Ground Water Quality Technical Report No. 26

Arena Valley Ground Water Quality, Wilder Area, Idaho

Prepared by Joe Baldwin
Idaho Department of Environmental Quality
State Office
May 2006

Table of Contents

List of Figures

List of Tables

Executive Summary

This report represents the findings from a recent study of ground water quality in Arena Valley, west of Wilder, Idaho.

Follow-Up to 2003 Finding of Elevated Nitrate

As a follow-up to a 2003 finding of elevated nitrate levels in one Arena Valley ground water monitoring well, DEQ conducted additional monitoring and analyses of nearby wells and agricultural drains. The results indicate that the 2003 result was anomalous, and the cause for the anomaly remains unknown. However, well and drain samples from other sample locations show nitrate concentrations as high as 14.6 mg/L.

Irrigation Drain Nitrate Exceeds Ground Water Standard (GWS)

Irrigation drains were sampled during a period when surface water was not contributing to flow in the drains. The drain samples represent the uppermost part of the shallow aquifer and show that ground water in the central, east and northern parts of the valley has elevated nitrate—in some areas above the Idaho ground water standard (GWS) of 10 mg/L (IDAPA 58.01.11.200.01(a)).

Elevated Wastewater Reuse Site Nitrate Pre-Dates Site Conversion

Sample results from dedicated monitoring wells around a wastewater reuse site in the eastern part of the valley show nitrate concentrations as high as 37.3 mg/L. Elevated nitrate may be the result of over-application of nitrogen fertilizer prior to conversion of the site to wastewater reuse. Samples have been collected from these wells since 1993; nitrate concentrations peaked in 1998 to 1999 and have been trending downward. Wastewater, plant tissue, and soil sampling show that nitrogen applications in the wastewater have been matched by crop uptake since the site was converted to wastewater reuse.

Arsenic Below Current Groundwater GWS, Above Public Drinking Water GWS

Arsenic was analyzed in the 2003 ground water samples, and results from past samples were also evaluated for this study. All arsenic concentrations were below the current Idaho GWS of 0.05 mg/L.

The Environmental Protection Agency has adopted an arsenic standard of 0.01 mg/L. Idaho has adopted this lower GWS for public drinking water systems but has not adopted the new GWS for ground water. If the lower GWS were applied to ground water, all wells would have exceeded the GWS on one or more sample events.

Phosphorus Exceeds TMDL

Phosphorus concentrations in three down stream drain samples collected during December 2005 were 0.332 mg/L (Allen Drain #1), 0.078 mg/L (Riverside Drain) and 0.110 mg/L (Stateline Drain). The mid-Snake/Succor Creek phosphorus TMDL is 0.070 mg/L; all three drain phosphorus concentrations exceed this value.

Nitrogen Isotopes Provide Evidence for Nitrate Sources

Samples for analysis of nitrogen isotopes were collected from four wells and nine drains. Drain sample locations provided representative data across the study area and isotope information at various points along a particular drain:

- In the eastern part of the study area irrigated agriculture predominates, and an isotope result from one drain was 3.38 parts per thousand (*permil*), which indicates a commercial fertilizer source.
- A well in the central part of the valley had a nitrogen isotope value of 3.84 permil, also indicative of a commercial fertilizer source.
- Isotope values from drains in the southwestern part of the valley indicated an animal or human nitrogen source; these results ranged from 12.00 to 15.64 permil. There is one dairy that has between 201 and 500 animal units, beef cattle are pastured in this part of the valley and housing densities are low. Nitrogen in ground water and surface water in this area most likely comes from animal sources.
- Isotope values from other drain and well samples ranged from 5.49 to 7.21 permil, an indication that nitrogen is originating from more than one source.

Introduction

The purpose of this report is to present data from ground water and surface water sampling conducted in an area known as the *Arena Valley*. Arena Valley is located in Canyon County, west of Wilder, Idaho (Figure 1). Arena Valley is included in the *Lower Boise/Canyon County Nitrate Priority Area*. (For a description of nitrate priority areas, including rankings and specific locations, see http://www.deq.state.id.us/water/prog_issues/ground_water/nitrate.cfm#ranking).

2003 Detection of Elevated Nitrate Levels

Elevated nitrate has been noted in some Arena Valley wells for the past thirteen years. In June 12, 2003, nitrate concentrations in a well located at 04N 06W 11DCA1 (the well is part of a statewide monitoring system) were reported at 16.3 mg/L. (For a discussion of the Idaho ground water quality monitoring network, see http://www.idwr.idaho.gov/hydrologic/info/pubs/wib/wib50p1-gwq_network_design.pdf).

Follow-Up Sampling in 2003 and 2005

According to the *Idaho Ground Water Quality Plan* (Ground Water Quality Council, 1992) DEQ was notified of the elevated result and conducted follow up sampling of well 04N 06W 11DCA1, four nearby domestic wells, and two agricultural drains in Arena Valley during October 2003. Based on these sample results, a second round of ground water and surface water sampling was conducted December 15 and 20, 2005.

This study included a review of hydrogeologic data from a wastewater reuse site located in the eastern part of the valley, a review of drillers' logs from domestic and irrigation wells in the area, and evaluation of analytical results for samples collected by DEQ from domestic wells and irrigation drains in 2003 and 2005. A literature review of previous investigations was also conducted for pertinent hydrogeologic and water chemistry data of the area.

Study Area Description

Arena Valley is located about fifteen miles west of Caldwell, Idaho and about three miles west of Wilder, Idaho (Figure 1). The area is bounded on the south and west by the Snake River and on the east and north by west- and south-facing slopes.

Location and Topography

The valley is roughly circular in shape. The west and south-facing slopes that form the northern and eastern sides of the valley may represent a meander scar of the ancestral Snake River or, possibly, an erosional feature related to the Bonneville flood event. North and east of Arena Valley lies a peninsular terrace, known as Deer Flat, that provides a surface water divide between the Snake and Boise Rivers. The Boise River lies about three miles northeast of Arena Valley.

Land Use

The land area within Arena Valley is about 7,400 acres. This area includes the part of the valley in Idaho and east and south of the Golden Gate Canal. Land in Arena Valley is mostly used for agricultural purposes. Crops grown include small grains, corn, alfalfa, and pasture. There is one dairy operation in the valley, located at 04N 06W 13AD (Figure 2). Exact animal numbers are not available, but Idaho Department of Agriculture (ISDA) records indicate the facility is within the range of 201 to 500 animal units. A small hog raising operation is located in the southeast quarter of 04N 06W section 12, and beef cattle are grazed on pastures on the western part of the valley.

A nitrogen budget provides a way to evaluate the relative impacts to water resources from various nitrogen sources. Estimates of nitrogen loads to the environment are prepared by totaling nitrogen inputs from all sources. The various sources of nitrogen in the environment include commercial fertilizer, animal waste, human waste, nitrogen in precipitation, nitrogen from industrial sources, and plow down of legumes, such as alfalfa.

