nitrite is rarely found in groundwater at significant levels due to geochemical conditions, these results represent a conservative measurement of nitrate. More information on nitrate risks and recommendations can be found on DEQ's Fact Sheet: Nitrate in Drinking Water (http://www.deq.state.or.us/wq/pubs/factsheets/groundwater/nitratedw.pdf).

In this study, 22 of the 107 wells sampled had an elevated nitrate concentration (3 mg/L or above). Four wells were above the maximum contaminant level of 10 mg/L (Figure 2). Based on the limited number of wells where the water bearing zone could be determined, elevated nitrate concentrations were found in wells where the top of the water bearing zone was shallower than about 60 feet below ground surface (Figure 3). However, not all shallow wells had elevated nitrate.

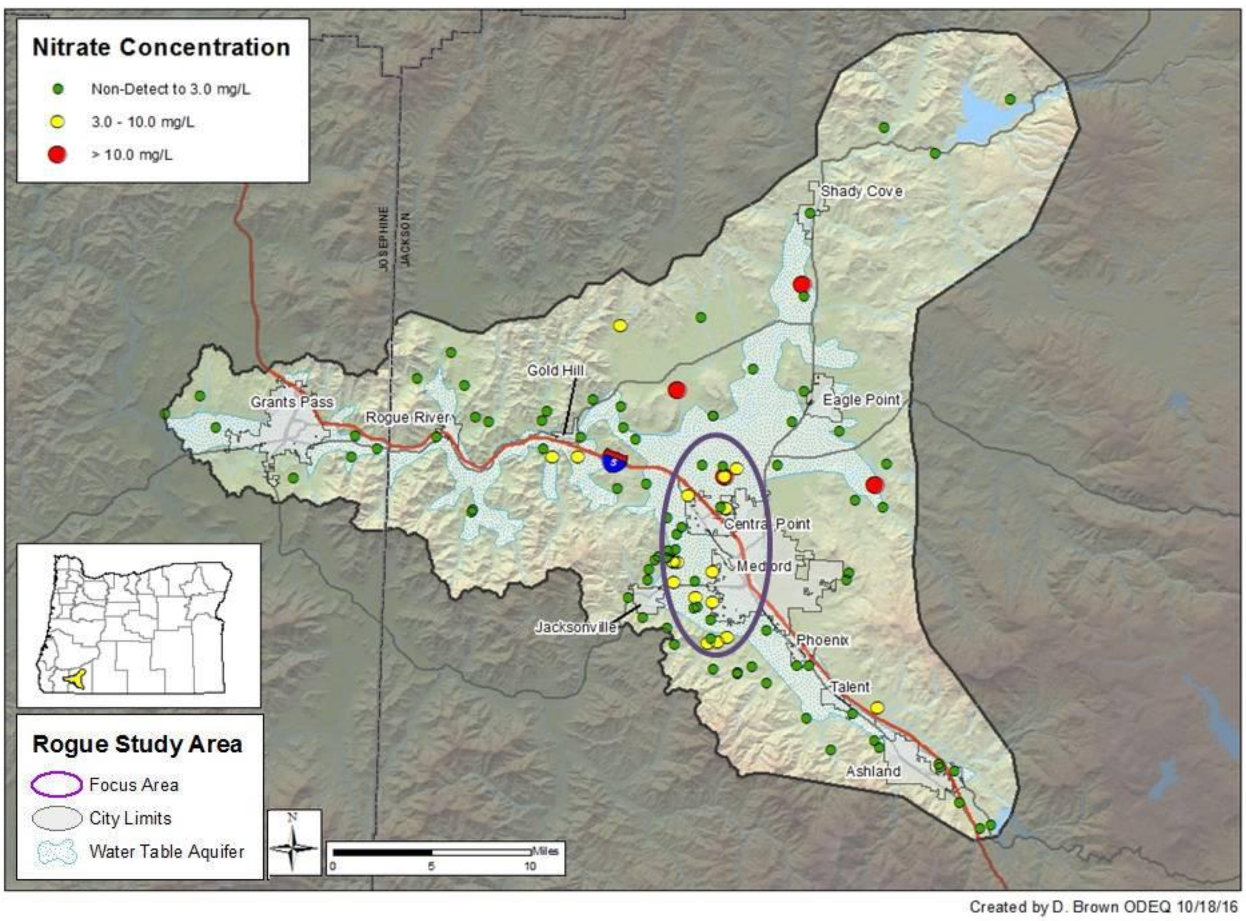

Figure 2. Nitrate concentration in sampled wells. Oval encompasses the area around Central Point and north and west of Medford where a high nitrate results were concentrated in the 2011 and 2015 studies. Results higher than 3 mg/L are considered elevated due to human activities. The maximum contaminant level for nitrate in drinking water is 10 mg/L.

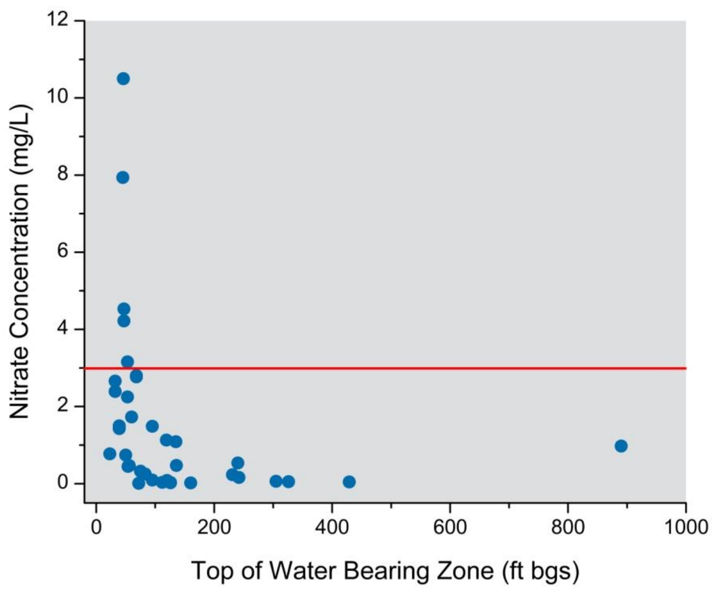

Figure 3. Nitrate concentration and depth to top of the water bearing zone for wells where well log information was available. Red line indicates a concentration of 3 mg/L, which DEQ considers to be an elevated nitrate concentration.

In the area north and west of Medford and around Central Point (circled in Figure 2), samples from 15 of 30 wells had elevated nitrate concentrations. The results in this area ranged from non-detect to above the maximum contaminant level (<0.005 mg/L to 10.1 mg/L). This indicates more variability in nitrate concentrations in this area than observed during the 2011 study in which all wells sampled in this area had elevated nitrate concentrations. However, this is still a very high occurrence of elevated nitrate concentrations in well water. One well from the 2011 study was also sampled in 2015. In July 2011, March 2015 and October 2015, the nitrate concentration in this well was 4.5, 4.22, and 4.53 mg/L indicating little to no change over this five-year period.

The four wells with results over the maximum contaminant level are spread out north and east of Central Point. Two of the wells have logs, which indicate shallow water sources. The other two do not have well logs, limiting the interpretation of the results.

3.2.2 Arsenic

Arsenic is a naturally occurring element found in the earth's crust. It is found in groundwater throughout Oregon, often associated with volcanic geology. In the past, arsenic was also used in some agricultural practices such as the insecticide lead arsenate (especially in orchards), as well as for embalming fluids prior to approximately 1945 (indicating historic cemeteries as potential sources). While it is not believed that this is a common source of arsenic in groundwater, arsenic geochemistry is complex and several factors may influence the mobility of arsenic from these sources into shallow groundwater (Welch et al, 2000). Most arsenic in groundwater is a result of dissolution of arsenic-containing minerals in soil and rock. Arsenic in drinking water is a health hazard and EPA has established a maximum contaminant level for total arsenic at 10 µg/L (parts per billion). However, the maximum contaminant level goal is zero.

Arsenic was detected in 24 of the 107 wells in this study (measured as total recoverable arsenic). Six wells had arsenic concentrations above the maximum contaminant level of 10 µg/L (Figure 4). Five of the six highest concentrations were found close to the Rogue River and Lost Creek Lake; the other high value was south of Medford (Figure 4). Arsenic concentrations in the Rogue River are low (ODEQ 2015a) and not expected to be the source of the arsenic in the groundwater. Well logs were located for only two of the six wells with arsenic above the maximum contaminant level. These wells are deep and have water-bearing zones that begin at 312 and 160 feet below ground surface (107 and 38.8 µg/L, respectively). Further investigation is necessary to understand the contributing factors for these high concentrations.

The 2011 Rogue Basin groundwater study reported arsenic to a lower level (1 µg/L) than the 2015 study (2 µg/L). To compare results from the 2011 study to the 2015 study, only results of 2 µg/L or higher are counted as detects. Seven out of 52 wells sampled in 2011 were at or above 2 µg/L (13 percent). Further analysis of well logs for both studies, which is outside the scope of this report, may help explain the difference in arsenic results between the two studies.

