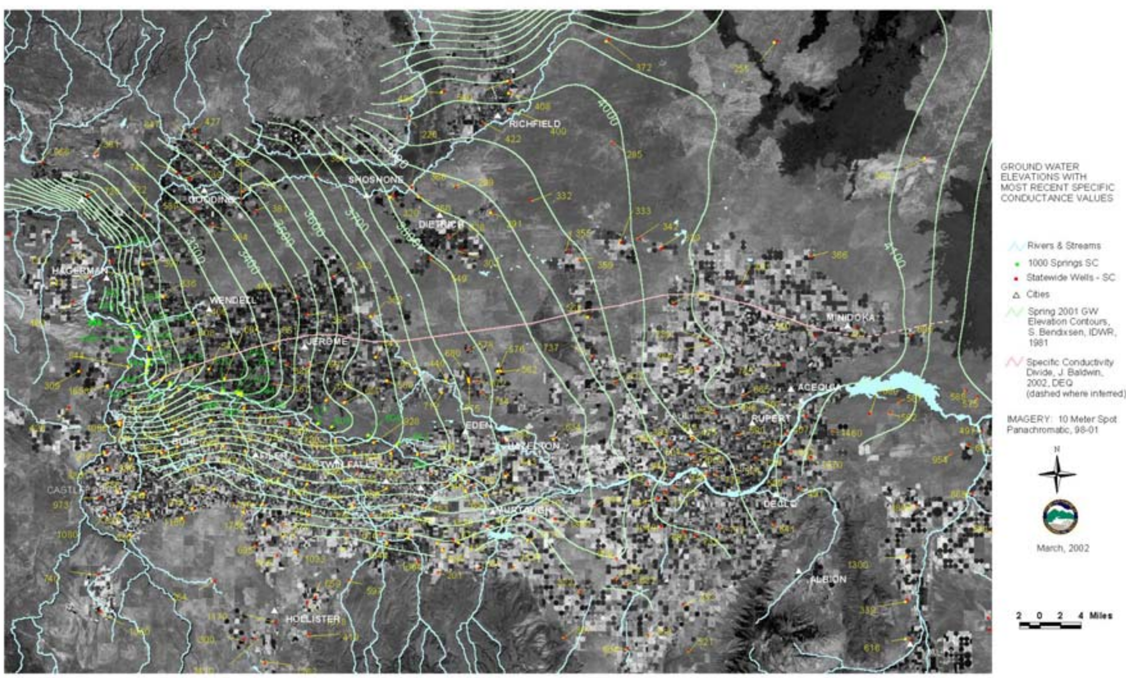
Ground Water Quality Technical Report No. 27

2005 Update, Thousand Springs Area of the Eastern Snake River Plain, Idaho



Idaho Department of Environmental Quality
State Office
December 2006

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2005 Update, Thousand Springs Area of the Eastern Snake River Plain, Idaho

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December 2006

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Acknowledgments

The authors wish to acknowledge the review comments provided by Dr. John Welhan, Department of Geosciences, Idaho State University. His comments helped to refine the data evaluation and conclusions of the report and are greatly appreciated.

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Cover photo: 1997 Landsat photo of western portion of East Snake River Plain showing potentiometric contours (green lines) and line delineating northern and southern portions of the aquifer (pink line).

Executive Summary

This study was undertaken to evaluate nitrate concentration trends in selected springs discharging from the eastern Snake River Plain aquifer. Springs discharging from the aquifer contribute large quantities of good quality water to the Snake River. The aquifer was designated a sole source aquifer by the U.S. Environmental Protection Agency in 1991. Springs discharging from the aquifer supply water for aquaculture, irrigation and drinking water needs, provide recreational opportunities and serve important ecological functions. Nitrate concentration trends in spring discharge had been evaluated for five springs over the period 1991 through 1999. The results, included in a 2000 DEQ study concluded that an increasing trend in nitrate concentrations existed. The purpose of this study is to re examine nitrate concentrations in the same springs, prepare a nitrogen loading budget for the study area and evaluate factors that contribute to water quality changes in the study area.

Numerous data sources were utilized to evaluate nitrate concentrations in springs over time and space and to evaluate the effects of hydrogeologic and land use factors on nitrate concentrations. These data sources included monitoring data from four springs used for aquaculture (the Snake River Farm, Box Canyon, Crystal Springs 1 and Crystal Springs 2 facilities operated by Clear Springs Foods) and one spring at the U.S. fish and Wildlife Service Hagerman National Fish Hatchery (NFH-15). Additional data sources included spring discharge and water chemistry information from U.S. Geological Survey files. Also, water chemistry data for selected springs along the reach of the Snake River from Twin Falls to the Malad River were available from a University of Idaho sampling program conducted in 2000. Acreage devoted to various crops as well as animal numbers for dairies and feedlots in the study area were available from the Idaho Agricultural Statistics Service. Information on irrigation diversions from the Snake River was available from the North Side Canal Company and data on nutrient management activities in the study area were available from the Idaho State Department of Agriculture.

Evaluation of water chemistry and ground water flow path data indicate that the aquifer can be divided into a local flow system in the southern part of the study area and a regional flow system in the northern part of the study area. The local flow system is characterized an average specific conductance value of 715 microsiemens per square centimeter (μS/cm), an average nitrate concentration of 4.27 milligrams per liter (mg/L) and ground water flow paths that originate in the Lake Walcott area and traverse distances of up to 60 miles to the west across the study area. The regional flow system is characterized by an average specific conductance value of 417 μS/cm and average nitrate concentrations of 1.29 milligrams per liter (mg/L). Ground water flow paths for this part of the aquifer originate in the Idaho Falls area and traverse flow paths as long as 170 miles to the southwest and west across the study area. The transition between the two flow systems occurs over a short distance, on the order of one half to one mile. There likely is no exchange of water between the two flow systems.

A nitrogen loading evaluation was conducted to describe the relative percentage of potential nitrogen loads in the study area. Estimates of commercial nitrogen fertilizer

applied to crops probably are the least reliable since records of fertilizer application are not available. Recommended nitrogen applications from the University of Idaho fertilizer guides for each crop and reported crop acreage were used to estimate nitrogen fertilizer application loads. Estimates of nitrogen in animal waste were derived from laboratory testing and book values for various classes of animals times the number of animals in each class. The evaluation indicated that approximately 47 percent of the estimated nitrogen load in the study area is from fertilizer applications, approximately 43 percent is from animal waste, 8 percent is from plow down of legumes (alfalfa, peas and beans) and the remaining two percent is distributed among domestic, urban, industrial and precipitation sources.

A statistical evaluation of nitrate trends was conducted for the five springs for the period 1994 through 2004. All springs have significant monthly and quarterly variations in nitrate concentrations, with concentrations at the lowest point during the first quarter of the growing season (April through June) and increasing to higher concentrations in September through March of the next year. In contrast to the 2000 study no clear concentrate ion trend was evident. Nitrate concentrations increased through 1998 and then decreased beginning in 1999, and springs in close proximity have statistically different nitrate concentrations. Land use, crop acreages, irrigation water supply and precipitation factors were evaluated. None of these factors could be linked to changes in nitrate concentrations. The period over which nitrate observations are available may be too short to determine whether concentrations are increasing or decreasing.

Introduction

In July 2000, the Department of Environmental Quality (DEQ) published a report that evaluated water quality in springs discharging from the Eastern Snake River Plain (ESRP) aquifer to the Snake River reach, from Clear Lakes Spring to Thousand Springs (Baldwin et al, 2000). These springs discharge large quantities of good quality water to the Snake River and are used as aquaculture, irrigation, and drinking water sources, as well as providing recreational opportunities. The springs represent discharge from the eastern Snake River Plain aquifer, one of the most prolific aquifers in the United States. In 1991 the aquifer was designated a *sole source aquifer* by the U.S. Environmental Protection Agency because it is the only source of drinking water for nearly 200,000 people in southeastern and south central Idaho.

The primary water quality constituent of concern for the 2000 evaluation was nitrate plus nitrite as nitrogen (hereafter referred to as *nitrate*). As part of the 2000 report, a statistical analysis of nitrate concentrations was conducted for five study area springs where long-term water quality data were available: Box Canyon, Crystal Springs #1 and #2, Clear Spring, and Niagara Spring. An upward trend in nitrate concentration was identified through linear regression analysis, using data from 1991 or 1994 through 1999. The evaluation indicated that, if the trends continued, nitrate concentrations could reach 5 mg/L by 2005 at Clear Springs and 5 mg/L at Crystal Springs #2 in 2006.

Based on these statistical predictions it was determined that an updated evaluation of recent spring nitrate data should be conducted that would include the following:

- Expansion of the study area after an evaluation of water chemistry data indicated the existence of a discrete ground water flow system, or local aquifer, separate from the regional ground water flow system.
- A review of land use changes
- A nitrogen budget for the current study area
- Evaluation of ground water levels for selected wells

Purpose and Objectives

The purpose of this study was to evaluate nitrogen water quality data from springs that discharge along the north side of the Snake River canyon, including Box Canyon, Crystal Springs #1 and #2, Snake River Farm and Niagara Spring. Water chemistry trends at these sites Objectives of the study included the following:

- Summarize irrigated acreage and confined animal feeding operations (CAFOs)
- Estimate nitrogen sources and loads
- Perform advanced statistical evaluations of nitrate trends for the five study area springs and of water level data from nine wells
- Evaluate specific conductance and nitrate data that differentiate between local and regional ground water flow systems in the study area.

- Use information from previous studies to provide a refined conceptual model of ground water flow systems in the study area.

Study Area

The study area lies north of the Snake River and includes the southern parts of Gooding, Lincoln, and Minidoka Counties, and all of Jerome County (Figure 1). The northern boundary is the 43 degree north latitude line; the eastern boundary is the eastern boundary of Minidoka County. The south and west boundaries are defined by the Snake River.

The study area was expanded from that for the 2000 report based on the following information:

- Modeling done for the 2000 study indicated ground water flow velocities near the river are large, on the range of 130 to 180 feet per day (9 to 12 miles per year). These large velocities and rapid travel times, confirmed through other ground water studies of the ESRP (Garabedian, 1992; Moreland, 1976) illustrate that ground water chemistry impacts can be transmitted over large distances in this part of the ESRP. Because of this, a large east-west dimension was used for the study area.
- Potentiometric maps and water chemistry data, to be presented, indicate that the aquifer within the study area can be divided into two systems – a regional ground water flow system that covers the northern part of the study area and a second, local flow system found within the southern part of the study area. The study area boundaries encompass all of the local ground water flow system and a portion of the regional flow system.