Table 1 shows a summary of the nitrogen budget developed for Canyon County by DEQ staff, using data from 1999-2004. The results indicate that commercial fertilizer applications and nitrogen from animal sources constitute about 92 percent of the estimated nitrogen load to the environment. Nitrogen from domestic sources (septic tanks/drain fields and municipal wastewater treatment plants), precipitation, industrial sources, and plow down of legumes amounted to about 8 percent of the estimated load. Nitrogen loads in the Arena Valley are expected to be similar to nitrogen loads in Canyon County on a per acre basis.

Table 1. Summary of total estimated nitrogen loading for Canyon County.

Nitrogen Source	Nitrogen Contribution (lbs)	Percent Contribution
Commercial fertilizer	12,400,000	51
Animal waste	9,948,000	41
Legume crop plow down	1,020,000	4
Domestic waste	425,000	2
Precipitation	324,000	1
Industrial	333,000	1
Total	**24,450,000**	**100**

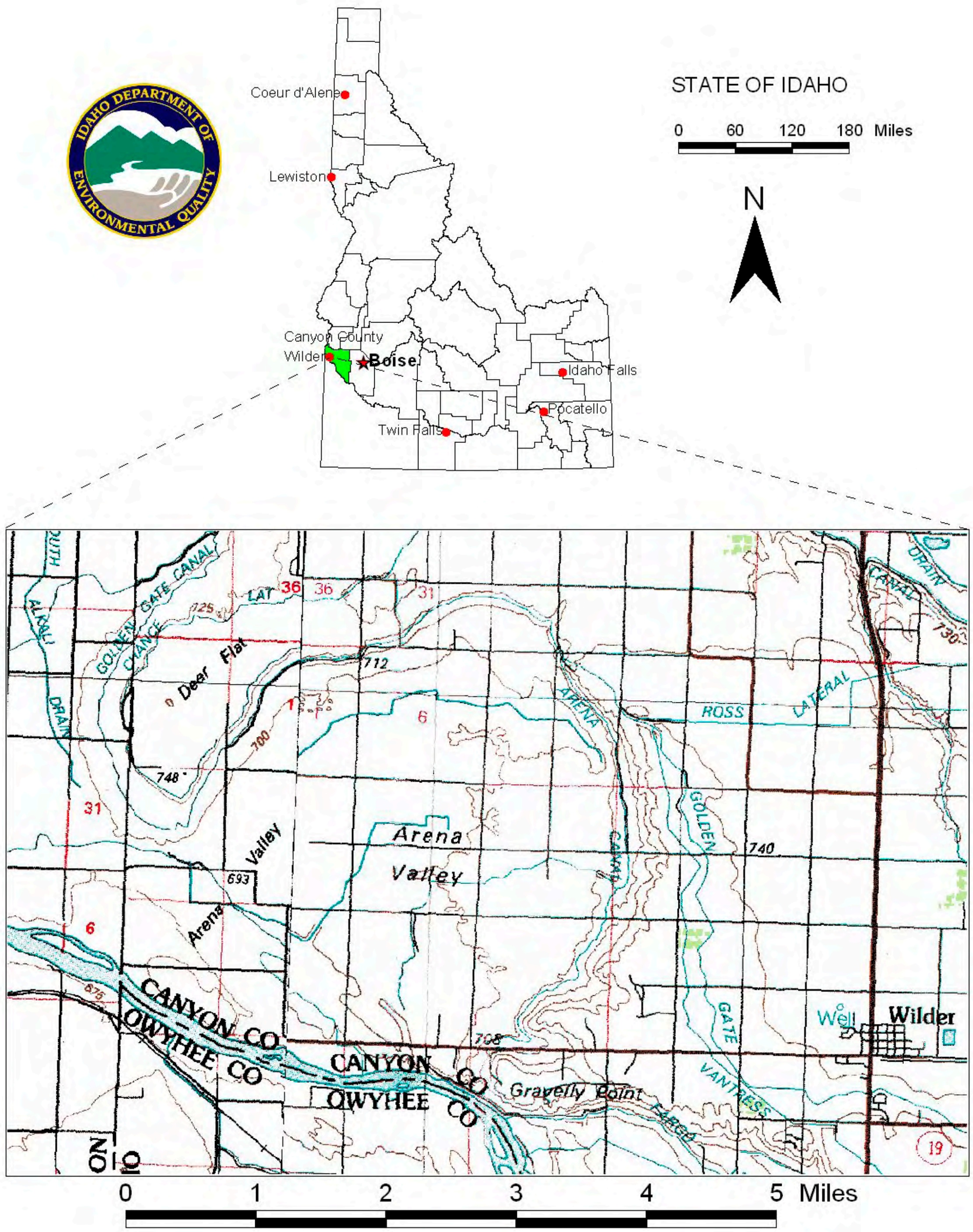

Figure 1. Location of Arena Valley study area, Canyon County Idaho.