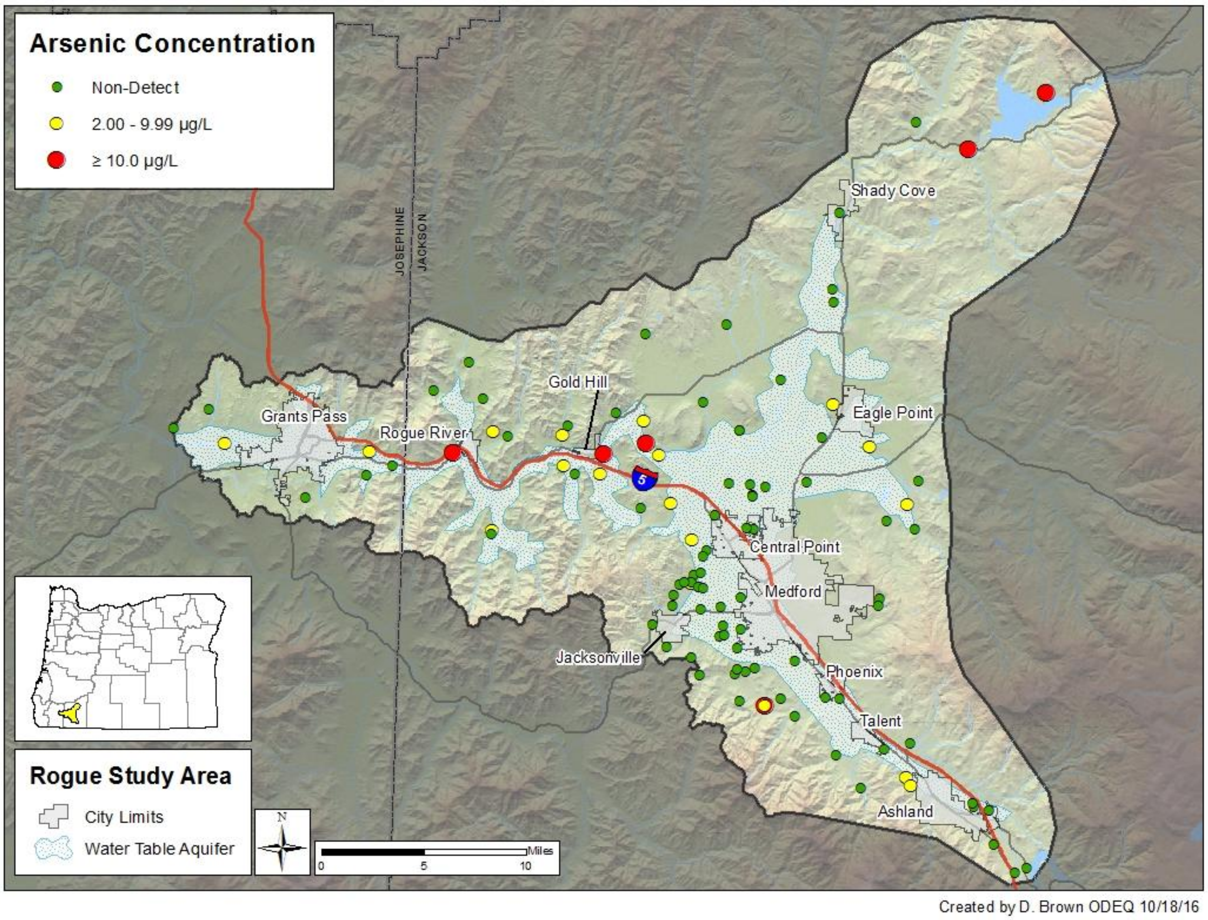

Figure 4. Arsenic concentrations in sampled wells. The maximum contaminant level goal for arsenic is zero. The maximum contaminant level for total arsenic is 10 µg/L.

3.2.3 Coliform Bacteria and *E. coli*

Coliform bacteria are a group of closely related bacteria that are typically not harmful to humans. However, coliform bacteria are a useful indicator to determine if similar, disease-causing microorganisms (e.g., bacteria, viruses) may be present in water bodies. *E.coli* is a specific class of coliform bacteria more commonly associated with illness. Presence of coliform bacteria may indicate a problem with the integrity of a well's construction allowing contamination from surface or soil sources into the well. Bacterial contamination may also affect shallow aquifers through improperly designed or maintained septic systems or leaching from areas where manure or biosolids are spread. The maximum contaminant level goal for coliform bacteria is zero.

Coliform bacteria were detected in 46 of 107 wells (43 percent), and *E. coli* was detected in eight of those wells. Detections were evenly distributed throughout the study area (Figure 5) and did not show a relationship with depth of the water bearing interval. Without further investigation, it is unknown if these results indicate structural problems with individual wells or if aquifer contamination is local or area-wide. Public health officials recommend testing well water for coliform bacteria annually and the prevalence of coliform bacteria detected in this study strongly supports that recommendation.

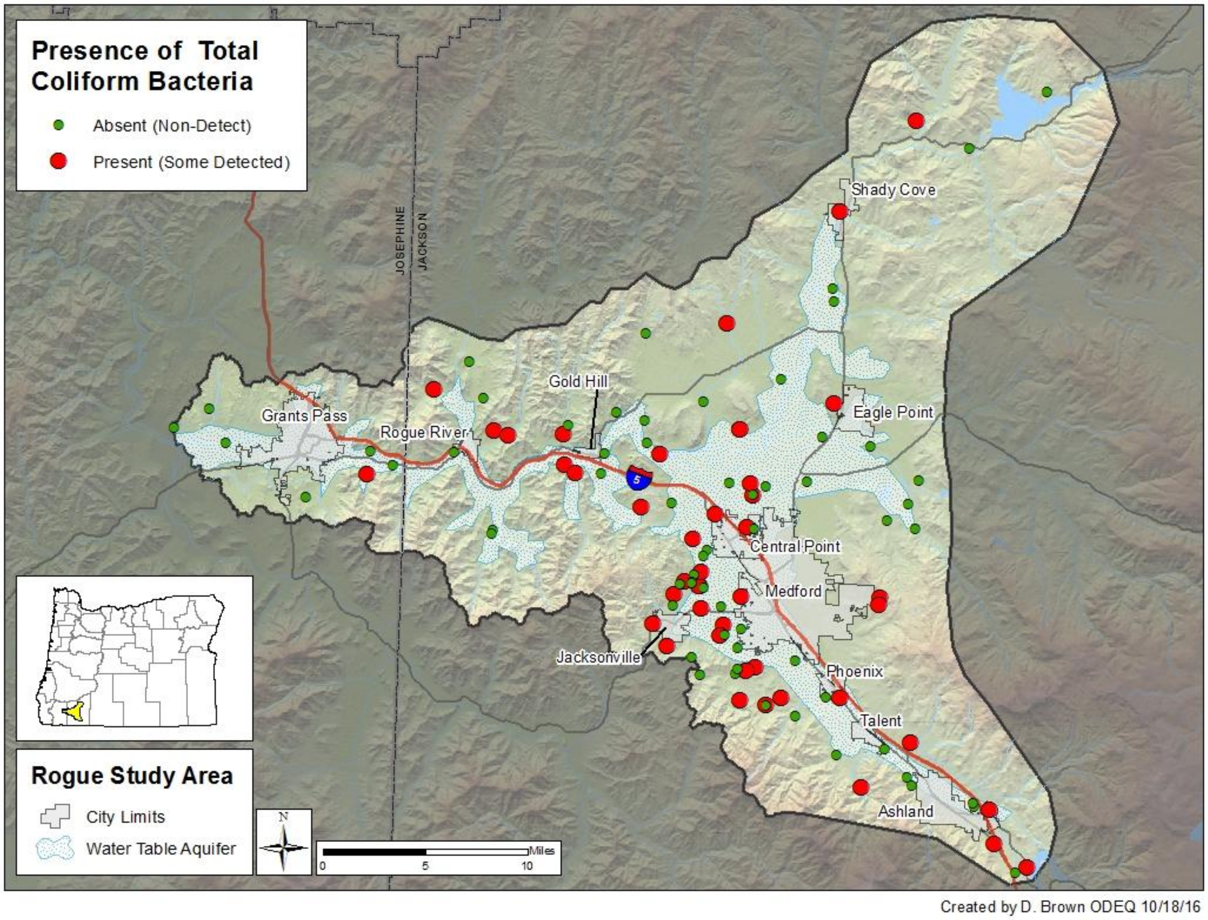

Figure 5. Bacteria results for sampled wells.

3.2.4 Pesticides

Pesticides are a broad class of chemicals that includes insecticides, herbicides and fungicides. Pesticides that are currently used and those no longer in use (legacy) are both included in the study. Legacy pesticides refer to chlorinated insecticides, such as DDT, which are banned in the United States. This study also measured several chemicals that are breakdown products of pesticides. Physical processes, such as photo-degradation by sunlight, or biological processes, such as metabolism by bacteria, can break parent pesticides down into different chemicals that may be more soluble and travel more easily into groundwater. In general, less information is known about the potential health impacts of these breakdown products than the parent pesticide. It is common to detect the breakdown product of a pesticide in a water sample, but not the parent pesticide, due to differences in solubility and other chemical properties. Pesticides were not measured in the 2011 study.

Seventeen different pesticide-related chemicals were detected in this study, representing 12 different parent pesticides (Table 1). At least one current use pesticide related chemical was detected in 37 of the 107 wells sampled in this study (Figure 6). Six wells had at least one chemical originating from a legacy pesticide detected in their water. While pesticides were detected throughout the study area, the wells in the area around Central Point and north and west of Medford had a high occurrence of pesticide detection (21 of 28 wells) (Figure 7).

The most commonly detected pesticides belong to the triazine herbicide group, which includes atrazine and simazine. Desethylatrazine and deisopropylatrazine are two of the highly soluble breakdown products of atrazine and simazine. These herbicides are widely used in agriculture and urban applications. There are several other breakdown products of these two pesticides, however they were not included in the analysis of these samples. At least one of these four chemicals was found in 24 of the study wells.

Table 1. Summary of pesticides and breakdown products detected.

	# wells detected	Max. Conc.	Units	Screening Level	Use
Current Use Pesticides					
*Total triazines**	24	259.6	ng/L	3,000[1]	
Atrazine	6	53.2	ng/L	3,000[1]	Herbicide
Simazine	12	51.3	ng/L	4,000[1]	Herbicide
Deisopropylatrazine	19	69.4	ng/L	Not Available	Breakdown product of atrazine and simazine
Desethylatrazine	12	137	ng/L	Not Available	Breakdown product of atrazine and simazine
2,4-D	2	1400	ng/L	70,000[2]	Herbicide
2,6-Dichlorobenzamide	12	692	ng/L	32,000[2]	Breakdown product of dichlobenil
Acetamiprid	1	5.96	ng/L	497,000[2]	Insecticide
DCPA acid metabolites	1	8300	ng/L	Not Available	Breakdown product of dacthal
DEET	1	45.2	ng/L	Not Available	Insect repellent
Diuron	7	57.5	ng/L	2,000[3]	Herbicide
Norflurazon	1	51.7	ng/L	105,000[2]	Herbicide
Prometon	2	9.53	ng/L	400,000[3]	Herbicide
Legacy Pesticides					
Total DDTs [#]	5	0.694	ng/L	100[3]	
2,4´-DDD	1	0.118	ng/L	Not Available	Breakdown product of banned insecticide DDT
4,4´-DDD	2	0.235	ng/L	100[3]	Breakdown product of banned insecticide DDT
4,4´-DDE	3	0.495	ng/L	100[3]	Breakdown product of banned insecticide DDT
4,4´-DDT	3	0.498	ng/L	100[3]	Banned chlorinated insecticide
Heptachlor epoxide	1	0.0803	ng/L	200[2]	Banned chlorinated insecticide

*includes atrazine, simazine, deisopropylatrazine and desethylatrazine

[#]includes 2,4'-DDD, 4.4'-DDD, 4,4'-DDE and 4,4'-DDT

[1]USEPA Maximum Contaminant Level

[2]USEPA non-regulatory Human Health Benchmark

[3]USGS Health-based Screening Level

All detected chemicals were well below any known human health screening level, often less than 1 percent of the screening value, and never more than 3 percent. Twenty-two of the wells had two or more pesticide chemicals detected (Figure 6), and 13 wells had chemicals from more than one parent pesticide detected (Figure 7). Very little research has been done on the combined effects of chemical mixtures on human health. A common practice is to add the concentration of all related chemicals (parents and their breakdown products, or chemically similar pesticides) and compare that concentration to the lowest screening level of those chemicals. This method assumes that the combined effect of the chemicals is no worse than the most toxic of the individual chemicals. Using this method, the results for total DDTs and total triazines are still far below a level that may cause any health risk (Table 1).