Climate

Climate is semi-arid, with an average annual precipitation of 10.2 inches, for the period 1950 through 2004, recorded at the Jerome weather station (Western Regional Climate Center, 2005). Annual precipitation for 1999 through 2004 has averaged 8.64 inches, a reflection of a regional drought pattern that has occurred across the area.

Two major irrigation canals, the Milner-Gooding and the North Side, divert water from the Snake River at Milner Dam and cross the study area from east to west. Both flood and sprinkler irrigation methods are used. Sprinkler irrigation predominates over flood irrigation, and conversion to sprinkler irrigation has continued to increase over the past several years. Declines in spring discharge have prompted a conversion from irrigation using ground water to irrigation using surface water sources.

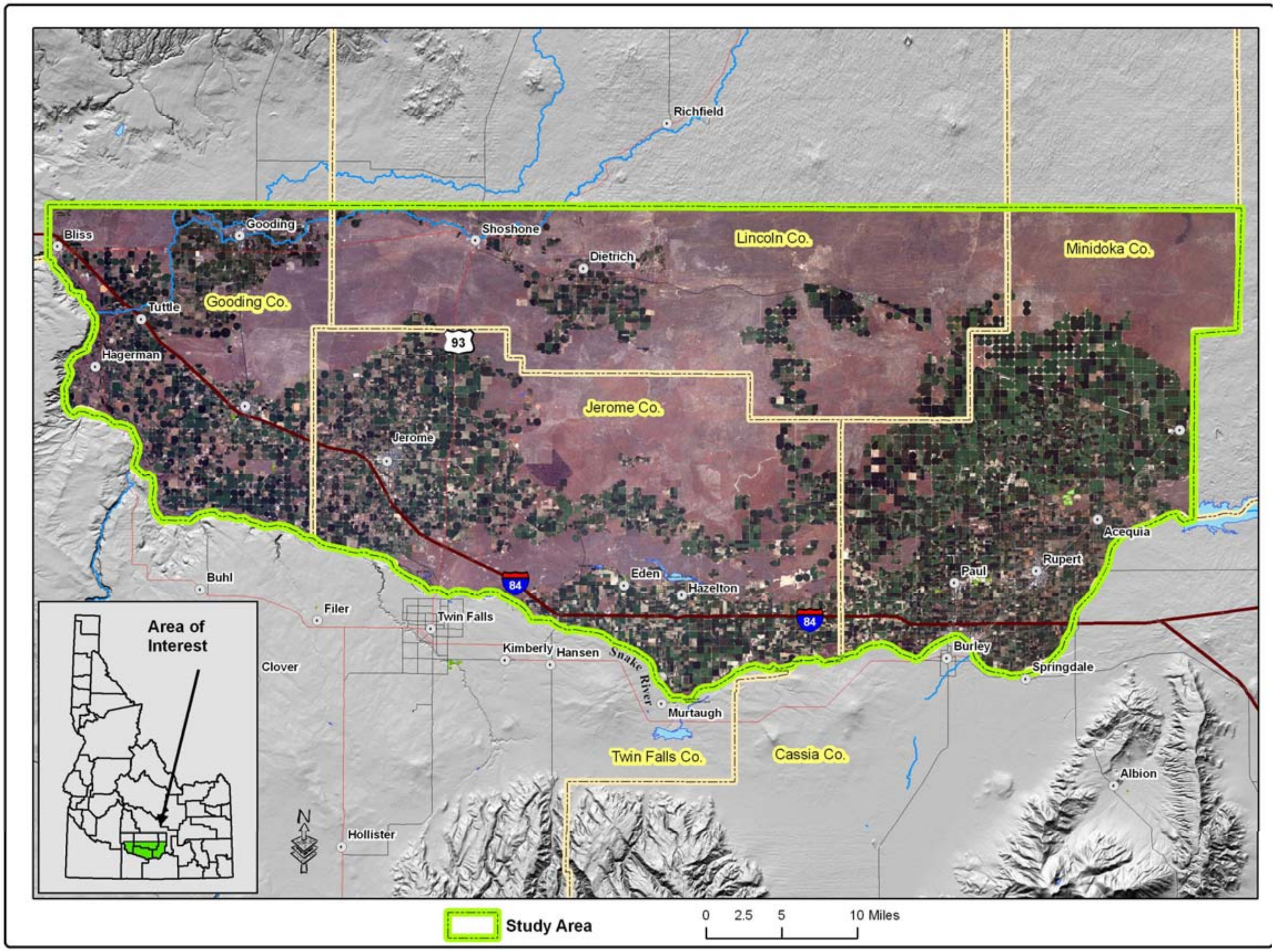


Figure 1. Study area, which includes all of Jerome County and the southern parts of Gooding, Lincoln and Minidoka counties.

Land Use

Land use is dominated by irrigated agriculture and livestock operations. These operations are subject to market forces that can create changes in the mix of various crop and livestock operations. These changes have the potential to impact ground water quality because of changes in crop nutrient requirements, fertilization practices, and the amount of animal waste generated and applied to the land

Land use changes have occurred and are occurring across the study area but not uniformly in space or time:

- From 1980 to 2004, acreage devoted to potato production *decreased* in Gooding, Jerome, and Lincoln counties, and *increased* in Minidoka County (Figure 2).
- Corn production increased in Gooding and Jerome Counties and remained constant in Lincoln and Minidoka Counties (Figure 3).
- Alfalfa production remained mostly constant for Gooding and Jerome Counties and increased for Lincoln and Minidoka counties (Figure 4).

A change in the crop mix could result in less nitrate contribution to ground water if the replacement crop requires less fertilizer than the pervious crop or vice versa. The year 2004 is the most recent year when data are available for the acreage of major crops grown in the study area.

Some operators in the study area are converting from potato to dairy operations. Nitrate contribution to ground water from an increased number of livestock operations may or may not increase if commercial fertilizer applications are reduced as animal waste applications increase.

Documenting the nitrogen load that enters the ground water system and changes in this load from various sources is beyond the scope of this project. Commercial fertilizer use in Idaho is not documented by location or by time, so variations in fertilizer applications also cannot be described.

Changes in Animal Numbers

Total animal numbers for all cattle and calves in Gooding and Jerome Counties have increased over the 25-year period from 1980 to January 2006 but have remained essentially constant in Lincoln and Minidoka Counties (Figure 5). The increase in total animal numbers in Gooding and Jerome Counties is mostly accounted for by an increase in milk cows (Figure 6). Since 1999, milk cow numbers have been more or less constant in Jerome County but have continued to increase in Gooding County. Total milk cow numbers in Gooding County were 139,000 head by January 1, 2006.

Most dairy facilities in Gooding County are located in the southern part of the county, south of I-84 (Figure 7), while most dairy facilities in Jerome County are located in the western part of the county on both sides of I-84.

Proposed new dairy facilities have the potential to double the number of milk cows in Minidoka County and increase by 25 percent the number of milk cows in Lincoln

County. There also will be a corresponding increase in replacement heifers if the proposed projects are developed.

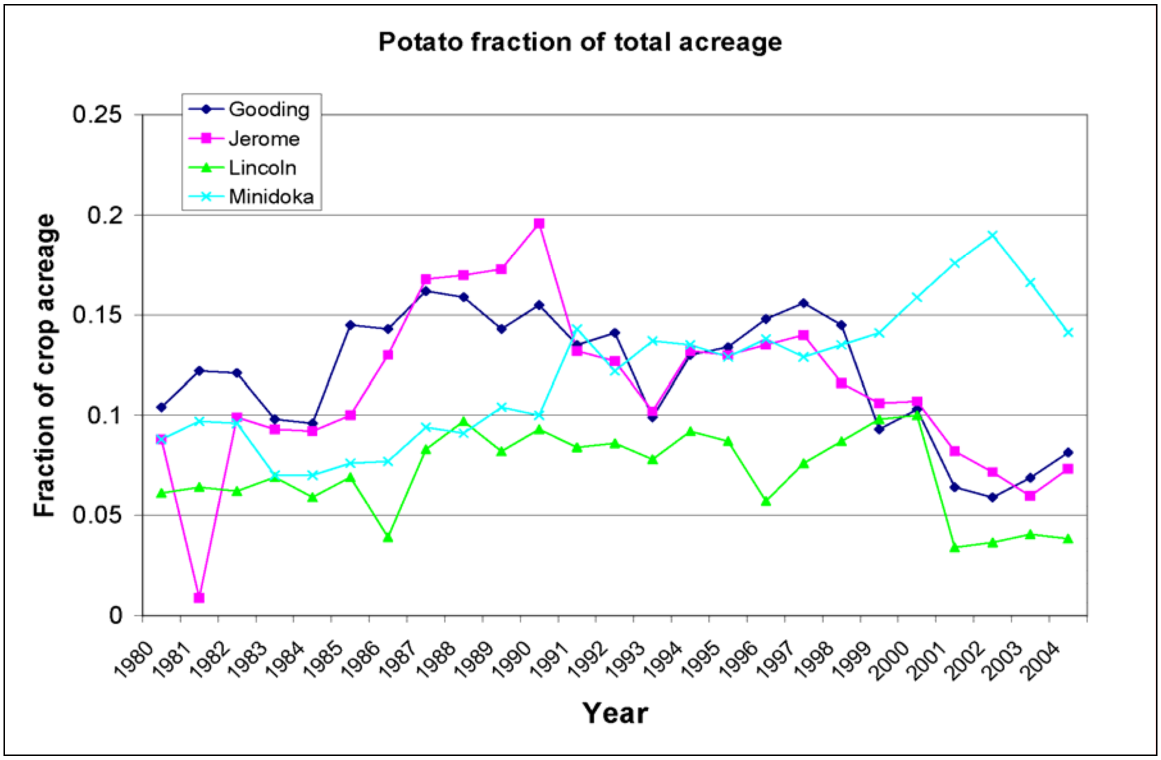


Figure 2. Potato fraction of total crop acreage for the four-county study area.