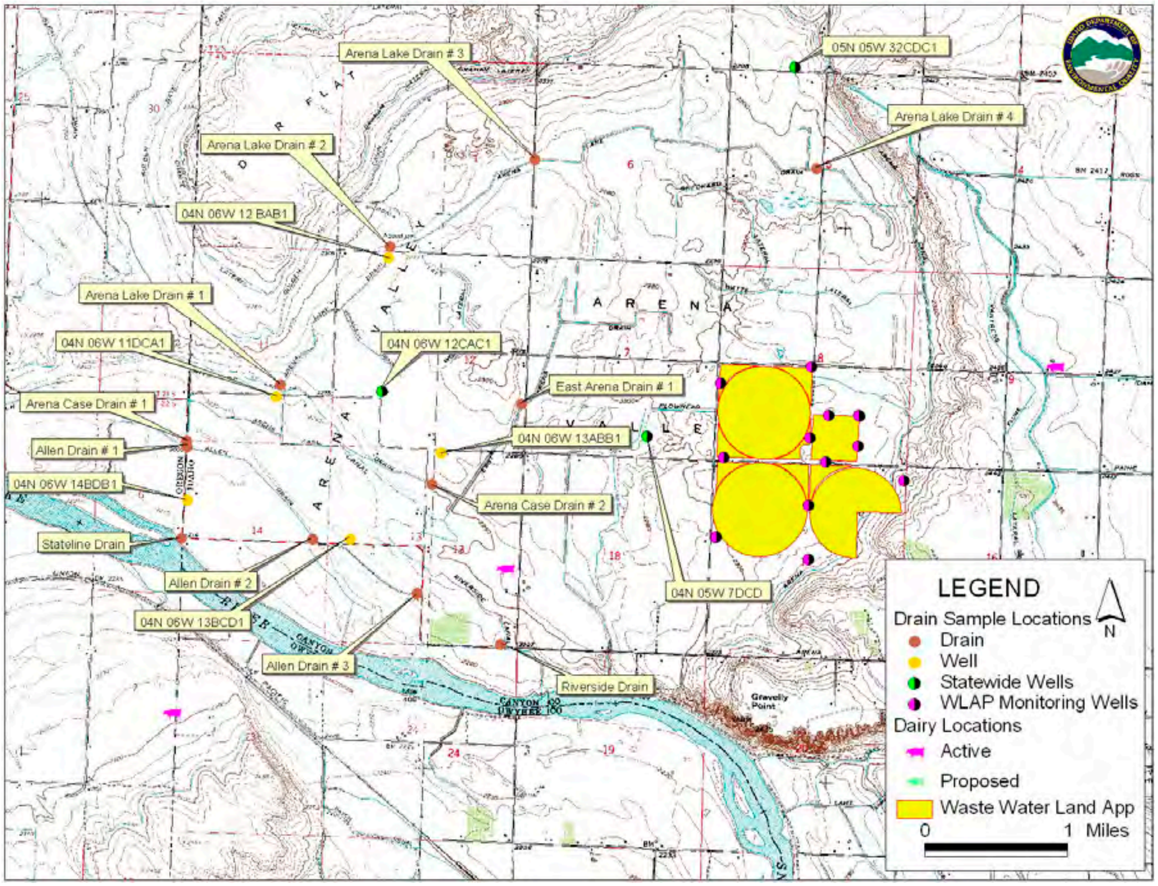

Figure 2. Well and drain sample locations for DEQ sample events conducted in October 2003 and December 2005.

The valley has a flat to gently rolling topography. There is roughly 130 feet of elevation difference from the terrace on the northeast to the valley floor; the elevation of the valley floor ranges from about 2,300 feet on the east to about 2,200 feet at the Idaho-Oregon border on the west.

Surficial Geology

The surficial geology of Arena Valley has been mapped by Othberg and Stanford (1992). Beukelmann (1997) prepared a geologic cross section that illustrates the stratigraphy of the study area. The valley is eroded into sediments of the Glenns Ferry Formation, a sequence of late-Cenozoic age siltstone and fine sandstone that was deposited in fluvial (river) and shallow lacustrine (lake) settings. Glenns Ferry sediments are also exposed on the south- and west-facing valley slopes of Arena Valley.

The Glenns Ferry sediments are overlain by modern flood plain deposits, Bonneville Flood slack water fine sediments, gravel deposits of Pleistocene age, and older Tertiary age sediments (Benkelmann, 1997).

Variation in Color or Drill Cuttings Indicates Aerobic to Anaerobic Transition

A distinguishing lithologic feature of the upper part of the Glenns Ferry sediments is the transition from tan or brown silt, sand, and gravels in the upper part to sediments that have a gray, blue, or black appearance in drill cuttings. This color transition represents a change from oxidized conditions (yellow, tan and brown colors) to reduced conditions (blue and gray colors). The color change marks the transition from alluvial sediments that were deposited in aerobic or oxygen-rich conditions to deep lake sediments deposited under anaerobic or oxygen-deficient conditions (Hutchings et al., 2002). Beukelmann (1997) notes that the color change occurs at elevations between 2,150 and 2,250 feet in the Notus and Parma areas. Driller's logs for wells in Arena Valley show that the color change occurs almost uniformly at an elevation of 2,200 feet.

The significance of the color change on ground water chemistry is discussed in later sections.

Soils

Soils in Arena Valley have been mapped as part of the Canyon County soils survey (Priest, et al., 1972). Arena Valley soils are derived from parent materials that include modern flood plain deposits, Bonneville Flood slack water fine sediments, and the gravel deposits described above.

The soils are mapped as a Turbyfill-Cencove-Feltham association and consist of well-drained and somewhat excessively-well-drained fine sandy loams and loamy fine sands that extend to depths of 60 inches or greater. The available water holding capacity for the 60-inch soil profiles are low, ranging from 3.75 to 5 inches for Cencove soils and 5 to 7.5 inches for Turbyfill soils.

Soil blowing and erosion can be severe for some soils in the Arena Valley. Almost all land is used for agricultural purposes, with the main crops being alfalfa, corn, small grains, and pasture.

Arena Valley Ground Water

Ground water and ground water flow conditions in the Treasure Valley, which includes Arena Valley, are described in Petrich and Urban (2004). Key points regarding Arena Valley ground water are described in the following.

Two Water-Bearing Zones

Stratigraphic and hydrogeologic data are available from a multi-completion monitoring well installed to the east, in the city of Caldwell, at 04N 03W 15BDD. The data indicate that two general water-bearing zones can be distinguished based on water level differences: a shallow water table aquifer and a deep regional confined system. These water-bearing units are hydraulically isolated from each other by thick clay units.

In the Caldwell area, the shallow aquifer extends to depths of about 400 feet, or an elevation of about 2,040 feet, and has water level elevations of about 2,365 feet. The shallow aquifer occurs both above and below the aerobic-to-anaerobic transition zone discussed earlier. In the deep water-bearing unit, a piezometer completed at a depth of 942 feet (1,498 feet elevation) had a water level elevation of about 2,403 feet. The regional aquifer occurs totally within blue or gray colored sediments.

All wells in Arena Valley are completed in the shallow aquifer. A review of available driller's logs indicated that the deepest well (well 04N 05W 17DC) was drilled to a depth of 405 feet and cased to a depth of 259 feet. The bottom hole elevation of this well is approximately 1,965 feet, which is believed to be above the elevation of the regional aquifer. Shallow wells in the Arena Valley, those completed to depths of 100 to 130 feet or less (elevations of 2,200 feet or higher), are competed in tan (aerobic) sediments.

Ground Water Divide Limits Sources for Contaminants

A surface water divide runs northwest, along Deer Flat Ridge, between the Snake River on the west and the Boise River on the east. There also is a ground water divide in the shallow aquifer that roughly parallels the surface water divide. Shallow ground water east of the divide flows east to discharge to the Boise River, and shallow ground water west of the divide flows west to discharge to the Snake River.

The location of the ground water divide was determined by measuring water levels in wells, converting the depth to water to water level elevations and preparing a map showing elevation contours on the water table (a potentiometric map). Nace et al. (1957) prepared a potentiometric map with the ground water divide approximately located.

The surface water divide follows the trace of the Golden Gate Canal, so the ground water divide probably follows this same feature (see Figure 1 for location of the Golden Gate Canal). The importance of the location of the ground water divide is that it marks the eastern and northern extent of the Arena Valley shallow aquifer, so the source for any contaminants found in the Arena Valley shallow aquifer must originate south and west of the ground water divide.