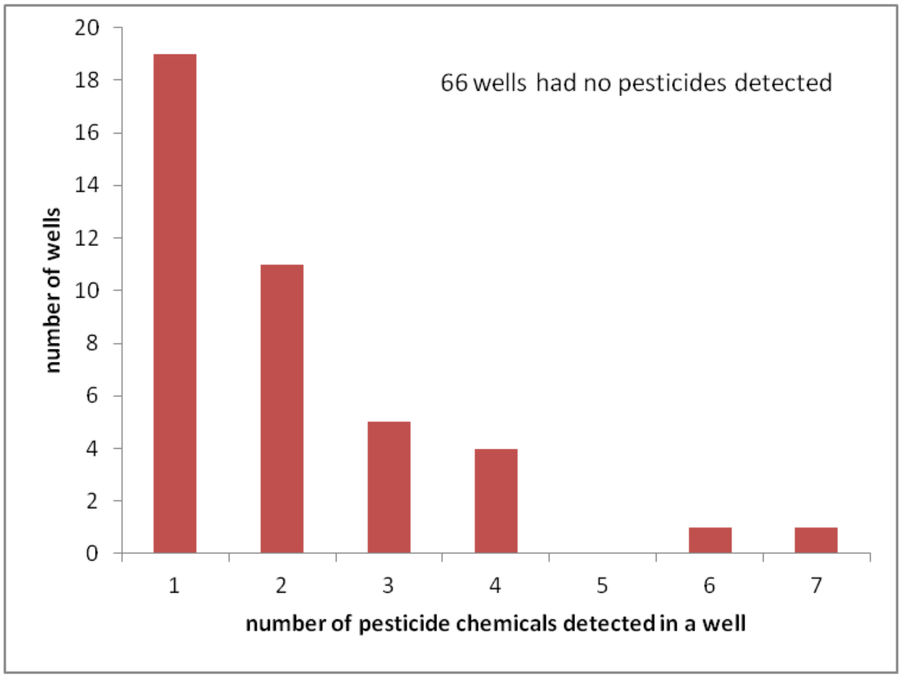

Figure 6. Histogram of total number of pesticide chemicals detected in a well.

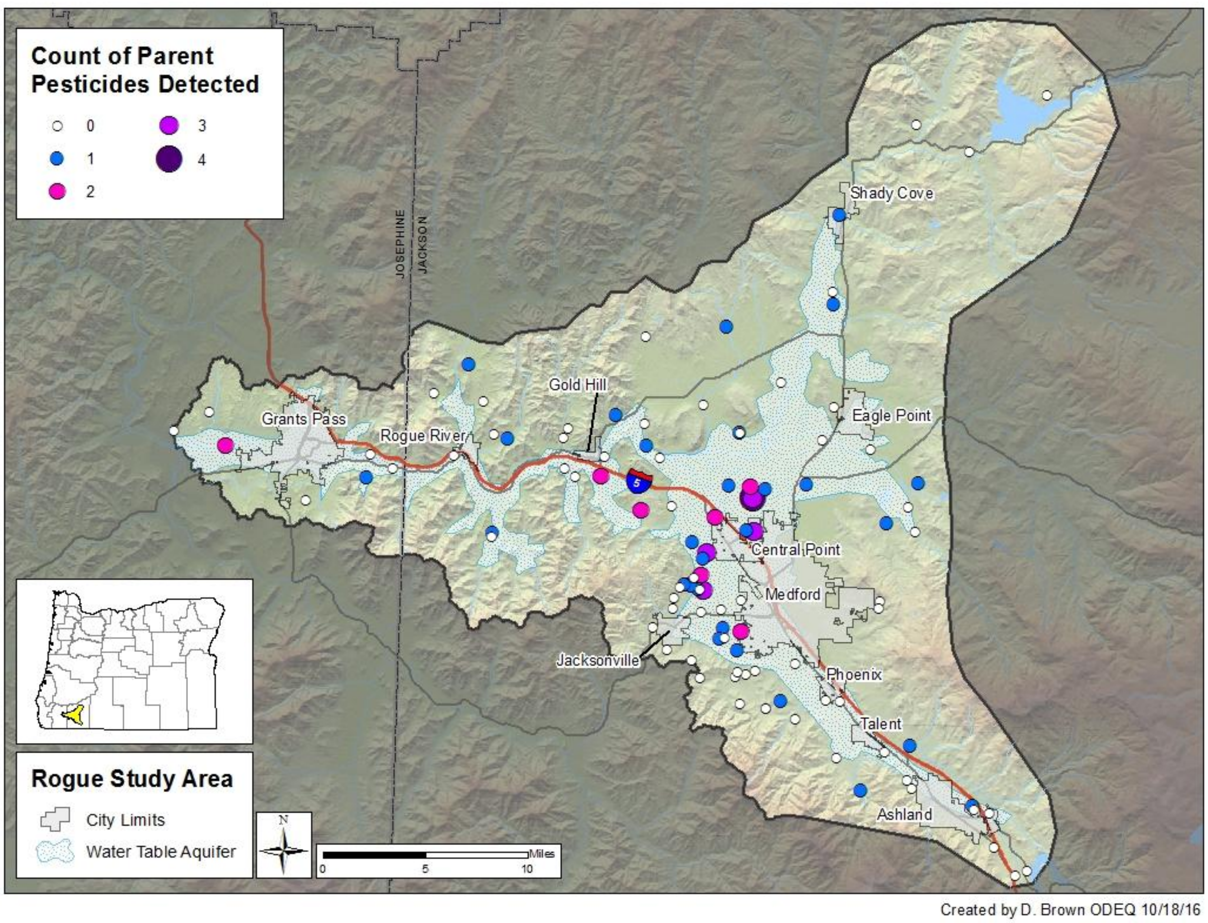

Figure 7. Number of parent pesticides detected in sampled wells.

3.2.5 Manganese

Manganese is an element found in many soils, rocks and minerals. In areas with manganese-containing minerals, manganese may be present in the groundwater under low-oxygen conditions. At high concentrations, manganese has been associated with neurological disease. EPA has set a secondary drinking water standard for manganese at 50 µg/L to avoid discoloration, staining and a metallic taste. EPA also has calculated a Lifetime Health Advisory for manganese in drinking water at 300 µg/L. Manganese was detected in 57 of the wells sampled in this study. Fifteen wells were above the 50 µg/L secondary drinking water standard and two were above the 300 µg/L Lifetime Health Advisory (Figure 8). Similar results were found in the 2011 study. While low concentrations are likely due to natural geochemical processes, further investigation is necessary to determine the sources of manganese in the wells with very high concentrations. Water above the secondary drinking water standard would not be palatable for drinking without treatment.

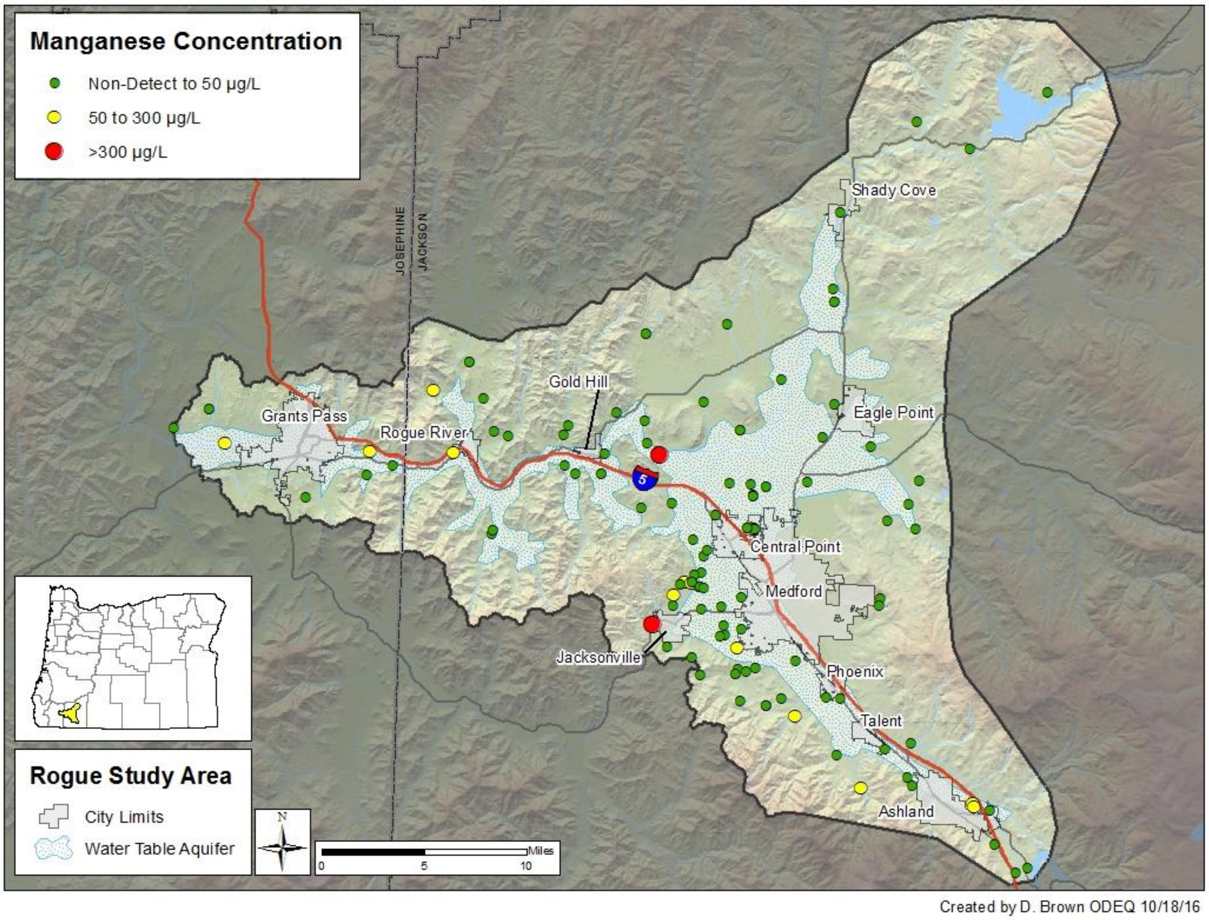

Figure 8. Manganese results in sampled wells. The secondary drinking water standard for manganese is 50 µg/L and the Lifetime Health Advisory is 300 µg/L.