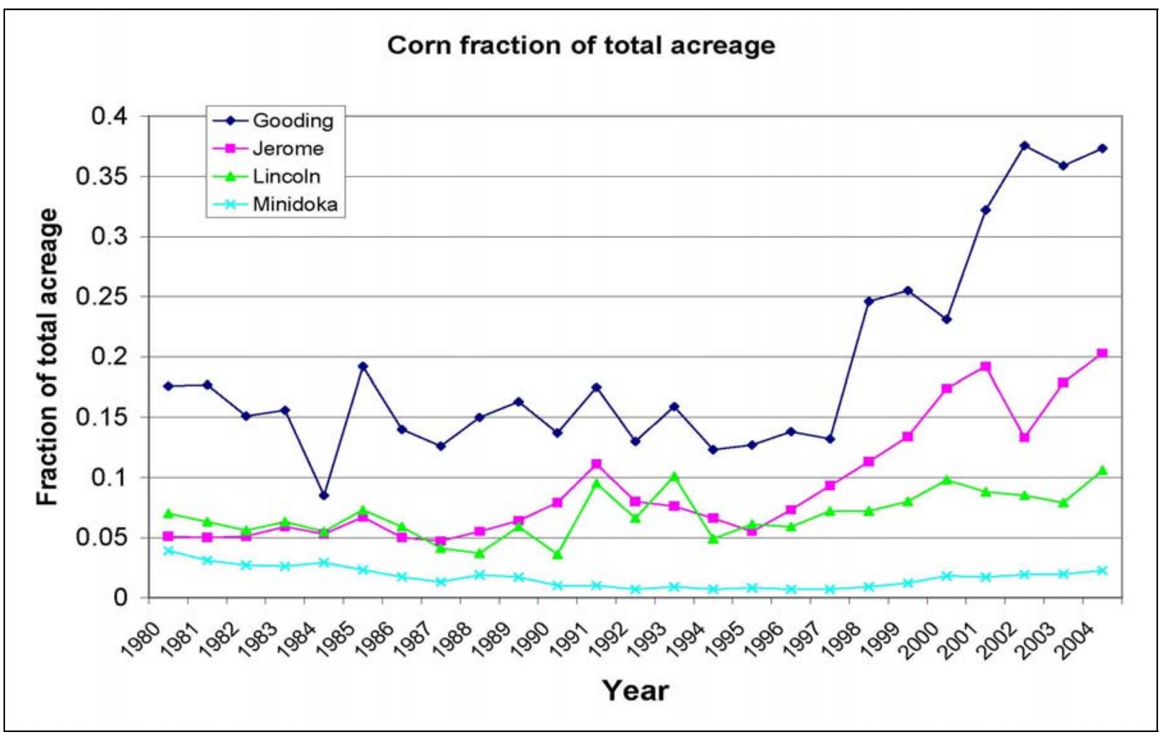


Figure 3. Corn fraction of total crop acreage for the four-county study area.

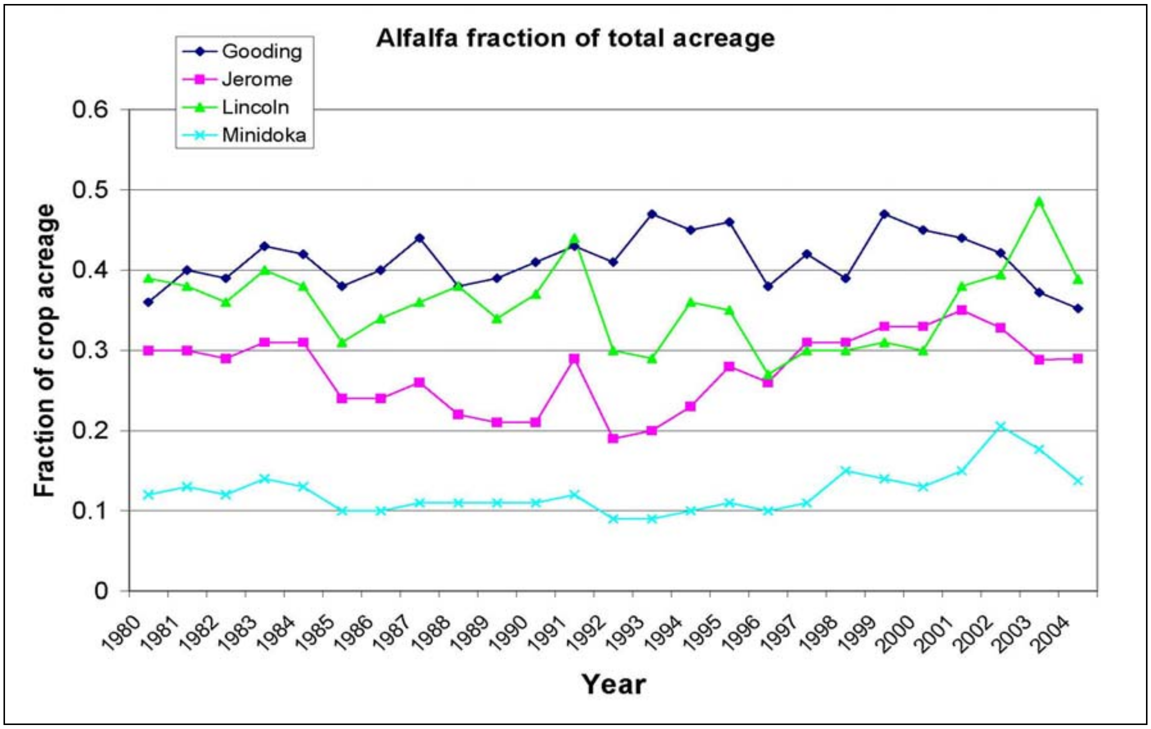


Figure 4. Alfalfa fraction of total crop acreage for the four-county study area.

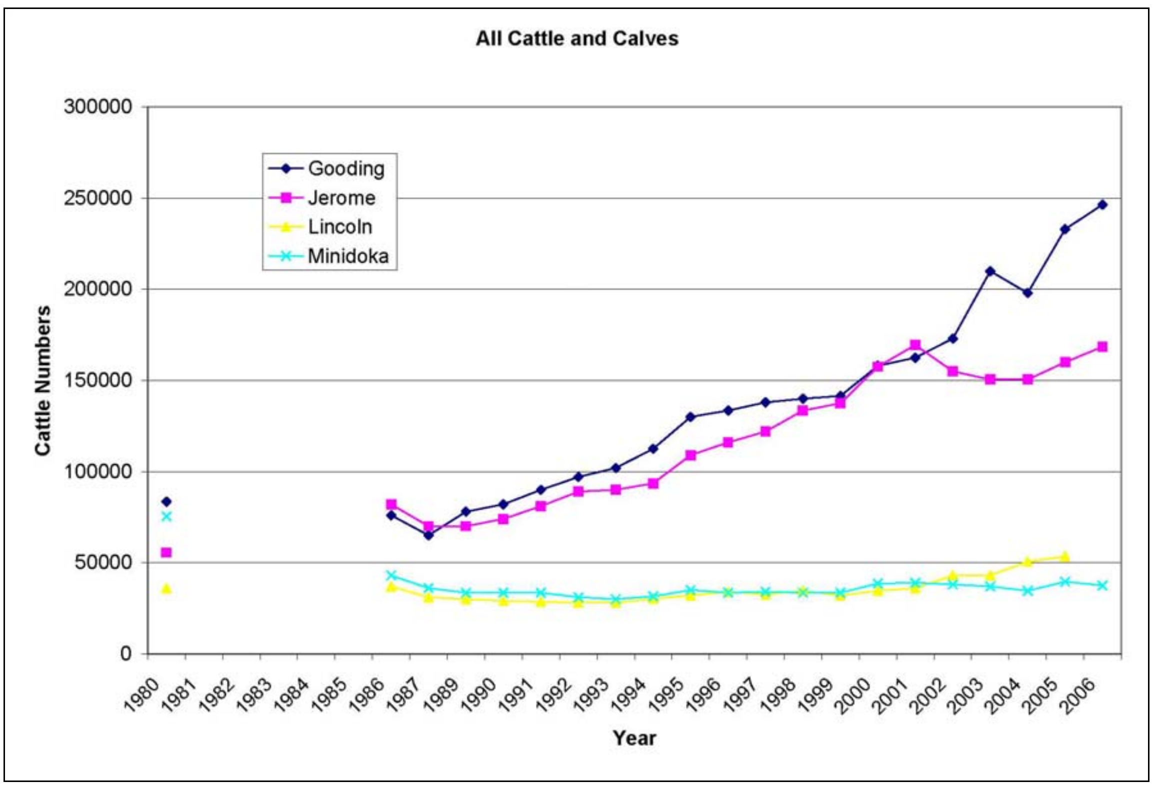


Figure 5. All cattle and calf numbers for the four-county area, 1980 through January 1, 2006.

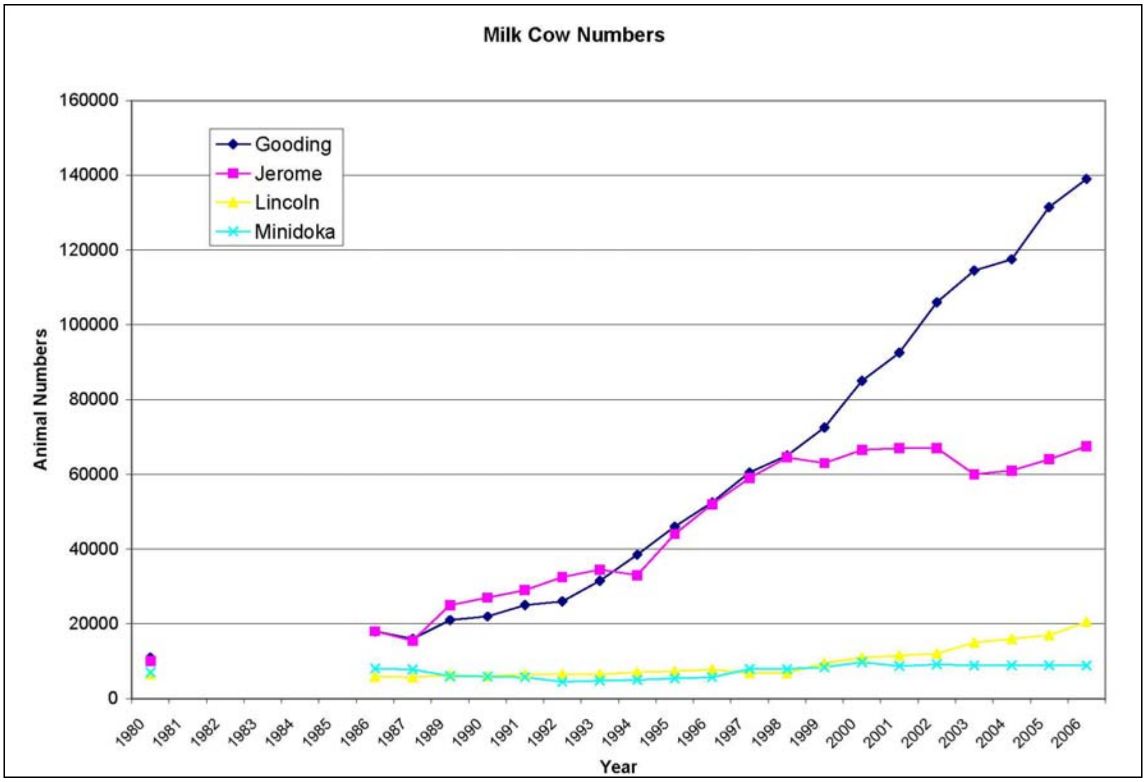


Figure 6. Milk cow numbers for the four-county area, 1980 through January 1, 2006.