Regional Aquifer Not Likely Impacted by Contaminants

The deep regional aquifer extends from the recharge area, along the Boise foothills, west to the discharge area at the Snake River. Due to its depth and lack of hydraulic connection with the shallow aquifer, the regional aquifer is likely not impacted by contaminant sources in the Arena Valley and is not discussed further in this report.

Surface Water Drains

Shortly after irrigation commenced in the early 1900s, water-logged soils began to develop in the valley, and it became necessary to lower the shallow water table. A series of irrigation drains were constructed in the early 1900s (Wilder Irrigation District, 2005). (See Figure 2 for irrigation drain locations.) The drain channels are from a few feet to 15-20 feet deep. Water in the drains generally flows east to west, where it discharges to the Snake River.

The drains flow year round, with larger discharges during the summer irrigation months, when the shallow water table is at its highest and irrigation return flow enters the drains. Most drains continue to flow during the non-irrigation season; the flow consists of shallow water table discharge only. Discharge probably decreases in the late winter and early spring, when the water table declines to its lowest elevation.

The longest drain is the Arena Lake Drain, which is located in the northern part of the valley and which extends from east to west a distance of about three miles. Figure 3 and

Figure 4 show photos of typical deep and shallow drains, respectively. Samples collected from drains during the winter months, when there is no irrigation return flow and no surface water runoff, represent water chemistry in the uppermost part of the shallow aquifer.

Figure 3. Arena Case Drain at sample location number 2. December 15, 2005, 1315 hours, water temperature 3.6 degrees Celsius.

Figure 4. Allen Drain at sample location 2, December 15, 2005, 1355 hours. Water temperature 13 degrees Celsius.

Ground Water Chemistry

Four of the statewide monitoring wells are located in Arena Valley, and these wells have provided a total of 22 samples from August 1990 through June 2004 (Table 2). Figure 2 shows the location of the four statewide monitoring wells.

Elevated Nitrate in 2003

Well 4N 6W 11DCA1 had a nitrate concentration of 16.3 mg/L in June 2003. In accordance with the Idaho Ground Water Quality Plan, the Idaho Department of Water Resources notified DEQ of the elevated nitrate concentration, and DEQ developed a sampling plan to determine if the nitrate result was from a local source, such as a septic tank/drain field, or represented a widespread regional problem, such as irrigated agriculture.

Follow-up Sampling

Samples were collected from well 4N 6W 11DCA1, four surrounding wells, and two irrigation drains during October 2003. Following the evaluation of these sample results, a second round of well and drain sampling was conducted during December 2005. Samples were collected from four of the five wells and from six drains.

Three drains were sampled synoptically at multiple locations to assess water chemistry in various reaches of a particular drain. One sample was collected from each of the other three drains.

The well and drain sample locations are shown in Figure 2, and sample results are listed in Table 3. The drain samples were collected during a period when daytime air temperatures had been below freezing for several days, so there was no surface water flow into the drains. Therefore, the drain samples represented ground water discharge from the uppermost part of the aquifer.

Table 2. Nitrate concentrations from four statewide monitoring wells in the Arena Valley, for sample dates from 1990 through 2004.

Well Location	Sample Date	NO_3-N (mg/L)	As (mg/L)
04N 05W 07DCD1	10/01/1991	4.0	0.037
04N 05W 07DCD1	07/19/1995	5.8	0.037
04N 05W 07DCD1	07/07/1999	11.0	0.038
04N 06W 11DCA1	09/02/1994	2.7	0.016
04N 06W 11DCA1	08/05/1998	4.32	0.016
04N 06W 11DCA1	06/12/2003	16.3	0.0131
04N 06W 11DCA1	10/15/2003	4.98	0.014
04N 06W 11DCA1	12/20/2005	4.32	
04N 06W 12CAC1	09/02/1994	0.05	0.011
04N 06W 12CAC1	08/19/1998	0.05	0.009
04N 06W 12CAC1	06/12/2003	0.053	0.0863
05N 05W 32CDC1	08/07/1990	1.2	0.020
05N 05W 32CDC1	08/29/1993	2.9	0.018
05N 05W 32CDC1	07/31/1996	2.8	0.018
05N 05W 32CDC1	08/05/1997	5.39	0.037
05N 05W 32CDC1	08/17/1998	2.5	0.018
05N 05W 32CDC1	07/01/1999	8.28	0.019
05N 05W 32CDC1	07/18/2000	6.7	0.018
05N 05W 32CDC1	07/12/2001	8.6	0.0179
05N 05W 32CDC1	07/24/2002	2.49	0.0204
05N 05W 32CDC1	07/08/2003	2.33	0.0205
05N 05W 32CDC1	06/22/2004	1.87	0.0175

Table 3. Laboratory sample results from October 2003 and December 2005 Arena Valley drain and well sampling events. Samples collected by DEQ.

Well location or drain sample name	Sample Date	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	TDS (mg/L)	NO_3-N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)	Total As (mg/L)
04N 06W 11DCA1	10/15/2003	52.8	27.0	52.0	9.3	0	349	13.9	47.0	430	4.98			0.014
04N 06W 11DCA1	12/20/2005							17.6		410	4.32		0.116	
04N 06W 12BAB1	10/15/2003	47.5	15.9	67.0	15.6	0	233	26.7	117.0	460	0.176			0.025
04N 06W 13ABB1	10/15/2003	64.9	32.1	47.0	9.1	0	377	11.2	56.9	490	9.1			0.014
04N 06W 13ABB1	12/20/2005							15.3		490	6.81		0.030	
04N 06W 13BCD1	10/15/2003	66.9	27.8	60.0	8.9	0	378	14.1	58.5	500	7.6			0.014
04N 06W 13BCD1	12/20/2005							21.6		560	7.03		0.049	
04N 06W 14BDB1	10/15/2003	83.4	43.4	79.0	86*	0	555	51.0	84.8	800	10.5			0.016
04N 06W 14BDB1	12/20/2005							49.9		770	14.6		0.336	
Allen Drain #1	12/15/2005	68	26	52	9	0	373	22.6	47.9	421	3.19	0.085	0.332	
Allen Drain #2	12/15/2005	66	27	49	8.6	0	361	15	45.4	443	3.8	0.081	0.115	
Allen Drain #3	12/15/2005	72	24	43	8.7	0	358	10.6	41.4	380	2.56		0.089	
Arena Case Drain #1	12/15/2005	60	32	71	10	0	360	31.2	75.2	400	7.13	0.072	0.153	
Arena Case Drain #2	12/15/2005	69	32	78	11	0	372	30.9	89.4	153	8.5	0.075	0.094	
Arena Lake Drain #1	12/15/2005	53	33	72	10	0	352	26.9	72.2	491	6.35	0.073	0.191	
Arena Lake Drain #2	10/15/2003									490	7.39	0.091		
Arena Lake Drain #2	12/15/2005	55	33	76	11	0	365	32.5	77.3	519	6.1	0.082	0.208	
Arena Lake Drain #3	12/15/2005	54	31	78	11	0	368	28	72.8	526	5.05	0.069	0.149	
Arena Lake Drain #4	12/15/2005	56	29	73	11	0	436	16.5	38.3	493	1.45	0.195	0.352	
East Arena Drain #1	10/15/2003									640	12	0.051		
East Arena Drain #1	12/15/2005	71	33	99	12	0	389	40.1	106	645	10.3	0.074	0.091	
Riverside Drain #1	12/15/2005	76	33	54	12	0	440	24.5	43.8	500	2.35	0.063	0.078	
State Line Drain	12/15/2005	100	33	55	7.4	0	469	19	64.5	520	1.35		0.110	