3.2.6 Uranium

Uranium is a natural element found throughout the environment. Uranium in water comes mainly from rocks and soil as water passes over them. Nearly all naturally occurring uranium is non-radioactive (Oregon Department of Human Services 2007). EPA has established a maximum contaminant level of 30 µg/L for uranium in drinking water. Low concentrations of uranium were detected in 71 of the 107 wells sampled in this study. The maximum concentration measured was 8.28 µg/L, less than one-third of the maximum contaminant level. Uranium was not measured in the 2011 study.

3.2.7 Vanadium

Vanadium is found in many different minerals as well as in coal and other fossil fuels. Vanadium may be released to the environment through the combustion of fossil fuels, or through natural weathering processes of rocks and soils. There is no federal or state regulatory standard for vanadium in drinking water. However, EPA has set a Regional Screening Level for resident tap water of 86 µg/L for vanadium. Vanadium was detected in 44 of the 107 study wells. The maximum concentration measured was 31.1 µg/L, similar to the results from the 2011 DEQ study in this region.

3.3 Well log comparison

The Oregon Water Resources Department has required wells logs since 1955. The logs are completed by a well driller and provide details on well construction including a description of the geologic material drilled through and material used to case and seal the well. While the information in well logs is extremely useful in interpreting groundwater data, well logs can be difficult to locate and verify. Some of the reasons for this include:

- A well log may never have been completed.
- The location of a well is described by township, range, and section on the well log, and there may be more than one well in any given section.
- There may be mistakes, especially in the location, that cause the well log to be misfiled and difficult to find.

With the emergence of electronic record keeping and the requirements to have new well locations tagged with their GPS coordinates (since 2009), it is much easier to locate well logs for recently drilled wells. This study included wells with and without well logs. While the absence of some well logs limits the interpretation of the data, it also provides an opportunity to compare the results between these two groups and identify any potential bias that may be introduced when excluding wells without a well log from a study.

Figure 9 shows the distribution of nitrate results between wells with and without well logs. The group of wells without well logs has a higher percentage of results above 3 mg/L. However, this might reflect the geographic distribution of the wells in each group (Figure 10), with many of the wells without well logs located in the area north and west of Medford. There was no significant difference in results between the two groups (ANOVA: F = 2.35, df = 87, P = 0.13).

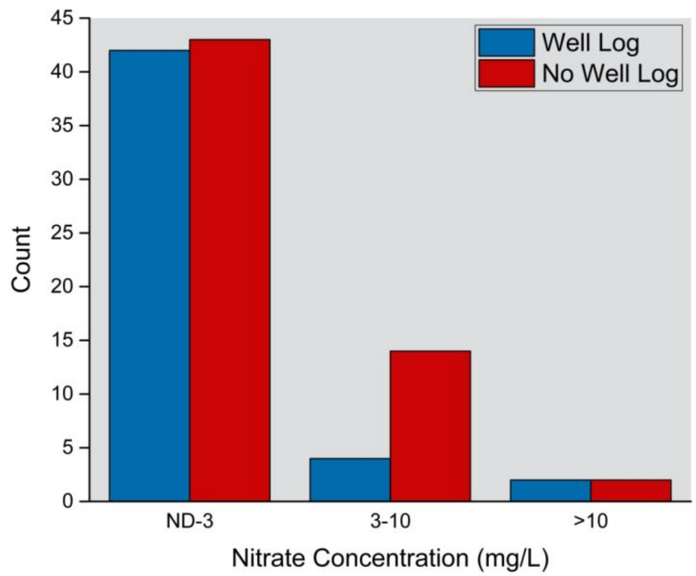

Figure 9. Comparison of the distribution of nitrate results for wells with and without well logs.

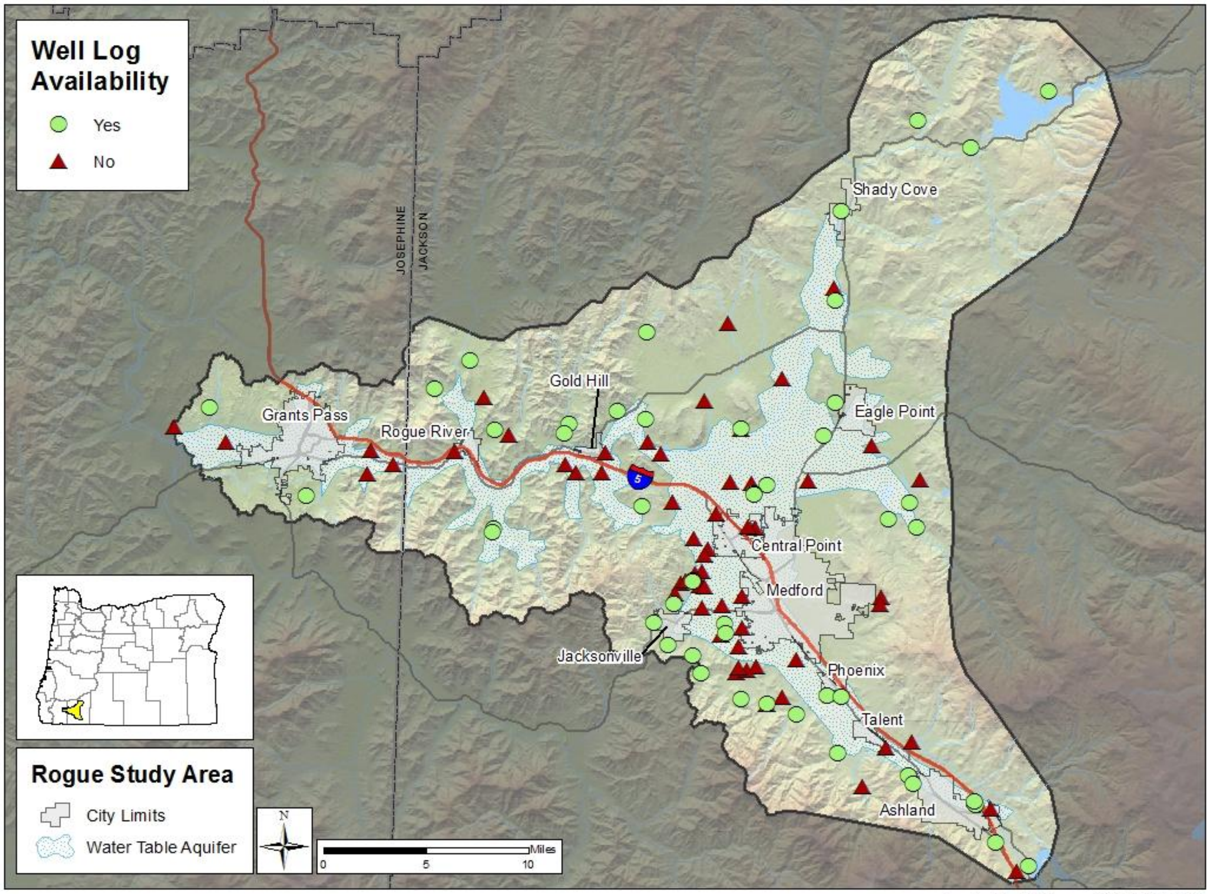

Figure 9. Distribution of wells with and without well log records.

3.4 Seasonal differences

Thirteen wells were sampled during both the winter (February-March) and fall (October) sampling events in an effort to capture the seasonal variability of results. Wells chosen for resampling were shallow and therefore most likely to be affected by seasonal changes in rainfall or land management practices.

The seasonal differences in nitrate concentration ranged from 0.66 mg/L lower to 1.41 mg/L higher during the fall than the winter with no obvious pattern (Figure 11). Bacteria results were similar between the two sampling events, despite a large rain storm just prior to the first week of the winter sample collection, which could have been a risk for contamination due to flooding. There were nine wells in the resample group with pesticide detects. All but one had more pesticide chemicals detected and/or higher concentrations in the winter sample (Figure 12). The other well had no pesticides detected in the winter and one detected in the fall. Lower results in the fall may indicate a hydrological disconnect between soils and the aquifer after a long dry summer.

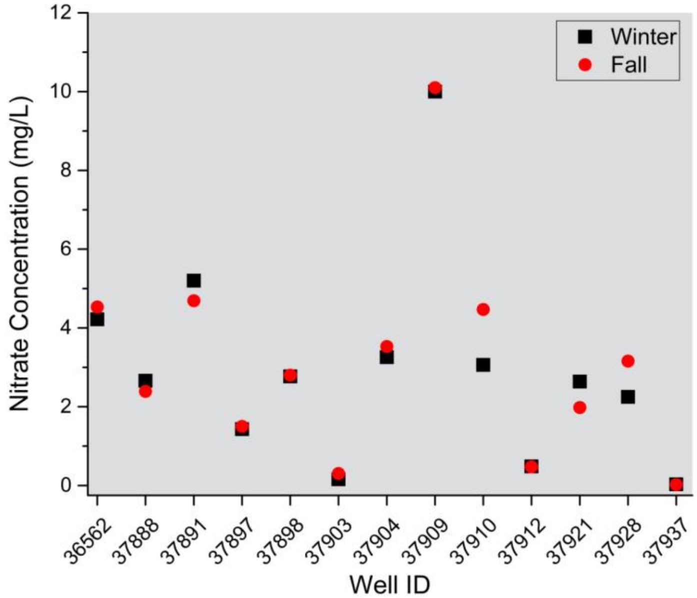

Figure 10. Nitrate concentrations for wells sampled during both events. Winter sampling occurred in February and March 2015 and fall sampling occurred in October 2015.