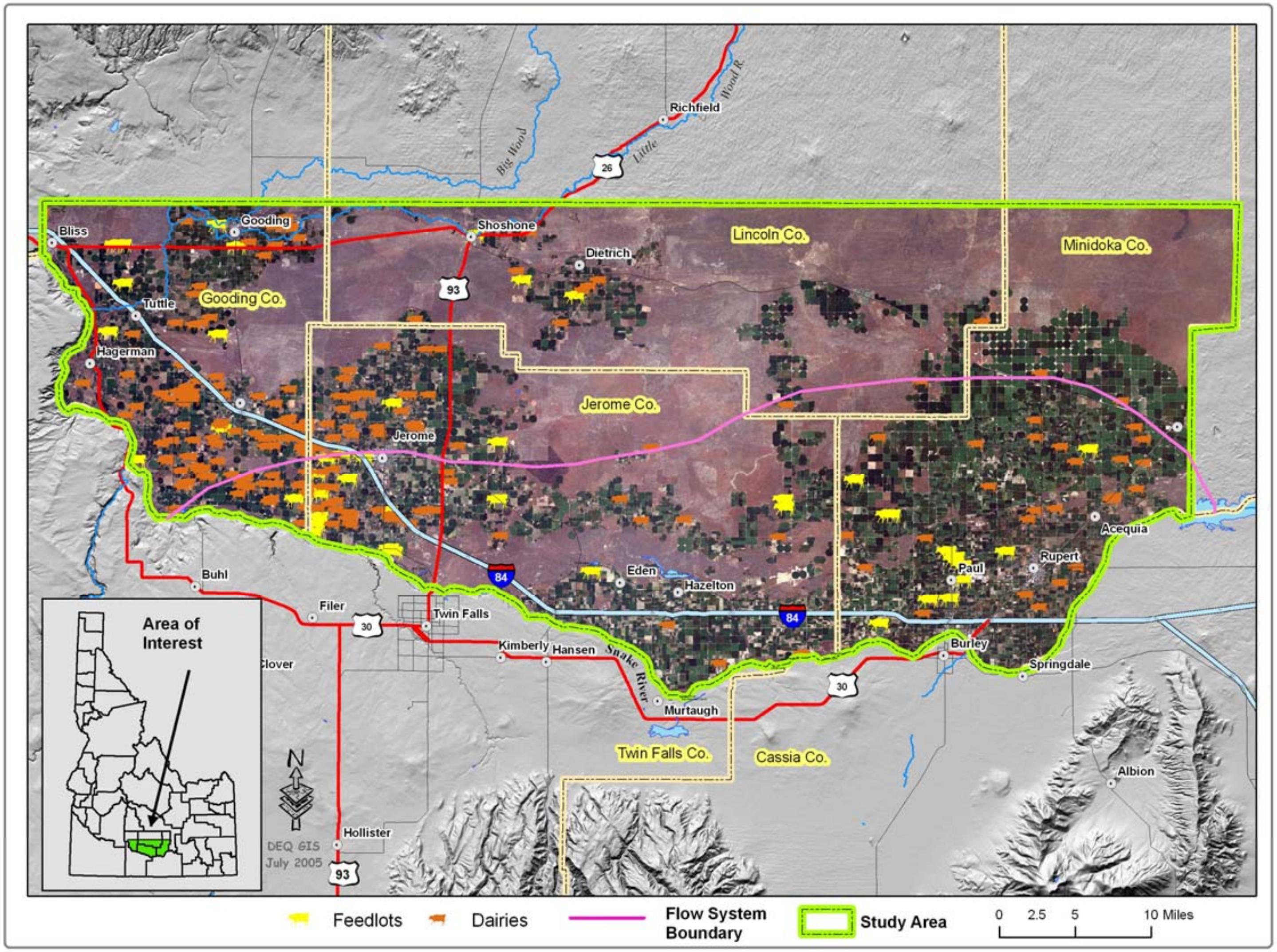


Figure 7. Dairy and feedlot locations in the four-county study area relative to ground water flow system boundary.

Water Supply

Spring discharge to the Snake River from the ESRP aquifer has declined significantly over the past 40 years and now is estimated to be about 5,200 cubic feet per second (Figure 8**)**. This decreased spring discharge is attributed to increased water use efficiency, conversion to sprinkler irrigation systems, a reduction in surface water diversions, conversion from surface water to ground water sources for irrigation water, and drought conditions. Discharge at Box Canyon Spring (USGS site 13095500) and Briggs Spring (USGS site 13095175) mirror these long-term trends (Figure 9).

Changes in Surface Water Diversions

Figure 10 illustrates the change in surface water diversions from the Snake River from 1990 through 2004 for the North Side Canal Company (NSCC) (Larry Pennington, NSCC, personal communication). The decreased diversions are the result of the prolonged drought in southern Idaho (reduced water supply for irrigation). Diversions for 2001 through 2004 were approximately 12 percent smaller than for 1990 through 2000. Ground water recharge projects have been proposed, and some are operational in an attempt to enhance water supplies to certain parts of the aquifer.

Implication of Water Supply Changes

These water supply changes have broad implications for ground water quality in the ESRP and springs discharging to the Snake River, with two competing interpretations possible. On the one hand, a smaller volume of water flowing through the aquifer system means less water is available to dilute contaminant loads entering the system. On the other hand, during years with a limited supply of irrigation water, irrigators may apply water more efficiently with the result that less water is available to move contaminants through the vadose zone to the aquifer.

In view of the trends identified in the 2000 report, showing an upward trend in nitrate concentrations, it was determined that periodic updates should be conducted to track impacts, review trend predictions, and provide additional information to land managers and county officials for land use decisions.

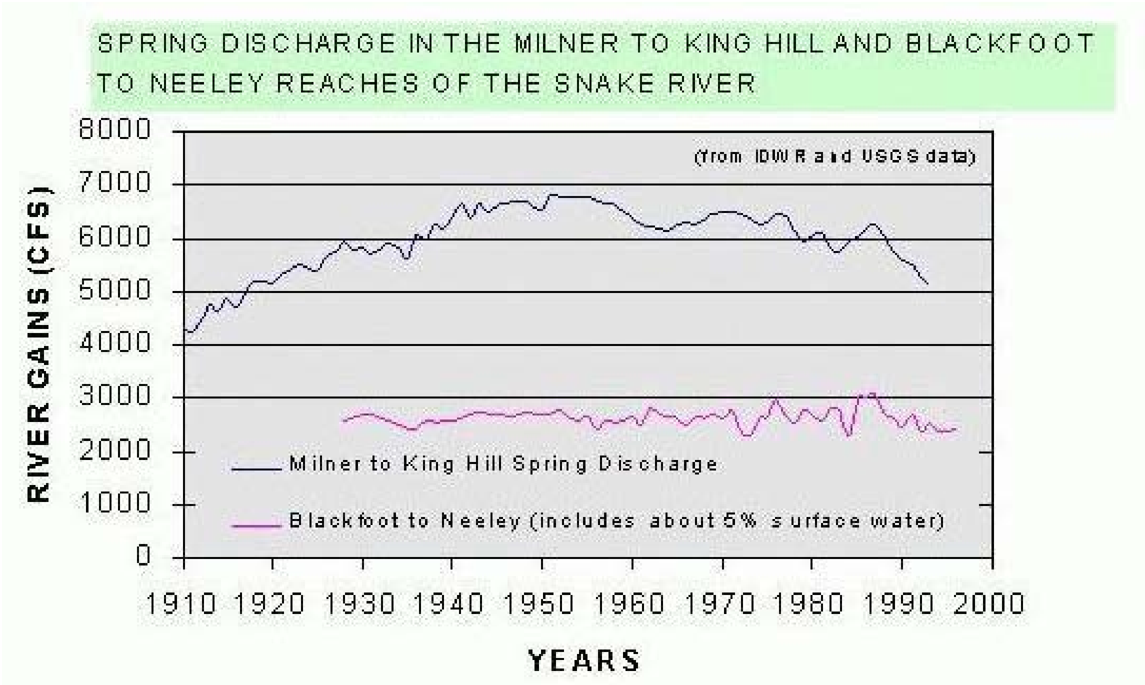


Figure 8. Long-term spring discharge in the Milner to King Hill and Blackfoot to Neeley reaches of the Snake River (IDWR and USGS data).