Notes: Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; CO_3 = carbonate; HCO_3 = bicarbonate; Cl = chloride; SO_4 = sulfate; TDS = total dissolved solids; NO_3-N = nitrate as nitrogen; Ortho-P = orthophosphorus; Total P = total phosphorus; Sp Cond = specific conductance.

*potassium concentration of 86 mg/L was confirmed by laboratory.

Sample Results

Analytical results from the follow-up sampling are presented in the following discussion.

High Nitrate Value of 2003 Appears Anomalous

The October 2003 and December 2005 nitrate-N results from well 04N 06W 11DCA1 were 4.98 mg/L and 4.32 mg/L, respectively (Table 2 and Table 3). These results, coupled with the 1994 and 1998 nitrate-N results (2.7 mg/L and 4.32 mg/L respectively), indicate that the 2003 result of 16.3 mg/L may have been an anomalous value at this well. Nitrate concentrations can fluctuate over a range of several milligrams per liter depending on the nature of nitrogen sources and timing of their release. Additional sampling on a more frequent interval would be necessary to adequately define nitrate concentrations at this well.

Nitrate concentrations in the remaining wells ranged from 0.176 at well 04N 06W 12BAB1 for October 2003 to 14.6 mg/L at well 04N 06W 14BDB1 for December 2005. The October 2003 nitrate result for well 04N 06W 14BDB1 was 10.5 mg/L, an indication that nitrate concentrations have been elevated over the long term in this area.

Low Nitrate Levels Reflect Well Depth

The low nitrate-N concentration at well 04N 06W 12BAB1 is related to the depth of the well completion. Wells completed at elevations lower than 2,200 feet withdraw water from the anaerobic part of the shallow aquifer and commonly have little or no dissolved oxygen, no detectable nitrate, and detectable ammonia concentrations.

For example, the driller's log for well 04N 06W 12BAB1 shows the well had a total depth of 322 feet and was cased into the upper part of the blue clay sediments. The anaerobic nature of the sediments results in reducing conditions that maintain nitrogen species in the ammonia form.

Nitrate-N concentrations from well 04N 06W 12CAC1 are also near or below the laboratory detection limit of 0.05 mg/L (Table 2). This well is 123 feet deep, and the drillers' log shows that blue clay was encountered at an elevation of approximately 2,195 feet. The well is cased to 83 feet, which is about 8 feet into the blue clay.

Elevated Nitrate for Well 04N 06W 14BDB1 Indicates Source in Shallow Aquifer

Nitrate concentrations at well 04N 06W 14BDB1 exceeded the GWS of 10 mg/L for nitrate-N for the October 2003 and December 2005 sample events. The elevated nitrate concentrations indicate the well produces water from material above the blue clay sediments.

A driller's log for this well shows the well depth is 35 feet. Blue clay was encountered at a depth of 21 feet, or at an elevation of about 2,189 feet. The well is cased to 22 feet and perforated from 18 to 22 feet. Black sand and gravel was noted from 5 to 22 feet below land surface. Apparently, all water production comes from the sand and gravel deposits that overlie the blue clay.

Ground Water Arsenic

Water samples from the four statewide wells and five wells sampled by DEQ were analyzed for total arsenic. Arsenic sample results are listed in Table 2 (statewide wells) and Table 3 (DEQ wells). Concentrations ranged from 0.00863 to 0.038 mg/L.

In Idaho, arsenic in ground water is derived from naturally occurring sources. For a description of arsenic sources and potential health impacts, the reader is directed to the following Web site: http://www.deq.state.id.us/water/assist_citizen_comm/drinking_water/arsenic.cfm.

The Environmental Protection Agency (EPA) has lowered the arsenic GWS to 0.010 mg/L from the previous GWS of 0.050 mg/L, and Idaho has adopted the new arsenic GWS for public drinking water systems. The lower arsenic GWS has not been adopted for general ground water.

Arsenic in all wells was lower than the current 0.050 mg/L GWS. However, if the lower standard is adopted for ground water, samples from all wells would have exceeded this GWS on at least one sample event.

Nitrate in Drain Samples Highest in Central Arena Valley

Nitrate-N concentrations in drain samples ranged from 1.35 to 10.3 mg/L (Figure 5). In the Arena Lake Drain, nitrate concentrations increased in the downstream direction, from 1.35 mg/L on the east to 6.35 mg/L on the west end of the drain. The east end of the drain is at the upper end of the valley's shallow ground water flow system, and there is limited agricultural land at this end of the drain. The downstream part of the drain receives ground water discharge from a broad area that is devoted to agricultural activities.

Nitrate-N concentrations were highest (10.3 mg/L) at the East Arena Drain #1 sample site. This sample point is located in the central part of the valley; the elevated nitrate-N concentration indicates that shallow ground water in the central part of the valley exceeds the nitrate-N GWS.