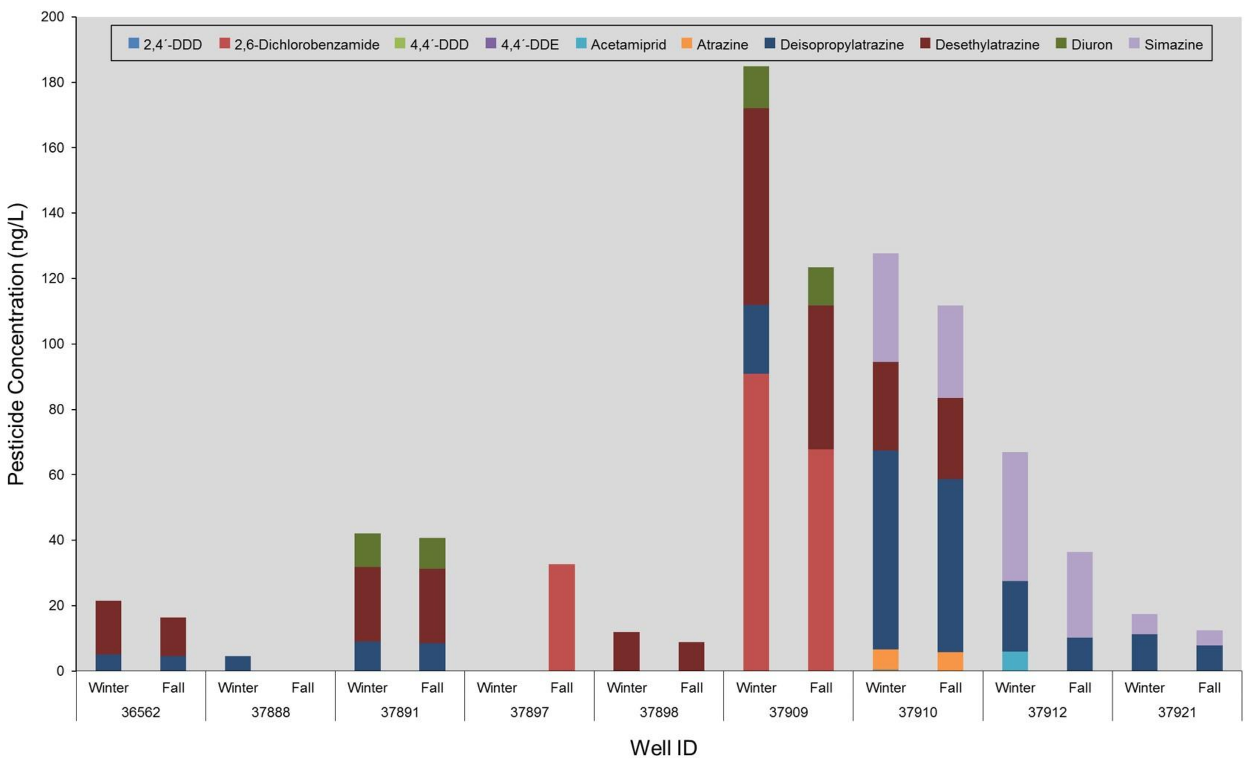

Figure 11. Pesticide results for wells sampled during both events. Winter sampling occurred in February and March 2015 and fall sampling occurred in October 2015. Wells without any detected pesticides were excluded from this figure.

4. Summary

The 2015 mid-Rogue Basin groundwater study met its objectives in the following ways:

1. *To collect high-quality data on nitrate, arsenic, coliform bacteria and pesticide concentrations in groundwater throughout the study area*
   Groundwater quality data for 107 wells within the study area are available. This represents the largest quality-controlled groundwater investigation in the area since the early 1970s (Patton and Eldridge, 2013). These data may be used in future analyses of specific groundwater issues or to support and focus outreach activities.

2. *To identify areas of groundwater contamination related to these parameters*
   Nitrate contamination was found in several areas in Jackson County, including the area around Central Point and Medford. Arsenic contamination was found in many sites along the Rogue River between Grants Pass and Gold Hill and in the area around Lost Creek Lake. Some wells around Eagle Point, Ashland and west of Phoenix and Central Point also had arsenic detections. The wells with high arsenic (>10 µg/L) were different than the wells with high nitrate (>10 mg/L). Bacterial contamination was detected throughout the study area as were low levels of pesticides.

3. *To inform well water users of the results of this study and provide information regarding potential risks to human health*
   In addition to the 46 wells with total coliform detections, there were 12 wells with other results exceeding a maximum contaminant level or other health-based benchmark. All of these well owners were notified of these results by DEQ staff and referred to local and state public health resources to discuss potential risks. While pesticides were detected in 41 wells, all results were well below any health-based benchmark and not expected to pose a health risk.

4. *To identify areas needing additional investigation in order to describe the extent of contamination and help focus efforts to prevent further contamination.*
   This study confirmed the presence of nitrate-contaminated groundwater in the area around Central Point and north and west of Medford. Several wells outside this area also had high nitrate and warrant further investigation to determine the extent of the contamination. Hydrogeologic analyses and investigations into the sources of contamination were outside the scope of this study.

5. Recommendations

Aquifer contamination is a long-lasting problem and steps should be taken to reduce any further negative impacts from human activity. Additional analysis of data from this study, as well as data from previous studies and the Oregon Health Authority's Real Estate Transaction Act (ORS 448.271) data, can further refine the extent of aquifer contamination and contribute to identifying the sources of nitrate, pesticide and bacterial contamination. With this information, strategies can be developed to help prevent further degradation of aquifer water quality.

Long-term monitoring of nitrate and pesticides is recommended, especially in the area north and west of Medford. While the concentrations measured in this study are mostly below the health-based benchmarks, these levels may rise over time. A network of wells should be established and monitored to detect any changes over time.

Since there is no regulatory oversight for private wells, and many private well owners are currently unaware of the quality of their drinking water, results from this study can be used to focus public health outreach in areas where contamination exits. Local, county or state public health outreach should encourage homeowners to get their wells tested annually for nitrate and bacteria and to test it at least once for arsenic. Overall results of this study and the on-going statewide monitoring program can be used to better understand the threats to and quality of the groundwater resources of Oregon.

There are many resources available to help domestic well owners in Oregon. As part of the recommendations of this Mid-Rogue Basin Groundwater Report, the following list of resources is provided to well owners:

- The *Oregon Domestic Well Safety Program* (www.healthoregon.org/wells) focuses on improving local and state capacity to assess and manage risks associated with private wells. DWSP partners with local health departments and water information providers to further promote domestic well safety.

- The Oregon Water Resources Department and Oregon Health Authority publish a brochure, "Water Well Owner's Handbook: A guide to water wells in Oregon" which provides general information on groundwater, water wells, well construction, operation, maintenance and abandonment information (http://www.oregon.gov/owrd/PUBS/docs/Well_Water_Handbook.pdf).

- DEQ's Drinking Water Protection Program has developed many tools for public water systems that can be readily used for domestic wells:
    - Basic Tips for Keeping Drinking Water Clean and Safe http://www.deq.state.or.us/wq/pubs/factsheets/drinkingwater/BasicTips12WQ005.pdf
    - Groundwater Basics for Drinking Water Protection http://www.deq.state.or.us/wq/pubs/factsheets/drinkingwater/GroundwaterBasics.pdf
    - Other technical assistance fact sheets http://www.deq.state.or.us/wq/dwp/assistance.htm

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Appendix A – Complete Site List

Pages A-1 through A-5

Well ID	Rogue Basin Groundwater Study Site ID	Latitude	Longitude	Well Log Availability	Well log	Top of Water Bearing Zone (ft bgs)	Bottom of Water Bearing Zone (ft bgs)	Well Vertical Migration Potential	2016 Sampling Season
36562	RV-066	42.41329	-122.88377	Yes	JACK-52545	47	58	High	Winter/Fall
37886	RV-115	42.39579	-123.32271	Yes	JOSE-1342	50	66	High	Winter
37888	RV-117	42.54566	-122.82348	Yes	JACK-61885	32	35	Unknown	Winter/Fall
37890	RV-119	42.45246	-123.07396	Yes	JACK-58069	95	120	High	Winter
37896	RV-125	42.47438	-123.20331	Yes	JACK-9662	44	65	Moderate	Winter
37897	RV-126	42.49518	-123.17072	Yes	JACK-5369	39	65	High	Winter/Fall
37898	RV-127	42.37667	-123.14353	Yes	JACK-14229	68	83	Moderate	Winter/Fall
37899	RV-128	42.19132	-122.67604	Yes	JACK-20357	Unknown	Unknown	High	Winter
37900	RV-129	42.22537	-122.80850	Yes	JACK-15542	23	90	High	Winter
37902	RV-131	42.26528	-122.82027	Yes	JACK_14885	92	105	High	Winter
37906	RV-135	42.31466	-122.92061	Yes	JACK_13878	Unknown	47	Moderate	Winter
37908	RV-137	42.40721	-122.89555	Yes	JACK-7347	45	60	Low	Winter
37909	RV-138	42.40692	-122.89611	Yes	JACK-7384	Unknown	40	Low	Winter/Fall
37912	RV-141	42.34457	-122.95149	Yes	JACK-34989	Unknown	70	High	Winter/Fall
37917	RV-146	42.40358	-122.74671	Yes	JACK-54897	46	80	High	Winter
37919	RV-148	42.44642	-123.14475	Yes	JACK53151 (new), JACK-59259 (deepening)	326	500	High	Winter
37924	RV-153	42.67455	-122.74916	Yes	JACK_56916	126	200	High	Winter
37925	RV-154	42.65671	-122.69785	Yes	JACK18822, JACK-30911	160	300	Moderate	Winter
37926	RV-155	42.69854	-122.62464	Yes	JACK_51045	312	345	High	Winter

Well ID	Rogue Basin Groundwater Study Site ID	Latitude	Longitude	Well Log Availability	Well log	Top of Water Bearing Zone (ft bgs)	Bottom of Water Bearing Zone (ft bgs)	Well Vertical Migration Potential	2016 Sampling Season
37928	RV-157	42.51938	-123.00336	Yes	JACK4516 (new), JACK-4515 (deepening)	53	320	High	Winter/Fall
37929	RV-158	42.46257	-123.02839	Yes	JACK8136 (new), JACK-57391 (deepening)	83	760	High	Winter
37932	RV-161	42.27867	-122.94113	Yes	JACK-33311	305	320	High	Winter
37933	RV-162	42.26118	-122.90271	Yes	JACK16689, JACK16649, JACK16647, JACK16646	Unknown	405	Moderate	Winter
37937	RV-166	42.45601	-123.41768	Yes	JOSE-19047	126	150	High	Winter/Fall
37942	RV-171	42.45301	-122.90990	Yes	JACK_58138	72	147	High	Winter
37944	RV-173	42.25178	-122.84951	Yes	JACK_15162	135	700	High	Winter
37946	RV-175	42.37457	-123.14457	Yes	JACK55759	135	700	High	Fall
37947	RV-176	42.60885	-122.81976	Yes	JACK792 (new) JACK705 (deepening)	135	700	High	Fall
37949	RV-178	42.45795	-123.00151	Yes	JACK-8249	50	437	High	Fall
37952	RV-181	42.34397	-122.95193	Yes	JACK-33003	105	120	High	Fall
37955	RV-184	42.14886	-122.62436	Yes	JACK-20770	56	360	High	Fall
37956	RV-185	42.16480	-122.65635	Yes	JACK-22560	136	150	High	Fall
37958	RV-187	42.19339	-122.67748	Yes	JACK 20348 (new) JACK 20347 (Recon) JACK-54646 (Deepening)	Unknown	121	High	Fall