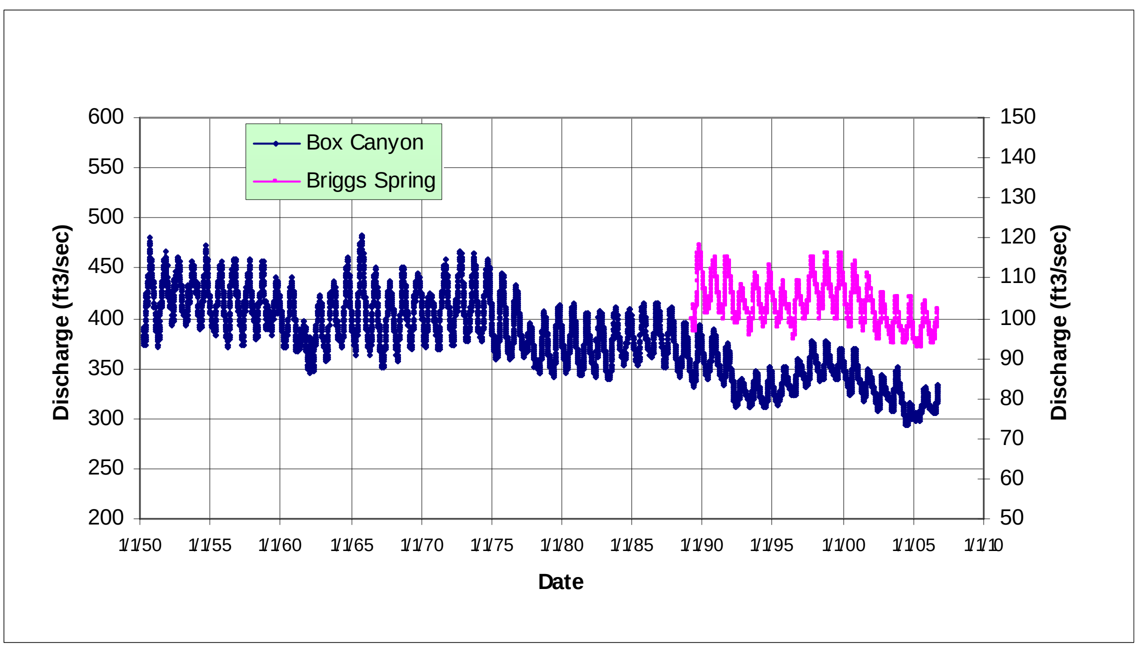


Figure 9. Long-term discharge at Box Canyon Spring (USGS site 13095500) and Briggs Spring (USGS site 13095175).

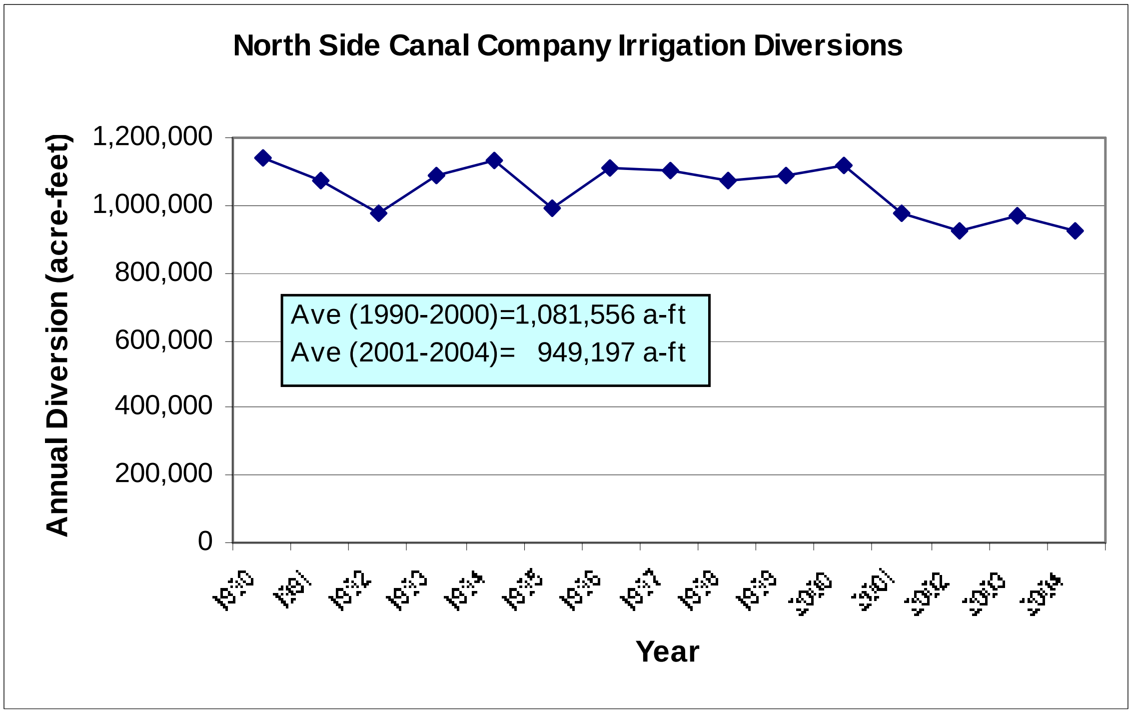


Figure 10. Annual irrigation surface water diversions, in acre feet, from the Snake River by the North Side Canal Company. Diversions for the period 2001 through 2004 are approximately 12 percent less than for the period 1990 through 2000.

Nitrate Background Information

Nitrate (NO_3) in ground water can come from a variety of sources, including decomposition of soil organic matter, commercial fertilizer application, application of animal waste, septic system and municipal wastewater effluent, industrial nitrogen sources, and nitrogen in precipitation. Due to its negative charge, the nitrate ion is not strongly attracted to soil particles and is, therefore, very mobile. It also is very soluble in water and moves quite readily with water that percolates through the soil horizon. Once nitrate has moved below the root zone, it is no longer available for plant uptake and it moves unimpeded through the vadose zone to the water table, its movement not retarded by either sorption or break down under aerobic conditions. The rate of movement of nitrate through the vadose zone is mainly controlled by the availability of water.

Organic nitrogen in plant matter, soil organic matter, and animal waste must be converted to the nitrate form through the process of mineralization. In the mineralized or inorganic form, nitrate is plant available. Organic nitrogen is mineralized to the plant available form over an extended period, with mineralization rates depending on the characteristics and source of the organic nitrogen, soil moisture, soil temperature, and soil biological activity.

Nitrogen mineralization from manure applications can occur over an extended period. For a one-time manure application, a typical mineralization series might be 0.5, 0.15, 0.1, 0.05 (50 percent of the organic nitrogen is mineralized the first year following the application, 15 percent is mineralized the second year, etc). For fields where continuous manure application is practiced, mineralization from previous years must be included, along with mineralization for the current year's application, in calculations of plant available nitrogen to get a correct indication of the available nitrogen.

Dairy Oversight

The proper operation of CAFO waste storage facilities and treatment of animal waste is an important factor in the management of nitrogen sources and protection of ground water quality. A significant change in the regulation of the Idaho dairy industry occurred in October 1995, with the development of the Idaho Dairy Pollution Prevention Initiative Memorandum of Understanding (MOU). Signatory parties to the MOU included the Idaho Department of Agriculture (IDA), DEQ, US Environmental Protection Agency (EPA) and the Idaho Dairymen's Association. The MOU was updated in August 2001 and is reviewed annually by the signatory parties. Prior to development of the MOU oversight and regulation of Idaho dairies was shared by several state and federal agencies.

Following adoption of the MOU, IDA implemented the following measures:

- Requirement for 180 days of liquid waste storage in engineered impoundments
- Cost-share programs, in cooperation with other state and federal agencies, to provide funding to facilities where upgrades are needed for waste handling facilities

- A Nutrient Management Standard, in cooperation with the Natural Resources Conservation Service (NRCS) and state agencies, and a requirement for Nutrient Management Plans to be developed by all Idaho dairies for land application of dairy waste on lands owned by the facilities
- A "regulatory soil phosphorous testing program" for dairy waste applied on facility-owned land, to assess compliance with Nutrient Management Plans
- Routine inspection of all dairies to ensure compliance with relevant state and federal regulations
- A ground water testing program for wells that supply water to dairies

These measures have resulted in improved oversight of dairies, waste storage facilities, and treatment of dairy waste. Over the period that the requirements were implemented, the total number of producers in the state decreased, to 736 in January 2005 from 1016 in September 1998, while dairy cow numbers have increased, from 276,695 to 384,829 (Marv Patton, personnel communication).

The regulatory soil phosphorus testing program only applies to land owned or controlled by the dairy. In many cases, the land owned by a dairy represents a small percentage of the total acreage required for application and treatment of animal waste, and soil testing is not conducted on this "third party" acreage.

Hydrogeology and Water Chemistry

The hydrogeology and water chemistry for the study area is discussed in the following sections.

Hydrogeology

The study area lies within the western part of the ESRP, a northeast-southwest trending structural feature tentatively identified as the track for the Yellowstone Hotspot. Rocks within the study area include Quaternary-age basalt of the Snake River Group and sedimentary units of Quaternary to recent age.

The total thickness of the basalt in the ESRP may be several thousand feet in the central part of the plain. Individual basalt flows average about 20 feet thick (Whitehead, 1986). Along the western side of the study area, the basalt thins and is interbedded with and underlain by deposits of clay, silt, sand, and gravel. On the east side of the study area, in northern Minidoka County, the basalt is up to 2,000 feet thick thinning to 300 to 400 feet thick in southern Minidoka County, where it is interbedded with and overlain by sedimentary units of sand, silt and clay. These sedimentary units represent lake deposits are known locally as the Burley Lake beds. The active part of the ground water flow system is believed to include the upper 200 to 400 feet of the saturated rocks. (Garabedian, 1992)

Figure 11 shows the extent of the ESRP aquifer, potentiometric contours on the water table, and ground water flow lines drawn perpendicular to potentiometric contours. Along the river, the potentiometric contours show areas where water moves from the river to the aquifer and areas where the river gains water from the aquifer. Ground water recharging the eastern portion of the aquifer in the Idaho Falls region follows long flow paths to the west-southwest and discharges to the Snake River in the reach from Thousand Springs/Box Canyon to Bliss. This part of the aquifer can be defined as a regional ground water flow system, where ground water flow paths are tens to hundreds of miles long and travel times are several tens to a few hundreds of years.