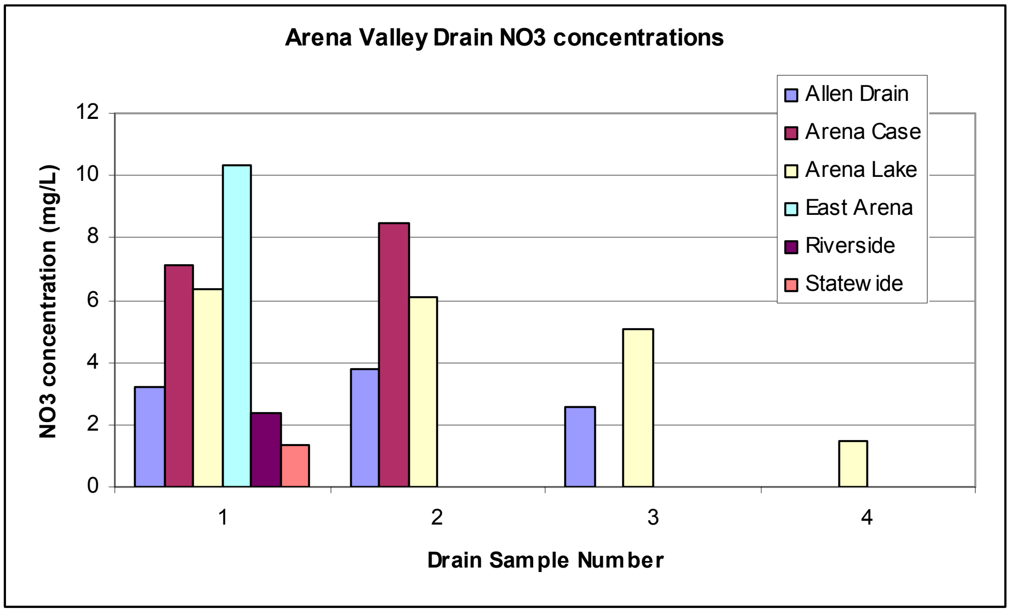

Figure 5. Nitrate concentrations in Arena Valley drains sampled during December 2005. For drains with multiple sample locations (Allen Drain, Arena Case Drain and Arena Lake Drain) the downstream sample location is 1 and upstream locations are 2, 3 or 4.

The Allen Drain collects ground water discharge from the southwestern part of the valley; nitrate-N concentrations ranged from 2.56 mg/L at the upstream end (Allen Drain #3) to 3.19 mg/L at the downstream sample location (Allen Drain #1). Two nearby drains, Riverside Drain and Stateline Drain had nitrate-N concentrations of 2.35 and 1.35 mg/L, respectively. These data indicate that ground water in the southwestern part of the valley has had minimal impact from land use activities.

The Arena Case Drain collects ground water from a small area in the west-central part of the valley. Also, the Arena Lake Drain and the East Arena Drain both flow into this drain. Nitrate-N concentrations at the upstream and downstream sample locations on this drain were 8.5 and 7.13 mg/L respectively. Water quality in this drain is consistent with impacted ground water quality in the central and western parts of the valley.

Sodium Versus Calcium Concentrations Indicate Water Chemistry Differences

Figure 6 shows a plot of sodium versus calcium concentrations for drains in the valley. The water quality relationships discussed earlier are evident in this plot, mainly that the impacted drains–Arena Lake Drain, East Arena Lake Drain, and the Arena Case Drain—have different water chemistry than drains that have smaller water quality impacts—Stateline, Riverside, and Allen.

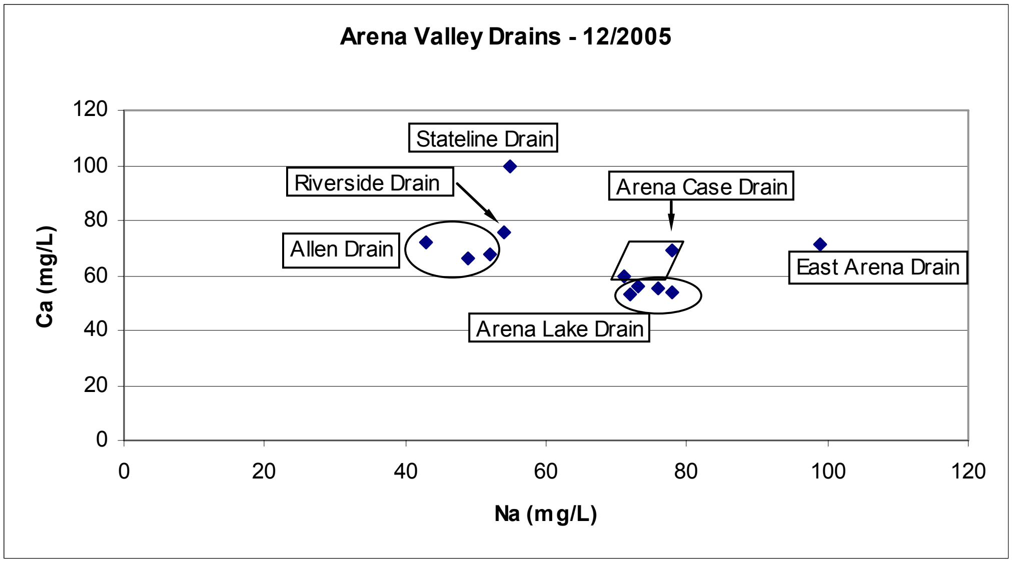

Figure 6. Sodium versus calcium for Arena Valley drain samples collected during December 2005.

Phosphorus Results Indicate Possible Impact of Ground Water Discharge

Drains were also sampled for total phosphorus, because this constituent is responsible for water quality impacts to Idaho's rivers, lakes, and streams. Drain phosphorus concentrations are shown in Table 3.

Variations in phosphorus concentrations along a drain can help in an evaluation of phosphorus sources, but the downstream sample location best describes the phosphorus contribution of that drain to the Snake River. Three Arena Valley drains discharge directly to the Snake River. The sample locations that were closest to the river were Allen Drain #1, Riverside Drain, and Stateline Drain.

Total phosphorus concentrations at these locations were 0.332 mg/L, 0.078 mg/L, and 0.110 mg/L, respectively. The mid-Snake River phosphorus TMDL is 0.070 mg/L. (See the following Web site for a discussion of the mid Snake River-Succor Creek TMDL: http://www.deq.state.id.us/water/data_reports/surface_water/tmdls/snake_river_succor_creek/snake_river_succor_creek.cfm).

Cattle were wintering on pastures adjacent to the Allen Drain, and elevated turbidity was observed in the sample collected from Allen Drain #1. The elevated phosphorus may have been caused by cattle having direct access to the drain. However, well 04N 06W 14BDB1, which is located approximately one quarter mile south of the Allen Drain #1 sample location, had a total phosphorus concentration of 0.336 mg/L, indicating that surface water phosphorus may be impacted by ground water discharge. Phosphorus is normally sorbed to soil particles and doesn't migrate to ground water. Indeed, Neely and Crockett (1998) noted that the median orthophosphorus concentration in the Treasure Valley shallow aquifer was 0.04 mg/L. The drillers log lists the depth to water at well 04N 06W 14BDB1 as 4 feet. This shallow depth to water combined with sandy soils in the area may contribute to phosphorus movement to ground water.

Wastewater Reuse Site

A wastewater reuse site is located in the eastern part of the Arena Valley (see Figure 2). This 408-acre site is used for slow rate treatment of wastewater generated at a food processing facility two miles to the east. The water is piped to the site and applied year round through three center pivot systems.

There are 15 dedicated monitoring wells up gradient and down gradient of the site. Wastewater was first applied to the site in December 1993. Prior to wastewater application, two rounds of samples were collected from seven monitoring wells. Nitrate-N concentrations in these samples ranged from 5.0 to 23.6 mg/L, indicating that ground water was impacted prior to application of wastewater.