Well ID	Rogue Basin Groundwater Study Site ID	Latitude	Longitude	Well Log Availability	Well log	Top of Water Bearing Zone (ft bgs)	Bottom of Water Bearing Zone (ft bgs)	Well Vertical Migration Potential	2016 Sampling Season
37959	RV-188	42.26537	-122.80742	Yes	JACK-14849	231	280	High	Fall
37960	RV-189	42.44578	-123.07894	Yes	JACK-8339	119	140	High	Fall
37964	RV-193	42.31353	-122.98793	Yes	JACK-33846	242	540	High	Fall
37965	RV-194	42.29836	-122.97329	Yes	JACK-53696	429	460	High	Fall
37966	RV-195	42.29083	-122.94920	Yes	JACK-58067	95	300	High	Fall
37969	RV-198	42.30745	-122.91922	Yes	JACK-31052	147	200	High	Fall
37972	RV-201	42.21011	-122.74113	Yes	JACK-54627	890	940	High	Fall
37973	RV-202	42.20476	-122.73684	Yes	JACK-33887	240	517	High	Fall
37974	RV-203	42.25847	-122.87768	Yes	JACK-34025	54	205	High	Fall
37975	RV-204	42.38690	-122.73924	Yes	JACK-19617	180	226	High	Fall
37976	RV-205	42.39165	-122.76652	Yes	JACK6794 (new), JACK 6791 (reseal)	120	218	High	Fall
37978	RV-207	42.47319	-122.82103	Yes	JACK-1236	Unknown	340	Unknown	Fall
37979	RV-208	42.44993	-122.83152	Yes	JACK-61259	75	200	High	Fall
37984	RV-213	42.32733	-122.96965	Yes	JACK51097	112	420	High	Fall
37987	RV-216	42.39581	-123.00265	Yes	JACK-30605	60	142	High	Fall
37887	RV-116	42.55458	-122.82446	No	Not Found				Winter
37889	RV-118	42.47182	-122.94557	No	Not Found				Winter
37891	RV-120	42.41890	-123.04168	No	Not Found				Winter/Fall
37892	RV-121	42.45292	-122.90980	No	Not Found				Winter
37893	RV-122	42.43350	-122.98536	No	Not Found				Winter
37894	RV-123	42.41559	-122.91914	No	Not Found				Winter
37895	RV-124	42.37465	-122.95165	No	Not Found				Winter
37901	RV-130	42.23020	-122.76358	No	Not Found				Winter
37903	RV-132	42.25878	-122.87758	No	Not Found				Winter/Fall
37904	RV-133	42.28036	-122.90752	No	Not Found				Winter/Fall

Well ID	Rogue Basin Groundwater Study Site ID	Latitude	Longitude	Well Log Availability	Well log	Top of Water Bearing Zone (ft bgs)	Bottom of Water Bearing Zone (ft bgs)	Well Vertical Migration Potential	2016 Sampling Season
37905	RV-134	42.31195	-122.90386	No	Not Found				Winter
37907	RV-136	42.42043	-122.73733	No	Not Found				Winter
37910	RV-139	42.38341	-122.89416	No	Not Found				Winter/Fall
37911	RV-140	42.34957	-122.95033	No	Not Found				Winter
37913	RV-142	42.34142	-122.94413	No	Not Found				Winter
37914	RV-143	42.34147	-122.94445	No	Not Found				Winter
37915	RV-144	42.34081	-122.94046	No	Not Found				Winter
37916	RV-145	42.23501	-122.73888	No	Not Found				Winter
37918	RV-147	42.42444	-123.07617	No	Not Found				Winter
37920	RV-149	42.43082	-123.18254	No	Not Found				Winter
37921	RV-150	42.38419	-122.90037	No	Not Found				Winter/Fall
37922	RV-151	42.34266	-122.96300	No	Not Found				Winter
37923	RV-152	42.35121	-122.94341	No	Not Found				Winter
37927	RV-156	42.48942	-122.87155	No	Not Found				Winter
37930	RV-159	42.43378	-123.03918	No	Not Found				Winter
37931	RV-160	42.33699	-122.77163	No	Not Found				Winter
37934	RV-163	42.14540	-122.63529	No	Not Found				Winter
37935	RV-164	42.20210	-122.78416	No	Not Found				Winter
37936	RV-165	42.32557	-122.94256	No	Not Found				Winter
37938	RV-167	42.43178	-123.40113	No	Not Found				Winter
37939	RV-168	42.41308	-123.26567	No	Not Found				Winter
37940	RV-169	42.42936	-123.26248	No	Not Found				Winter
37941	RV-170	42.42018	-123.24031	No	Not Found				Winter
37943	RV-172	42.47017	-123.15648	No	Not Found				Winter
37945	RV-174	42.44171	-123.45117	No	Not Found				Fall
37948	RV-177	42.52742	-122.92488	No	Not Found				Fall
37950	RV-179	42.26364	-122.86354	No	Not Found				Fall

Well ID	Rogue Basin Groundwater Study Site ID	Latitude	Longitude	Well Log Availability	Well log	Top of Water Bearing Zone (ft bgs)	Bottom of Water Bearing Zone (ft bgs)	Well Vertical Migration Potential	2016 Sampling Season
37951	RV-180	42.28537	-122.88877	No	Not Found				Fall
37953	RV-182	42.36749	-122.93785	No	Not Found				Fall
37954	RV-183	42.36279	-122.94164	No	Not Found				Fall
37957	RV-186	42.18883	-122.66199	No	Not Found				Fall
37961	RV-190	42.44374	-123.13120	No	Not Found				Fall
37962	RV-191	42.33489	-122.90451	No	Not Found				Fall
37963	RV-192	42.32727	-122.92267	No	Not Found				Fall
37967	RV-196	42.29836	-122.90619	No	Not Found				Fall
37968	RV-197	42.30701	-122.92284	No	Not Found				Fall
37970	RV-199	42.28203	-122.89821	No	Not Found				Fall
37971	RV-200	42.28393	-122.90561	No	Not Found				Fall
37977	RV-206	42.44390	-122.78437	No	Not Found				Fall
37980	RV-209	42.41729	-122.84485	No	Not Found				Fall
37981	RV-210	42.29113	-122.85042	No	Not Found				Fall
37982	RV-211	42.34471	-122.95890	No	Not Found				Fall
37983	RV-212	42.33531	-122.96870	No	Not Found				Fall
37985	RV-214	42.41854	-123.06617	No	Not Found				Fall
37986	RV-215	42.44223	-122.99817	No	Not Found				Fall
37988	RV-217	42.40026	-122.97330	No	Not Found				Fall
37989	RV-218	42.39215	-122.93124	No	Not Found				Fall
37990	RV-219	42.41446	-122.89887	No	Not Found				Fall
37991	RV-220	42.33169	-122.77267	No	Not Found				Fall

Appendix B – Full Analyte List

Pages B-1 through B-3

List contains all compounds analyzed during the sampling period	Pesticides analyzed in a limited number of samples as discussed in section 2.2.1
Analyte group, *Analyte sub-group*, Analyte name	
Bacteria	**Current Use Pesticides, cont'd**
Total Coliform	*Herbicides*
E. Coli	Chlorpropham
Consumer Product Constituents	Cyanazine
DEET	Cycloate
Current Use Pesticides	Dacthal (DCPA)
Fungicides	DCPA acid metabolites
Chloroneb	Deisopropylatrazine
Chlorothalonil	Desethylatrazine
Etridiazole	Dichlobenil
Fenarimol	Dichloroprop
Pentachlorophenol	Dimethenamid
Propiconazole	Dinoseb
Pyraclostrobin	Diphenamid
Triadimefon	Diuron
Tricyclazole	EPTC
Herbicides	Fluometuron
2,4,5-T	Fluridone
2,4-D	Hexazinone
2,4-DB	Imazapyr
2,6-Dichlorobenzamide	Linuron
Acetochlor	MCPA
Acifluorfen	MCPP
Alachlor	Metolachlor
Ametryn	Metribuzin
Aminocarb	Metsulfuron Methyl
Atrazine	Molinate
Bromacil	Napropamide
Butachlor	Neburon
Butylate	Norflurazon

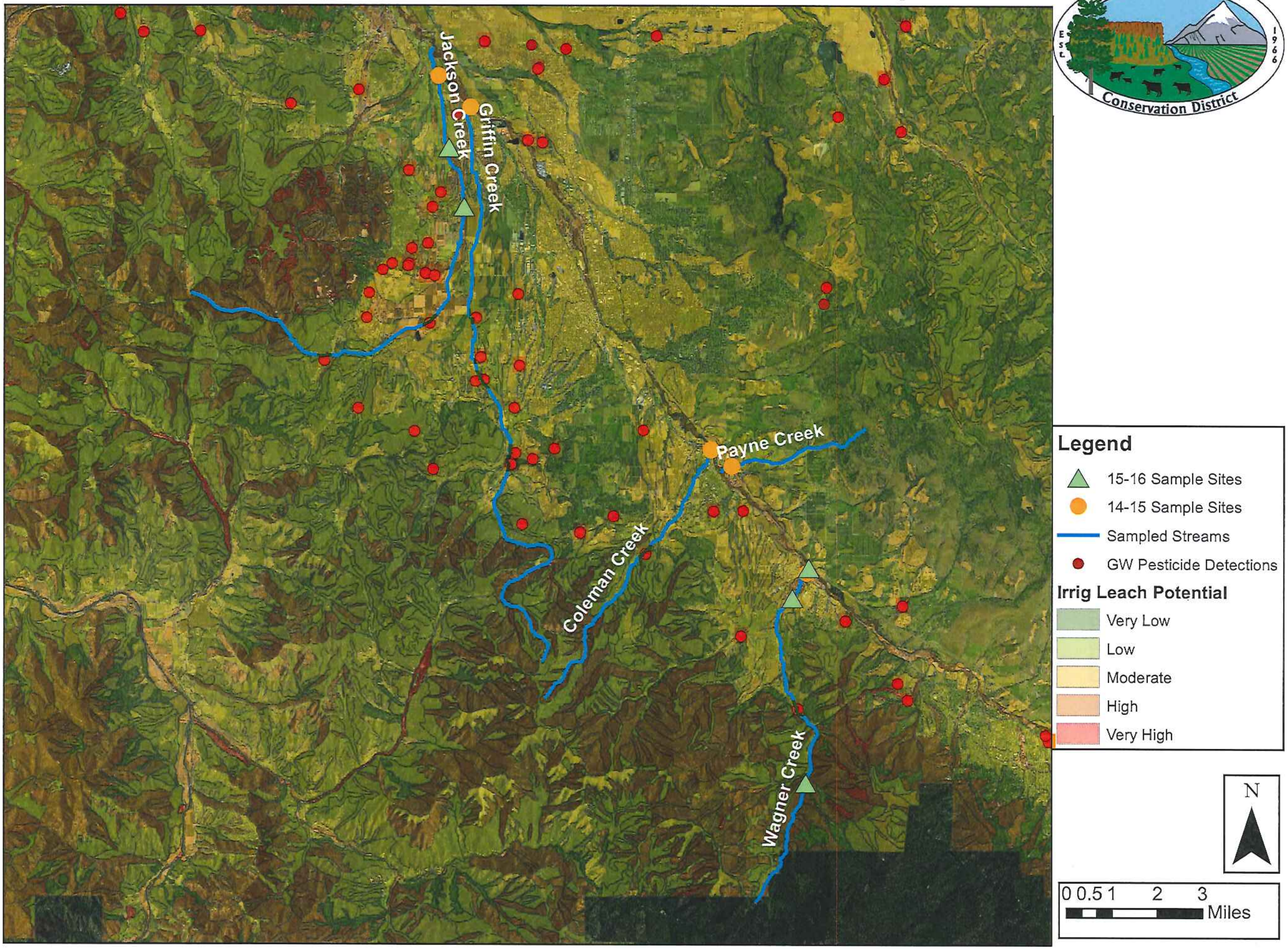
List contains all compounds analyzed during the sampling period	Pesticides analyzed in a limited number of samples as discussed in section 2.2.1
Analyte group, *Analyte sub-group*, Analyte name	
Current Use Pesticides, cont'd	**Current Use Pesticides, cont'd**
Herbicides	*Insecticides*
Pendimethalin	Fenamiphos
Picloram	Fenvalerate+Esfenvalerate
Pendimethalin	Imidacloprid
Picloram	Malathion
Prometon	Methiocarb
Prometryn	Methomyl
Pronamide	Methyl paraoxon
Propachlor	Mevinphos
Propazine	Mexacarbate
Siduron	MGK 264
Simazine	Mirex
Simetryn	Oxamyl
Sulfometuron-methyl	Parathion-ethyl
Tebuthiuron	Parathion-methyl
Terbacil	Permethrin
Terbutryn (Prebane)	Pyriproxyfen
Terbutylazine	Terbufos
Triclopyr	Tetrachlorvinphos (Stirophos)
Trifluralin	**Industrial Chemicals or Intermediates**
Vernolate	3,5-Dichlorobenzoic acid
Insecticides	**Legacy Pesticides**
Acetamiprid	2,4,5-TP (Silvex)
Azinphos-methyl (Guthion)	Aldrin
Baygon (Propoxur)	Chlorobenzilate
Bifenthrin	cis-Nonachlor
Carbaryl	Dieldrin
Carbofuran	Endosulfan I
Chlorpyrifos	Endosulfan II
Diazinon	Endosulfan sulfate
Dicamba	Endrin
Dichlorvos	Endrin aldehyde
Dimethoate	Endrin ketone
Ethoprop	Endrin+cis-Nonachlor