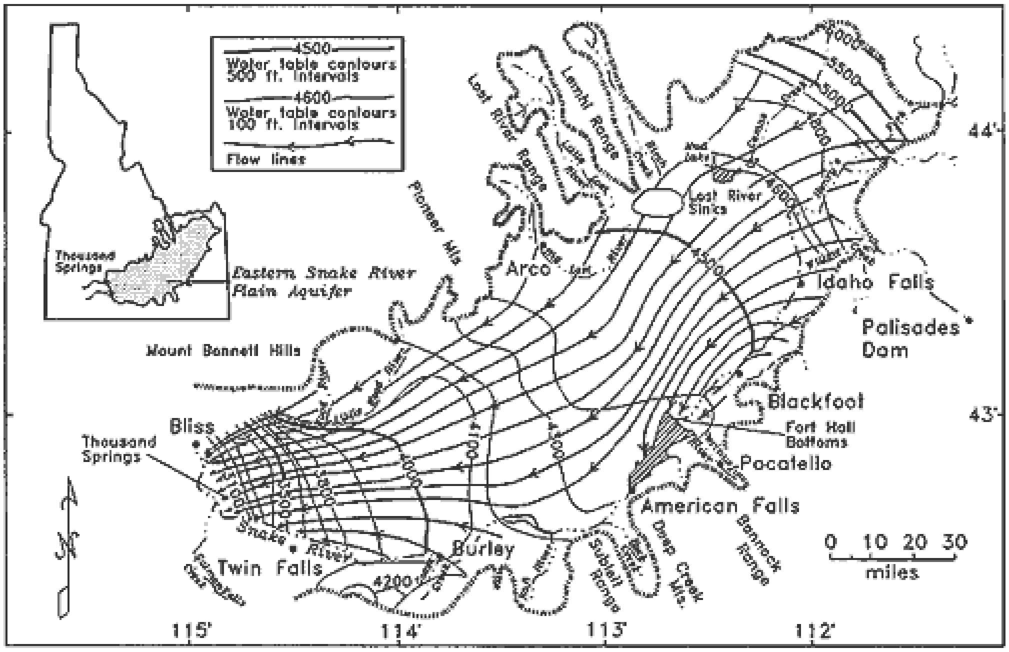


Figure 11. Generalized potentiometric map of the Eastern Snake River Plain aquifer (from Link and Phoenix, 1996).

Local Recharge and Discharge

A local ground water flow system exists within the study area. Near Burley, water that leaks from the Snake River supplies some water to the aquifer. This ground water follows flow paths to the west, where it discharges to springs in the river reach from Twin Falls to Banbury Springs. Some ground water may also move north from the Burley area under the river and enter the flow system on the north side of the river. Significant recharge to the local aquifer also occurs from leakage from irrigation canals and laterals and from deep percolation of irrigation water across the area of the local flow system.

A combination of hydraulic gradient (the slope on the water table), hydraulic conductivity (resistance to flow), and effective porosity controls the rate of ground water movement through an aquifer. In the study area, the hydraulic gradient averages about 0.0028 ft/ft (about 15 feet per mile); the gradient is steeper on the west (0.004 ft/ft or 21 ft/mile) and flatter along the eastern side of the study area (0.0008 ft/ft or 4 ft/mile). The hydraulic conductivity of an aquifer is a measure of the ability of the aquifer material to transmit water and depends on the size and arrangement of pores and fractures in the aquifer. Hydraulic conductivity and porosity values for that portion of the aquifer within the study area are available from Garabedian (1992).

Ground water flow velocities for the study area were estimated using values from Garabedian (1992) and the following equation:

$$v = (K\ i)/\ n_e$$

where: v = ground water flow velocity (ft/day)
K = hydraulic conductivity (ft/day)
i = hydraulic gradient (ft/ft)
n_e = effective porosity.

In southern Minidoka County, where the Snake River borders the aquifer, the hydraulic gradient is relatively flat, and the sedimentary units have a low hydraulic conductivity. This results in ground water flow velocities of less than one foot per day. In northern Minidoka and eastern Lincoln Counties the gradient is relatively flat, but hydraulic conductivity values are large, so the ground water flow velocity is estimated to be 100 feet per day. The steep gradient near the discharge area on the western side of the study area, combined with large hydraulic conductivity values, results in ground water flow velocities as high as 100 to 150 feet per day.

Knowledge of ground water flow velocities is useful in evaluating the potential for contaminants to impact water quality in an aquifer. If all other factors are equal, larger flow velocities result in larger volumes of ground water moving through an aquifer, so contaminants entering the aquifer are diluted. Ground water flow velocities are also useful in determining the time it takes for a particle of water (and any associated contaminant) to reach a capture zone around a pumping well or to travel through the aquifer to a discharge point.

Snake River Gains and Losses

Leakage of water from the Snake River into the aquifer is controlled by the hydraulic conductivity of the least conductive sediments adjacent to the river, which in this case are the lake sedimentary units. Perhaps more importantly, leakage of water from the river into the aquifer in southern Minidoka County is mostly controlled by the stage (height) of the river and duration of high runoff events.

A seepage study conducted along the Snake River (Hortness and Vidmar, August 2003) during 2001 and 2002 confirmed these discharge and recharge relationships. Discharge measurements were conducted four times during the spring and fall of 2001 and 2002, along the river from the Henrys Fork near Ashton to the Snake River at King Hill. A summary of the gain/loss results for river reaches within the study area is listed in Table 1 and shown graphically in Figure 12. These river reaches include the Snake River at Neely to Snake River at Lake Walcott near Minidoka, Snake River at Lake Walcott near Minidoka to Snake River above Crystal Spring, Snake River above Crystal Spring to Snake River above Banbury Spring, and Snake River above Banbury Spring to Snake River below Lower Salmon Falls.

Table 1. Summary of seepage study results for selected reaches of the mid Snake River (from Hortness and Vidmar, 2003).

Snake River reach	Gain (Loss) in cubic feet per second over the specified reach			
	April 2001	November 2001	April 2002	November 2002
Below American Falls Dam to below Lake Walcott	(121)	114	(1085)	125
Below Lake Walcott to above Crystal Springs	883	875	583	354
Above Crystal Springs to above Banbury Springs	1287	1106	1324	1189
Above Banbury Springs to below Lower Salmon Falls	2493	2803	2350	2488

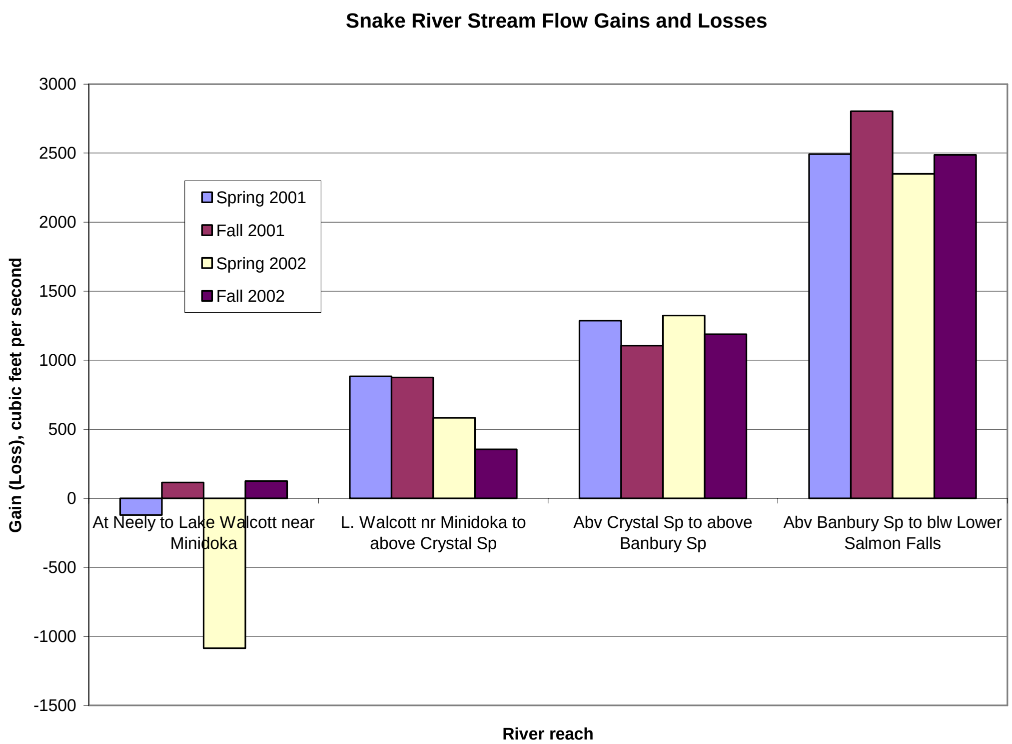


Figure 12. Snake River stream flow gains and losses from Neely to below Lower Salmon Falls (data summarized from Hortness and Vidmar, August 15, 2003).

A complex gain/loss relationship exists in the reach extending from American Falls Dam to below Lake Walcott that is dependent on river stage relative to water levels in the aquifer:

- The river lost water to ground water during the spring of 2001 and 2002 measurement periods and gained small amounts from ground water during the fall 2001 and 2002 measurement periods.
- For the river reach from Lake Walcott to above Crystal Springs, river gains were smaller during the spring and fall of 2002 than for the spring and fall of 2001, possibly due to drought conditions.

- The river reaches from above Crystal Springs to above Banbury Springs and above Banbury Springs to below Lower Salmon Falls had a more consistent discharge relationship for all four measurement periods.

Water Chemistry

Previous researchers have noted differing water chemistry and isotopic characteristics in springs discharging to the river along the reach from Twin Falls to the Malad River (Mann and Low, 1994 Clark and Ott, 1996; Plummer, et al, 2000). Springs discharging to the river from Banbury Spring upstream to Twin Falls (hereafter *upstream springs*) had tritium concentrations indicative of recent (post-1952) water from a local aquifer system. Low tritium concentrations in springs discharging to the river along the reach from Banbury Spring to the Malad River (hereafter *downstream springs*) indicate that most of this ground water has been in the aquifer for a long time and is from the regional flow system.

Nitrates

Upstream springs also have larger nitrate and total dissolved solids concentration compared to downstream springs. The source of water for the upstream springs is leakage from irrigation canals, deep percolation of irrigation water or leakage from the Snake River into the aquifer in the losing reach in the Lake Walcott area.

To assess background water chemistry conditions in the up-gradient part of the local aquifer, the two principal sources of recharge, Snake River water and ambient ground water near the river, were evaluated. Mean nitrate concentrations in the Snake River near Minidoka (USGS gage site 13081500) were 0.223 mg/L for the period 1973 through 2003 (n=88). The mean specific conductance value of the river water was 449 microSiemens per centimeter (µS/cm - formerly, units of measurement were micromho/cm at 25 degrees Celsius) at the same gage for the same period (n=222).