Eight additional monitoring wells have been installed since 1993, and all wells have been sampled quarterly for nitrate and other parameters. Figure 7 shows nitrate sample results for six up gradient monitoring wells. The highest nitrate-N concentration was 64 mg/L at MW-3S in January 1998.

Nitrate-N concentrations peaked in the 1998 to 1999 time frame and have been decreasing since then. The wastewater reuse site is at the upper end of the Arena Valley ground water flow system, so there are no other up gradient nitrate sources. It is believed that excess nitrogen application from previous agricultural operations was stored in site soils, and this nitrogen load has either been taken up by crops raised on the site or has leached to ground water and is migrating offsite. Analysis of wastewater and soil samples indicate that nitrogen applied in the wastewater is approximately equal to that removed by crops grown on the site.

The nitrate in ground water beneath the site is migrating to the west at the prevailing ground water flow velocity. Brockway (2006) estimated the ground water flow velocity beneath the wastewater reuse site to be 1.47 feet per day. At this rate, it will take approximately 10 years for ground water at the wastewater reuse site to move to the East Arena Drain, a distance of approximately one mile.

A similar flow velocity is believed to exist for ground water in other parts of the valley. If nitrogen applications were reduced to crop uptake values throughout the valley, it would take many years for ground water nitrate concentrations in the upper part of the shallow aquifer to decline to ambient concentrations. The ambient shallow ground water nitrate concentration is believed to range from 1 to 2 mg/L.

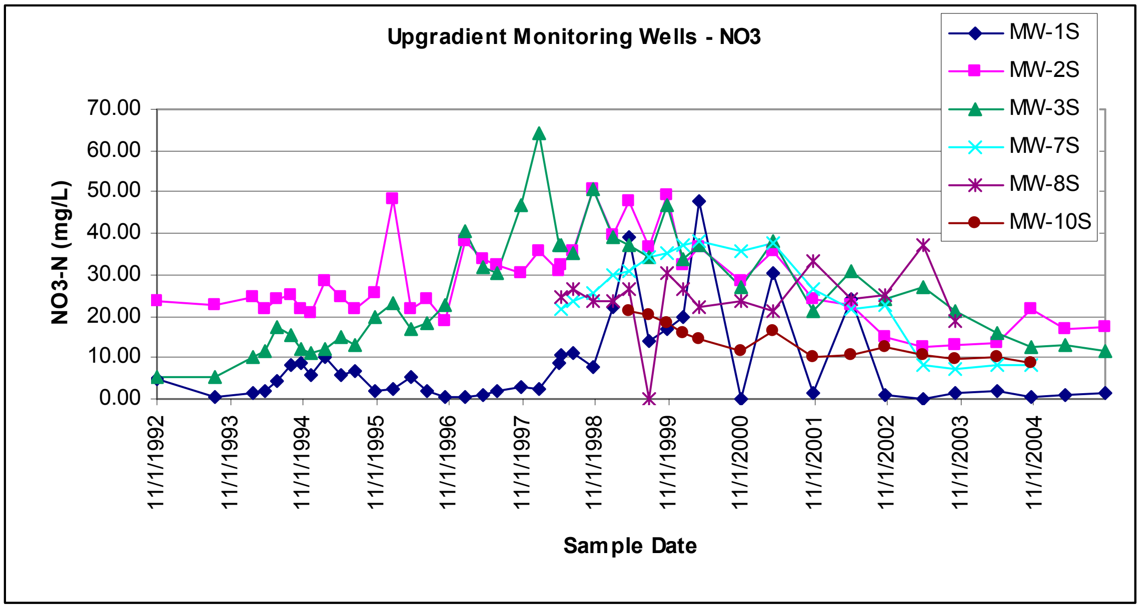

Figure 7. Nitrate concentrations in monitoring wells at a wastewater reuse site located in eastern Arena Valley. The wells are located on the up gradient side of the wastewater reuse site.

Nitrogen Isotopes

Isotopes of an element have the same number of protons but different numbers of neutrons. Because of the slight differences in mass, certain biological, physical and chemical processes preferentially use one isotope over the other. Nitrogen has two stable isotopes: nitrogen-14 (^{14}N) and nitrogen-15 (^{15}N). The ^{14}N isotope has an abundance of 99.63 percent and the ^{15}N isotope has an abundance of 0.37 percent. The ratio of the common to the rare isotope ($^{15}N/^{14}N$) compared to a standard is given in delta (δ) notation. Since variations in isotope concentrations between samples are usually quite small, results are expressed as parts per thousand or *permil* (‰).

Nitrogen isotopes have proven to be useful in distinguishing sources of nitrate contamination in ground water. Commercial fertilizer, which is produced from nitrogen gas in the atmosphere, has a $\delta^{15}N$ value of 0. Therefore, ground water contaminated with nitrogen from commercial fertilizer would have similar $\delta^{15}N$ values. Table 4 lists typical values of $\delta^{15}N$ for commercial fertilizer and other important nitrogen sources. Note that there can be considerable overlap of $\delta^{15}N$ values from the major nitrogen sources. Also, a mixture of water containing nitrogen from two or more sources often produces a blended or mixed result that is not indicative of any single nitrogen source.

Table 4. Typical δ15N values from various nitrogen sources (from Seiler, 1996).

Potential Contaminant Source	δ15N (‰)
Commercial fertilizer	-4 to +4
Animal or human waste	Greater than 10
Precipitation	-3
Organic nitrogen in soil	+4 to +9

Samples were collected for analysis of nitrogen isotopes from four wells and nine drains during December 2005. The results, listed in Table 5 and shown graphically in Figure 8, show that three sample locations, well 04N 06W 14DBD, and the Riverside and Stateline drains likely have either animal or human waste as nitrogen sources.

Table 5. Nitrogen isotope results for samples collected from wells and drains during December 2005.

Well location or drain sample	δ15N (per mil)
04N 06W 11DCA	6.65
04N 06W 13ABB	3.84
04N 06W 13BCD	5.40
04N 06W 14BDB	15.65
Arena Case Drain #1	6.78
Arena Case Drain #2	6.66
Arena Lake Drain #1	6.13
Arena Lake Drain #4	3.38
Allen Drain #1	7.18
Allen Drain #2	5.49
Allen Drain #3	7.21
Riverside Drain #1	12.54
Stateline Drain	12.00

All three samples were collected from locations in the southwestern part of the valley, where housing densities are light. There are corrals located a few tens of feet east of well 4N 06W 14BDB1, so an animal source is considered to be the likely contributor for nitrate at this well. As noted above, much of the land bordering the Allen and Stateline Drains is devoted to wintering beef cattle on pasture or dairy operations, so animal waste is considered the likely nitrogen source for ground water in this area.