List contains all compounds analyzed during the sampling period	Pesticides analyzed in a limited number of samples as discussed in section 2.2.1
Analyte group, *Analyte sub-group*, Analyte name	
Legacy Pesticides, cont'd	**Metals (Total Recoverable)**
Heptachlor	Aluminum
Heptachlor epoxide	Arsenic
Hexachlorobenzene	Calcium
Methoxychlor	Iron
BHC-Technical (HCH)	Magnesium
alpha-BHC	Manganese
beta-BHC	Potassium
delta-BHC	Sodium
gamma-BHC (Lindane)	Uranium
Chlordane	Vanadium
alpha-Chlordane	**Standard Parameters**
cis-Chlordane	Hardness as CaCO3, Total recoverable
gamma-Chlordane+trans-Nonachlor	Alkalinity, Total as CaCO3
Oxychlordane	Chloride
trans-Chlordane	Nitrate/Nitrite as N
trans-Nonachlor	Oxidation Reduction Potential
Total DDT	Phosphate, Total as P
2,4´-DDD	Sulfate
2,4´-DDE	Total Solids
2,4´-DDT	**Field Parameters**
4,4´-DDD	Conductivity
4,4´-DDE	Dissolved Oxygen
4,4´-DDT	pH
	Temperature

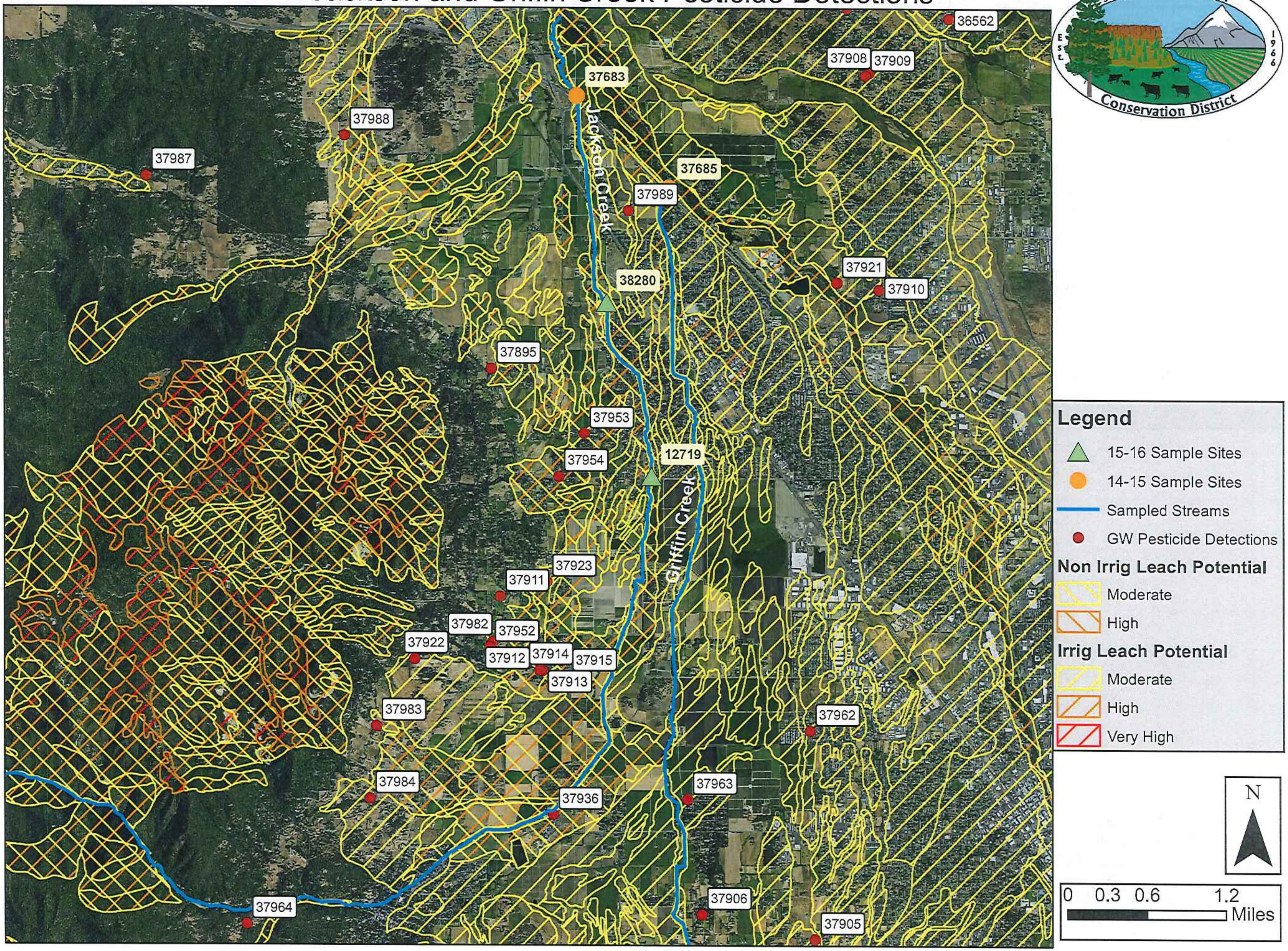
Appendix B

Maps of Well Locations Relative to Surface Water Sampling Locations

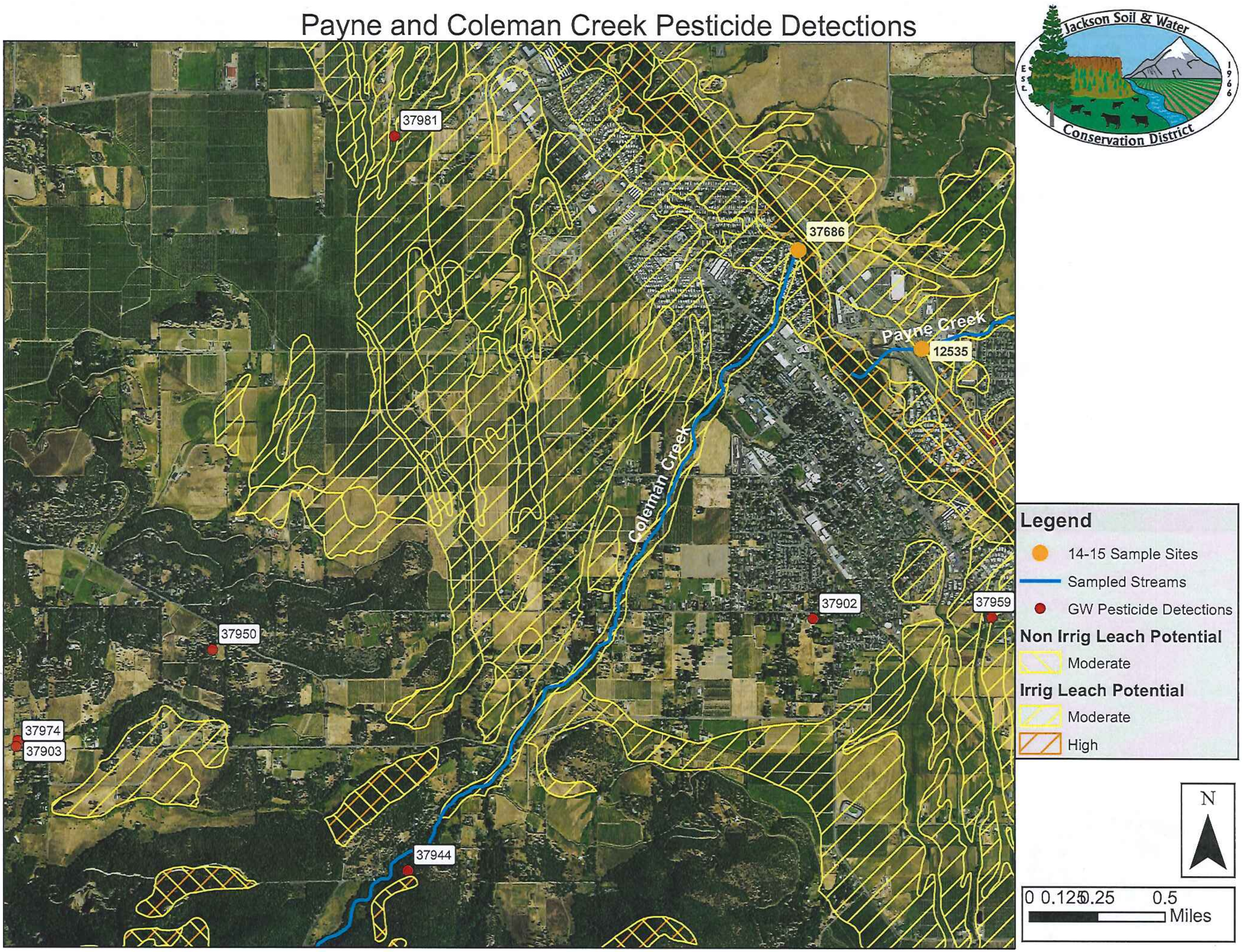
Groundwater Pesticide Detections and Surface Water Sampling Sites