Ground water nitrate concentrations in the up-gradient (eastern) part of the local aquifer, on the north side of the river, are available from wells in the Idaho statewide ground water monitoring well network. There are thirteen statewide monitoring wells in the area, providing a total of 48 analyses for nitrate and specific conductance. These wells are shown in Figure 13**,** and the nitrate and specific conductance data are shown in Table 2.

The mean nitrate concentration for the 48 analyses was 6.95 mg/L, and the median nitrate value was 0.66 mg/L. The large difference between the mean and median values indicates that the data set is dominated by a few high values, which, in this case, occurred at well 10S 23E 09CBCB1. (The well numbering system used in this report is described in Appendix A.) With well 10S 23E 09CBCB1 removed from the data set, the mean nitrate concentration for the 12 wells was 1.90 mg/L, and the median nitrate value was 0.46 mg/L (n=44). These data indicate that, with the exception of one well, ground water nitrate concentrations on the north side of the river were low but were slightly larger compared to nitrate in river water.

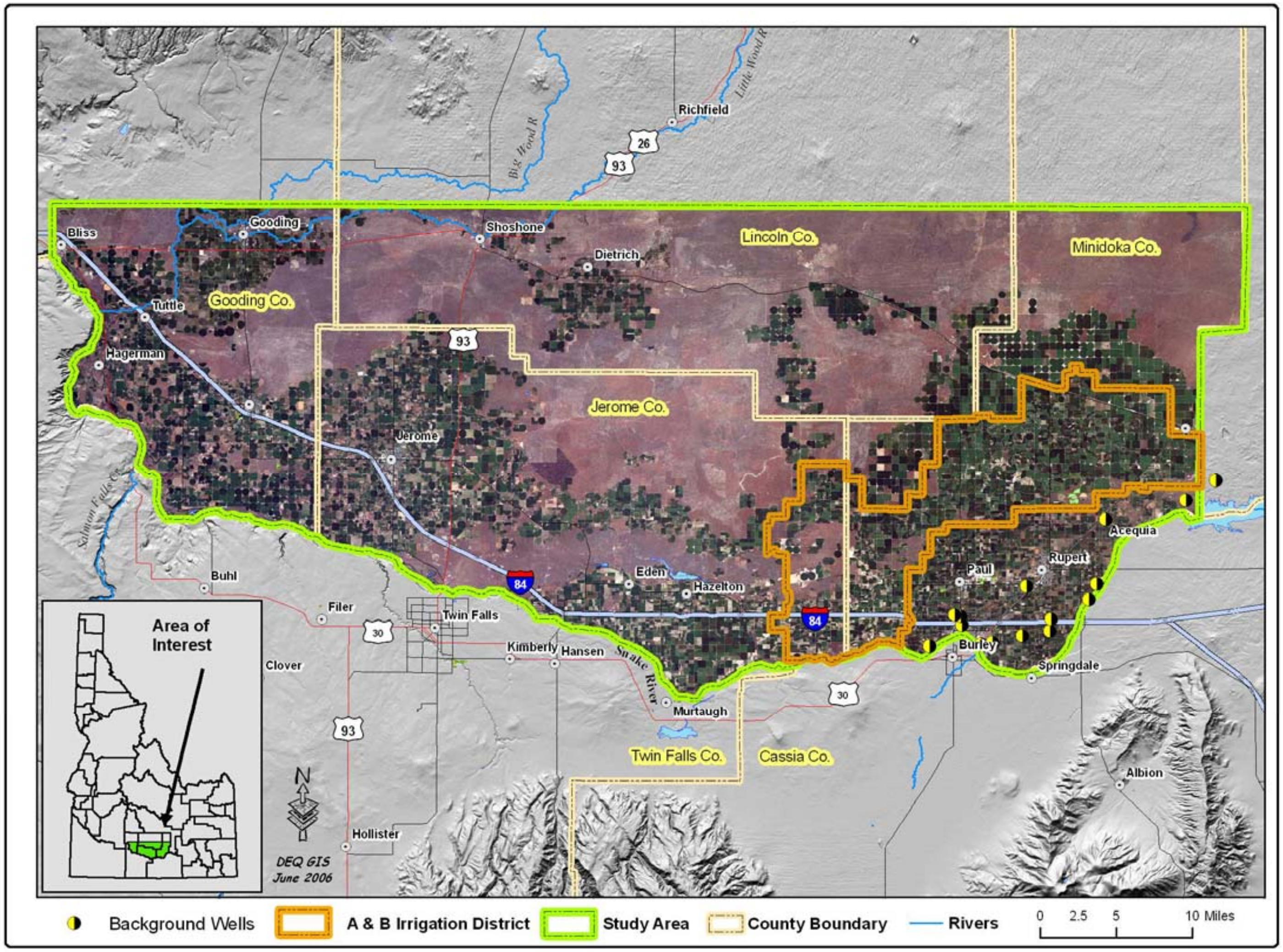


Figure 13. Location of A&B Irrigation District, eastern Jerome and southern Minidoka Counties and 13 statewide monitoring wells.

Table 2. **Nitrate concentrations and specific conductance values for statewide monitoring wells located adjacent to the north side of the Snake River from Lake Walcott to Heyburn (data from Idaho Department of Water Resources).**

Site ID Number	Latitude	Longitude	Township Range Section	Well Depth (feet)	Sample Date	NO3-N (mg/L)	Specific Conductance (uS/cm)
423248113492401	42.546667	-113.823333	10S 22E 24BAA1	61	8/24/1993	7	853
423248113492401	42.546667	-113.823333	10S 22E 24BAA1	61	9/3/1997	8.47	943
423248113492401	42.546667	-113.823333	10S 22E 24BAA1	61	8/13/2001	19.5	1370
423254113452601	42.548333	-113.757222	10S 23E 15CDC1	80	9/4/1991	3.9	910
423254113452601	42.548333	-113.757222	10S 23E 15CDC1	80	8/29/1995	2.5	1003
423254113452601	42.548333	-113.757222	10S 23E 15CDC1	80	8/16/1999	0.894	939
423254113452601	42.548333	-113.757222	10S 23E 15CDC1	80	7/22/2004	2.16	937
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/30/1994	**0.05**	853
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/29/1995	0.45	868
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	7/16/1996	0.7	850
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	9/3/1997	0.422	820
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/12/1998	0.885	828
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	9/7/1999	0.84	776
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/17/2000	0.943	807
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/13/2001	0.982	793
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	10/2/2002	0.89	773
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	7/18/2003	1.32	779
423300113443301	42.550000	-113.742500	10S 23E 14CCB1	57	8/25/2004	2.14	811
423322113421401	42.556111	-113.703889	10S 24E 18BCD1	29	8/30/1994	**0.05**	554
423338113400301	42.560667	-113.667667	10S 24E 17AAA1	83	10/7/2002	0.46	670
423359113465401	42.566389	-113.781667	10S 23E 09CBCB1	32	10/24/1991	4.4	1312
423359113465401	42.566389	-113.781667	10S 23E 09CBCB1	32	8/8/1995	78	1755
423359113465401	42.566389	-113.781667	10S 23E 09CBCB1	32	9/2/1999	100	2000
423359113465401	42.566389	-113.781667	10S 23E 09CBCB1	32	8/25/2004	67.9	1720
423419113395901	42.571944	-113.666389	10S 24E 09BCB1	20	8/17/1990	19	820
423431113470201	42.575278	-113.783611	10S 23E 08AAA1	122	8/24/1993	**0.05**	441
423431113470201	42.575278	-113.783611	10S 23E 08AAA1	122	9/3/1997	0.055	434
423431113470201	42.575278	-113.783611	10S 23E 08AAA1	122	10/2/2002	**0.06**	440
423435113472701	42.576389	-113.790833	10S 23E 05DCC1	330	9/4/1991	**0.05**	500
423435113472701	42.576389	-113.790833	10S 23E 05DCC1	330	8/3/1995	**0.05**	525
423435113472701	42.576389	-113.790833	10S 23E 05DCC1	330	8/30/1999	**0.05**	521
423435113472701	42.576389	-113.790833	10S 23E 05DCC1	330	8/25/2004	1.66	517
423526113704001	42.590556	-113.617778	10S 24E 02BAA1	110	9/3/1992	0.98	727
423526113704001	42.590556	-113.617778	10S 24E 02BAA1	110	7/16/1996	0.78	727
423526113704001	42.590556	-113.617778	10S 24E 02BAA1	110	8/15/2000	0.614	716
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	8/25/1992	**0.05**	577
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	7/16/1996	0.05	585
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	7/17/1997	**0.05**	590
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	8/20/1998	**0.05**	589
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	8/30/1999	**0.05**	590
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	8/15/2000	**0.05**	596
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	7/30/2001	**0.043**	602
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	9/26/2002	**0.03**	610
423613113415301	42.603611	-113.698056	09S 24E 31BAA1	110	7/7/2003	**0.06**	619
423620113362701	42.605556	-113.607500	09S 24E 25CCC1	30	7/27/1994	**0.05**	504
423620113362701	42.605556	-113.607500	09S 24E 25CCC1	30	8/12/1998	0.105	407
423620113362701	42.605556	-113.607500	09S 24E 25CCC1	30	7/7/2003	0.149	520
424002113354301	42.667000	-113.595333	09S 24E 01DBD1	172	10/1/2002	4.87	637

Values in **gray** are the laboratory detection limit, the actual concentration was below this detection limit.

Specific Conductance

Specific conductance values for the same 13 wells used for nitrate analysis are also shown in Table 2. The mean and median specific conductance values at these wells were 786 and 727 μS/cm, respectively. With well 10S 23E 09CBCB1 removed from the data set, the mean and median specific conductance values were 703 and 693 μS/cm. The data indicate that water chemistry at well 10S 23E 09CBCB1 is anomalous compared to the other wells. For the rest of the data, the specific conductance of ground water adjacent to the river had increased by about 40 percent compared to water in the river. This increase represents an additional mass of dissolved constituents that have been added to ground water between the river and the wells. Possible sources of this additional mass are discussed below.

Water chemistry data from wells located in the A&B Irrigation District Figure 13 provide information on nitrate concentrations farther down-gradient in the local flow system. Upward trends in nitrate concentrations have been documented within the district boundaries over the period 1980 through 1995 (Mitchell, 1998). Over a 10 year period, concentrations trended upward approximately 0.2 mg/L per year; some monitoring locations in the district had nitrate concentrations as high as 8 mg/L. Mitchell (1998) also indicated that nitrate concentrations increased from east to west across the district.