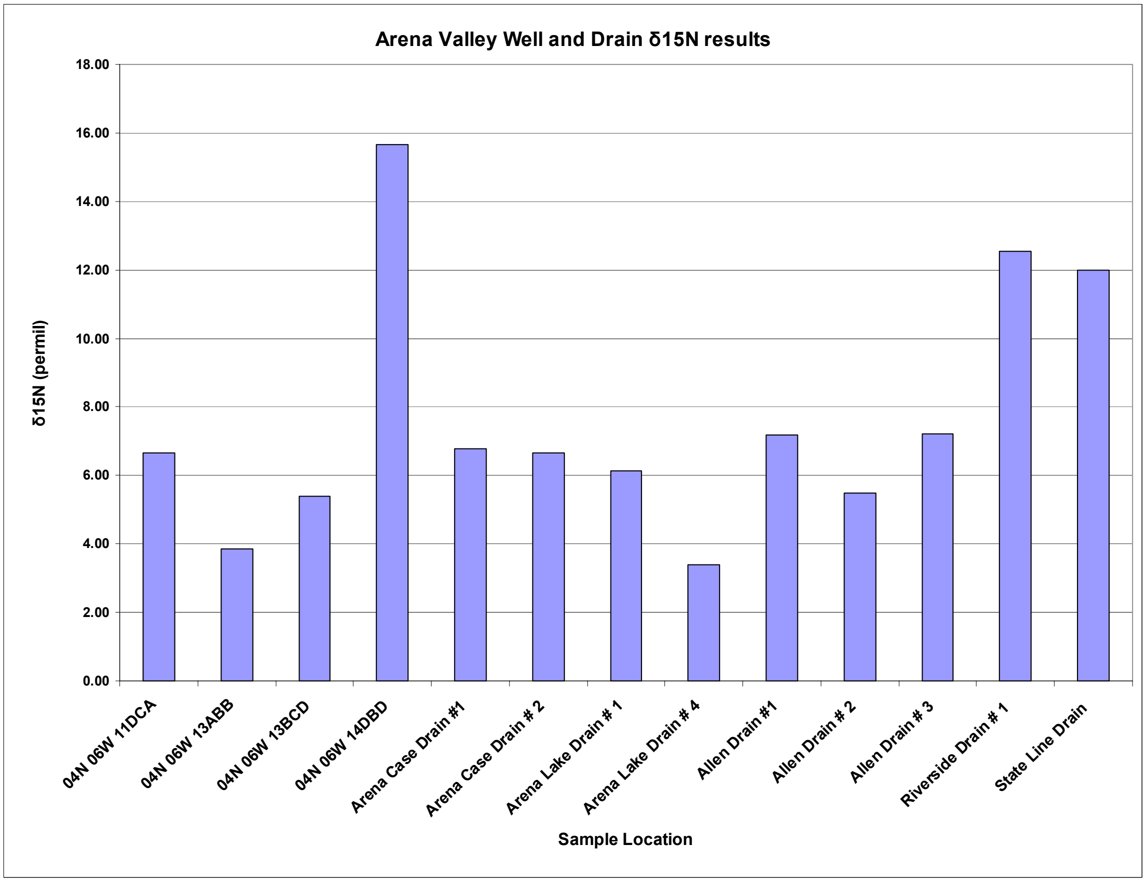

Figure 8. δ15N results from well and drain samples collected in the Arena Valley during December 2005.

The nitrogen source for well 4N 06W 13ABB and Arena Lake Drain #4 appears to be commercial fertilizer, based on the δ^{15}N values of 3.84 permil and 3.38 permil, respectively. The nitrogen source appears to change with down stream position along Arena Lake Drain, with isotope values increasing from 3.84 permil at sample location #4 to 6.13 permil at sample location #1. This increase may reflect nitrogen contribution from soil organic matter or from human or animal sources at down stream locations. Housing densities are light in the northern part of the valley, so nitrogen from human sources is not considered a likely pathway.

Isotope values for the remaining seven sample locations range from 5.40 to 7.21 permil. These values could represent nitrogen derived from the breakdown of soil organic matter or a mixture of nitrogen from more than one source.

Conclusions

Ground water and drain samples show that ground water in Arena Valley contains elevated nitrate. In some locations, nitrate concentrations exceed the Idaho nitrate GWS of 10 mg/L. Synoptic drain samples show that the north, central, and eastern parts of the valley are most heavily impacted. These impacts are most likely are from agricultural activities because elevated nitrate occurs over a widespread area. Nitrogen loading estimates prepared for a nitrogen budget of Canyon County also indicate that agricultural activities are a likely source of nitrates in ground water. The southwestern part of the valley has ground water nitrate concentrations in the range of two to three mg/L. The widespread elevated ground water and drain nitrate concentrations are believed to be the result of over application of nitrogen fertilizer and/or animal waste.

Nitrogen isotope results indicate that commercial fertilizer may be a nitrogen source for the eastern part of the valley and that animal or human sources may contribute nitrogen to ground water in the southwestern part of the valley. Contribution from human sources is expected to be small given the low housing densities throughout the valley.

Arsenic concentrations in well samples ranged from 0.00863 to 0.038 mg/L. The current Idaho arsenic GWS is 0.05 mg/L; the current EPA arsenic GWS is 0.01 mg/L. Arsenic in all wells was lower than the current Idaho arsenic GWS.

Phosphorus concentrations at the three drain discharge points nearest to the Snake River (Allen Drain #1, Riverside Drain and Stateline Drain) had concentrations of 0.332 mg/L, 0.078 mg/L and 0.110 mg/L respectively. All three phosphorus concentrations exceed the mid-Snake River-Succor Creek TMDL of 0.07 mg/L. A water sample from well 04N 06W 14BDB1 had a total phosphorus concentration of 0.336 mg/L, similar to the phosphorus concentration at the Allen Drain #1 sample location. At this well, the shallow depth to water and sandy soils may allow for the movement of phosphorus to the water table. Although none of the drain samples were collected at the confluence of the drain with the Snake River, little or no phosphorus attenuation is expected to occur between the sampling locations and the point where the drains discharge to the river. Therefore, phosphorus concentrations at the downstream sampling locations are considered to be representative of phosphorus contribution to the river.

Most aquifers in the state extend over large regional areas and have indistinct hydrologic boundaries. There often are multiple sources that contribute nitrate to ground water, and nitrate can enter and leave the aquifer at many points. The Arena Valley represents a unique hydrologic sub area with well defined lateral and vertical hydrologic boundaries. The shallow aquifer is isolated from up gradient sources and the valley has a relatively small surface area. Nitrogen sources within the valley are well identified and the relative contribution from the various sources is fairly well known. The shallow irrigation drains offer convenient monitoring locations for the shallow aquifer. If nutrient management plans are developed for more efficient nitrogen management, trends in water quality improvement can be tracked at drain sample locations.

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Index