Jackson and Griffin Creek Pesticide Detections

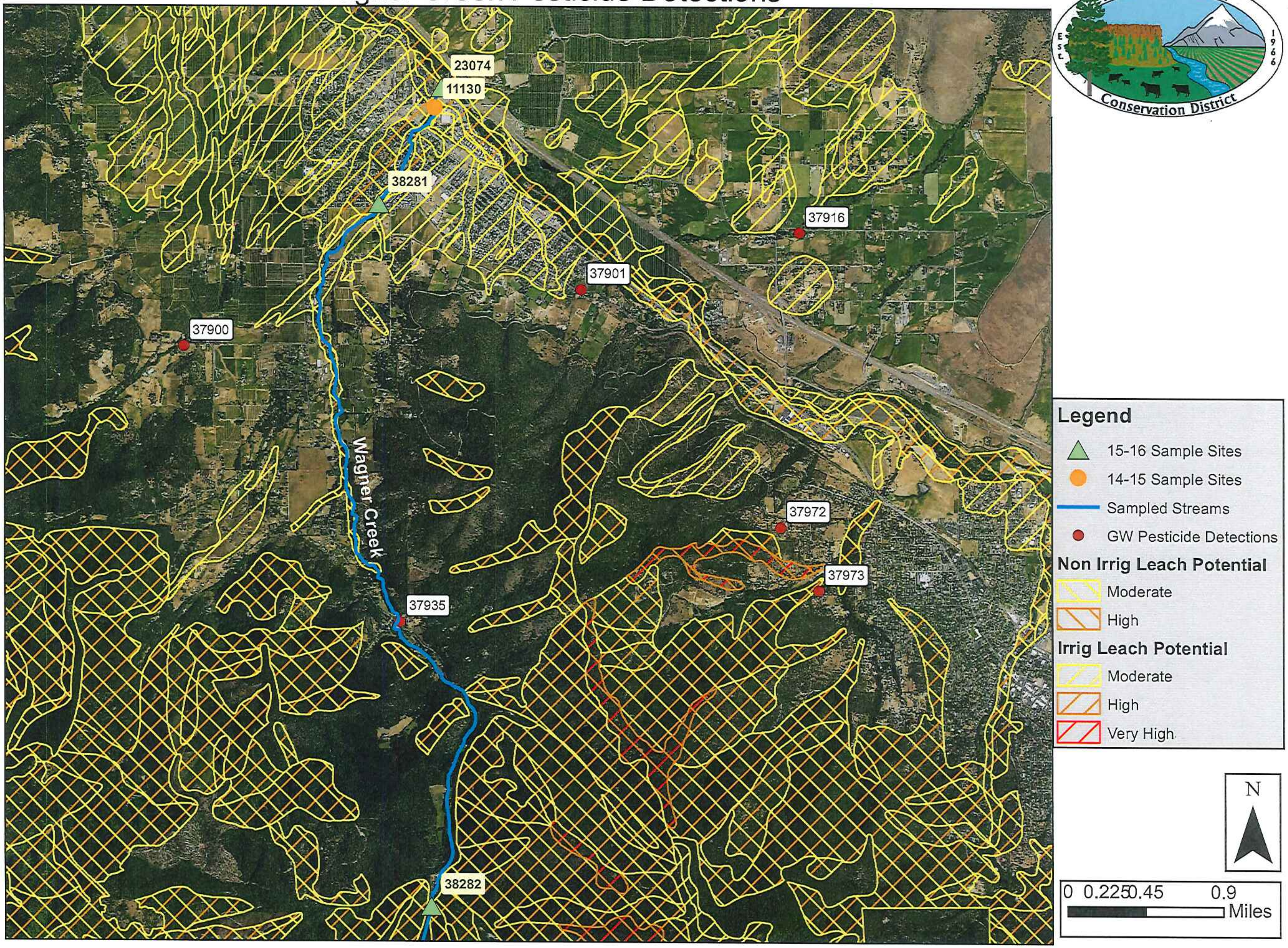


Payne and Coleman Creek Pesticide Detections



Wagner Creek Pesticide Detections

Jackson Soil & Water Conservation District
Est. 1966



GW Pesticide Analytes	SW vs GW Analytes	Pesticides Det in GW in Jackson & Griffin	Pesticides Det in SW- Jackson & Griffin	Pesticides Det in GW in Payne & Coleman	Pesticides Det in SW - Payne & Coleman	Pesticides Det in GW in Wagner Ck	Pesticides Det in SW - Wagner
2,4-D		X	X				
2,4-DB							
2,4,5-T							
2,4,5-TP (Silvex)	2,4,5-TP (Silvex)						
2,6-Dichlorobenzam	2,6-Dichlorobenzan	X,Y,Z	X		X	Y	
3,5-Dichlorobenzoic acid							
2,4 -DDD		Y					
4,4´-DDD	4,4´-DDD	Y		Y			
4,4´-DDE	4,4´-DDE	Y			X		
4,4´-DDT	4,4´-DDT	Y					
Acetamiprid	Acetamiprid	Y	X		X		
Acetochlor	Acetochlor						
Acifluorfen							
Alachlor	Alachlor						
Aldrin	Aldrin						
alpha-BHC	alpha-BHC						
Ametryn	Ametryn						
	AMPA (glyphosate degradate)		X		X		X
Aminocarb	Aminocarb						
Atrazine	Atrazine	X,Y,Z	X				X
Azinphos-methyl (G	Azinphos-methyl (Guthion)						
Baygon (Propoxur)	Baygon (Propoxur)						
beta-BHC	beta-BHC						
Bifenthrin	Bifenthrin						
Bromacil	Bromacil						
Butachlor	Butachlor						
Butylate	Butylate						
Carbaryl	Carbaryl		X				X
Carbofuran	Carbofuran						
Chlorobenzilate	Chlorobenzilate						
Chloroneb	Chloroneb						
Chlorothalonil	Chlorothalonil						
Chlorpropham	Chlorpropham						
Chlorpyrifos	Chlorpyrifos						
cis-Chlordane	cis-Chlordane						
Cyanazine	Cyanazine						
Cycloate	Cycloate						
Dacthal (DCPA)	Dacthal (DCPA)						
DCPA acid metabolites		X					

DEET	DEET		X				
Deisopropylatrazine	Deisopropylatrazine	X,Y,Z	X				
delta-BHC	delta-BHC						
Desethylatrazine	Desethylatrazine	X,Y,Z					X
Diazinon	Diazinon						
Dicamba							
Dichlobenil	Dichlobenil		X		X		
Dichloroprop							
Dichlorvos	Dichlorvos						
Dieldrin	Dieldrin						
Dimethenamid	Dimethenamid						
Dimethoate	Dimethoate						
Dinoseb	Dinoseb						
Diphenamid	Diphenamid						
Diuron	Diuron	Y,Z	X		X		X
Endosulfan I	Endosulfan I						
Endosulfan II	Endosulfan II						
Endosulfan sulfate	Endosulfan sulfate						
Endrin	Endrin						
Endrin aldehyde	Endrin aldehyde						
EPTC	EPTC						
Ethoprop	Ethoprop						
Etridiazole	Etridiazole						
Fenamiphos	Fenamiphos						
Fenarimol	Fenarimol						
Fenvalerate+Esfenv	Fenvalerate+Esfenvalerate						
Fluometuron	Fluometuron						
Fluridone	Fluridone		X				
gamma-BHC (Lindan	gamma-BHC (Lindane)						
	Glyphosate (roundup)		X		X		
Heptachlor	Heptachlor						
Heptachlor epoxide	Heptachlor epoxide	Z					
Hexazinone	Hexazinone						
Imazapyr	Imazapyr		X				X
Imidacloprid	Imidacloprid		X		X		X
Linuron	Linuron						
Malathion	Malathion						
MCPA							
MCPP							
Methiocarb	Methiocarb						
Methomyl	Methomyl						
Methoxychlor	Methoxychlor						

Methyl paraoxon	Methyl paraoxon						
Metolachlor	Metolachlor						
Metribuzin	Metribuzin						
Metsulfuron Methy	Metsulfuron Methyl						
Mevinphos	Mevinphos						
Mexacarbate	Mexacarbate						
MGK 264	MGK 264						
Mirex	Mirex						
Molinate	Molinate						
Napropamide	Napropamide						
Neburon	Neburon						
Norflurazon	Norflurazon	Z			X		
Oxamyl	Oxamyl						
Oxyfluorfen	Oxyfluorfen (Goal)		X				
Parathion-ethyl	Parathion-ethyl						
Parathion-methyl	Parathion-methyl						
Pebulate	Pebulate						
Pendimethalin	Pendimethalin		X				
Pentachlorophenol							
Permethrin	Permethrin						
	Phosmet						
Picloram							
Prometon	Prometon	Y	X				
Prometryn	Prometryn						
Pronamide	Pronamide						
Propachlor	Propachlor						
Propazine	Propazine						
Propiconazole	Propiconazole						
Pyraclostrobin	Pyraclostrobin						
Pyriproxyfen	Pyriproxyfen						
Siduron	Siduron						
Simazine	Simazine	X,Y				Y	
Simetryn	Simetryn						
Sulfometuron-meth	Sulfometuron-methyl (OUST)		X		X		X
Tebuthiuron	Tebuthiuron						
Terbacil	Terbacil						
Terbufos	Terbufos						
Terbutryn (Prebane	Terbutryn (Prebane)						
Terbutylazine	Terbutylazine						
Tetrachlorvinphos (	Tetrachlorvinphos (Stirophos)						
trans-Chlordane	trans-Chlordane						
trans-Nonachlor	trans-Nonachlor						

Triadimefon	Triadimefon						
Triclopyr	Triclopyr		X				
Tricyclazole	Tricyclazole						
Trifluralin	Trifluralin						
Vernolate	Vernolate						
X = wells nearest to the SW sampling sites							
Y = wells upgradient of SW sampling sites, in watershed							
Z = wells in vicinity of SW sampling sites, but not directly in areas likely discharging to SW sites							