External drainage from the district is poor in many areas, so injection wells have been used to remove tail water and/or excess spring runoff from low-lying areas. It had been proposed that elevated nitrate in injection well water was responsible for the observed nitrate trends. However, Mitchell (1998) determined, through a graphical and statistical analysis of the data, that the most likely source of elevated nitrate in ground water was deep percolation of nitrogen applied to fields within the district.

The above evidence indicates that water recharging the aquifer contains approximately 0.2 mg/L of nitrate. Within a short distance down-gradient of the river, nitrate concentrations have increased to approximately 2.0 mg/L. At a distance of approximately 10 miles down-gradient of the river, within the A&B Irrigation District, nitrate concentrations are in the range of 4 to 5 mg/L. Ground water nitrate concentrations remain at this level across the study area, as evidenced by a mean nitrate concentration of 4.27 mg/L from 228 samples collected from wells in the local aquifer. There probably is continued input from various nitrogen sources but this additional nitrate is diluted by good quality water leaking from irrigation canals and laterals.

Regional and Local Flow System Evaluation

Taken together, the hydrogeology and water chemistry data confirm the existence of two ground water flow systems in the study area with differing chemical and flow characteristics that are the results of land use and recharge conditions. These flow systems will be referred to as the *local aquifer* and the *regional aquifer*.

To delineate the local and regional aquifers, specific conductance and nitrate data from wells within the study area were evaluated. These data were collected by various agencies over several years.

In the following, a summary of the utility of specific conductance data in evaluating ground water flow systems is presented, along with specific conductance and nitrate data sets. Isotopes of oxygen (^{18}O) and deuterium (^{2}H) collected during late 2003 and early 2004, from two springs in the study area, were also analyzed to provide additional information on the two ground water flow systems.

Ground Water Chemistry Evaluation Using Specific Conductance

Field specific conductance measurements were used to describe water chemistry conditions and flow systems in the study area. Specific conductance is a measure of the ability of water to conduct an electrical current (Hem, 1985), expressed in (μS/cm) at 25 degrees Celsius. Pure water has a specific conductance on the order of a few hundredths of a μS/cm, but water of this quality is not found under natural conditions.

As it moves through soil and aquifer materials, water dissolves minerals from the soil and aquifer framework, depending on the solubility of the material. Specific conductance is related to the type and concentration of ions in solution and can be used to estimate the dissolved-solids content of the water. Ions in solution that contribute to electrical conductivity include chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium and iron.

Specific conductance measurements are routinely made in the field using hand held instruments and provide a real time measure of water chemistry at a sampling location. Two specific conductance data sets were used to evaluate area wide ground water chemistry in the study area.

University of Idaho Specific Conductance Data Set

As part of a 2000 University of Idaho ground water study funded by DEQ, field measurements of specific conductance were collected from springs discharging from the north canyon wall of the Snake River, from Twin Falls to the Malad River (Johnson and Struhs, 2000). Data were collected from 40 springs during August 2000; a second round of sample collection at 25 of the 40 springs was conducted in October 2000.

Table 3 lists specific conductance values and spring locations (latitude and longitude coordinates), and Figure 14 shows a plot of specific conductance versus river mile. Springs from river mile 618 (Devils Washbowl) through 591 (Briggs Spring) had specific conductance values in the range of 500 to 700 μS/cm. Springs discharging downstream of Briggs Spring (below river mile 591) to Malad Gorge Spring (river mile 571.5) generally have specific conductance values between 340 to 450 μS/cm. These results provide additional water chemistry data showing that there are two ground water flow systems in the study area with differing water chemistry characteristics.

Table 3. Specific conductance values for springs discharging to the Snake River. Data collected by Johnson and Struhs, 2000.

				Specific Conductance	
	Latitude	Longitude		(µS/cm)	
Spring Name	Decimal Degrees		River Mile	Aug-2000	Oct-2000
Devils Washbowl	42.5908	-114.3436	618	642	657
Country Club 1	42.6016	-114.3981	615	612	610
Country Club 2	42.6025	-114.3991	615	608	
Blue Lakes	42.6149	-114.4689	610.5	608	
Warm Springs	42.6197	-114.4941	610	617	
Ellison Spring	42.6380	-114.5621	605.2	688	688
Crystal 1a	42.6599	-114.6430	600.7	709	743
Crystal 1	42.6612	-114.6457	600.6	684	
Crystal 2	42.6617	-114.6470	600.5	676	
Crystal 6	42.6621	-114.6490	600.4	667	
Crystal 7	42.6623	-114.6493	600.3	659	
Crystal 8	42.6626	-114.6508	600.2	656	
Crystal 9	42.6590	-114.6409	600.1	642	660
Niagara Springs	42.6644	-114.6754	599	610	610
Clear Lakes 1	42.6743	-114.7780	593	461	559
Clear Lakes 2	42.6745	-114.7760	593	526	482
Briggs Spring	42.6737	-114.8054	591	507	556
Banbury Sp (composite)	42.6877	-114.8207	589.4	444	
Unnamed Sp below Banbury	42.6971	-114.8199	588.8	444	453
Blind Sp (composite)	42.7008	-114.8168	588.5	418	437
Box Canyon Sp (composite)	42.7066	-114.8163	588.2	405	416
Sand Spring	42.7245	-114.8176	586.1	396	407
10 springs 1	42.7384	-114.8373	584.9	406	406
10 springs 2	42.7385	-114.8372	584.9	395	
10 springs 3	42.7388	-114.8371	584.9	387	
10 springs 4	42.7392	-114.8367	584.9	381	
Thousand Springs 1	42.7418	-114.8376	584.8	387	399
Thousand Springs 2	42.7451	-114.8411	584.3	358	
Piscies Investments	42.7522	-114.8469	584	340	
NFH 15	42.7615	-114.8567	583	341	344
Curren Tunnel	42.7763	-114.8482	578.5	350	339
Lee's Spring			578	420	390
Weatherby Spring			577.5	365	376
Jones Spring			577	364	364
Florence Spring	42.8344	-114.8787	574	495	495
Birch Creek Spring	42.8538	-114.8817	572	433	
Malad Gorge Spring	42.8642	-114.8761	571.5	337	343
Old Stage Road Sp			571	707	707
Menchaca Spring			570.5	707	707
Glass House Spring			569	560	572

Note: River mile decreases in the downstream direction.

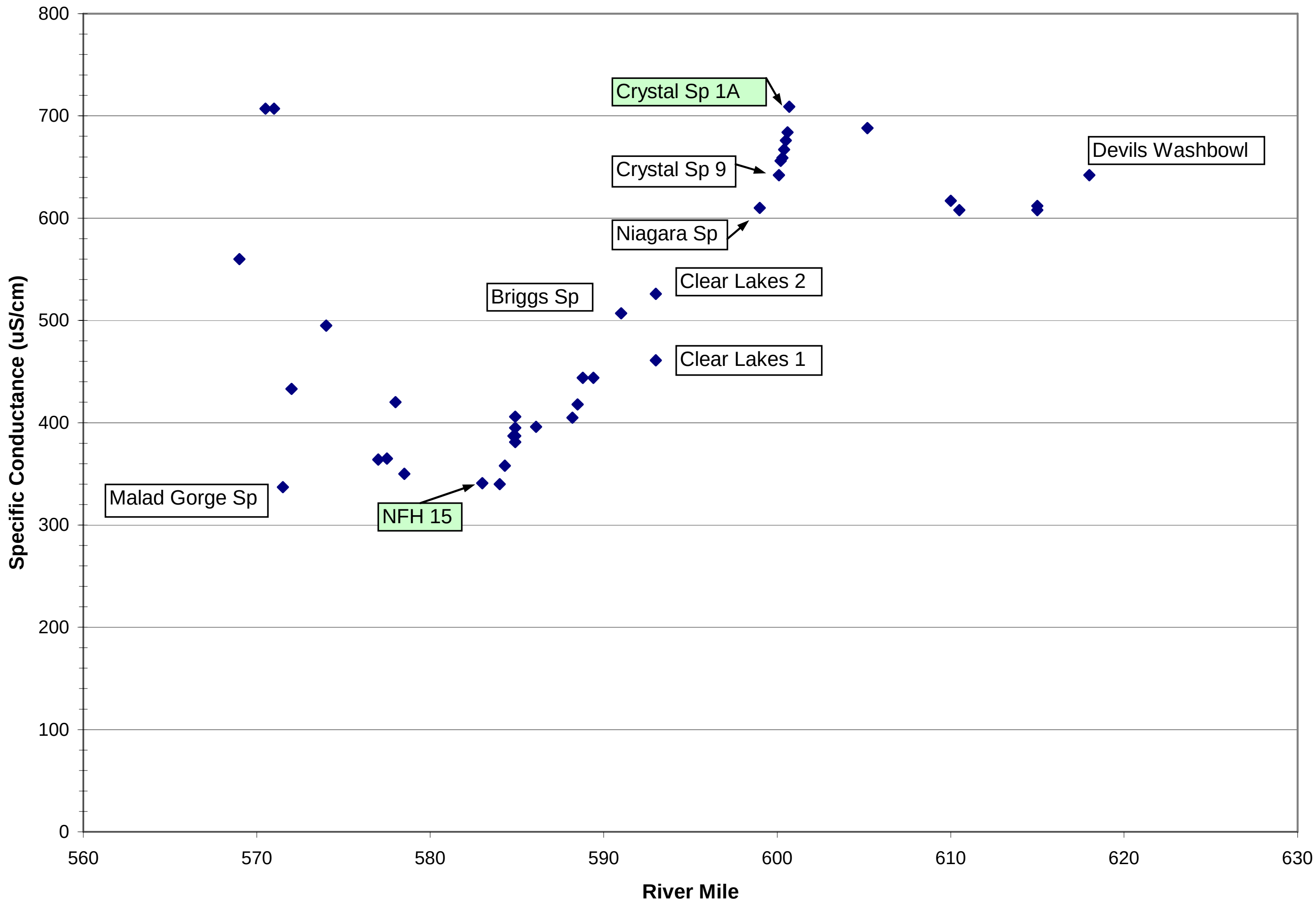


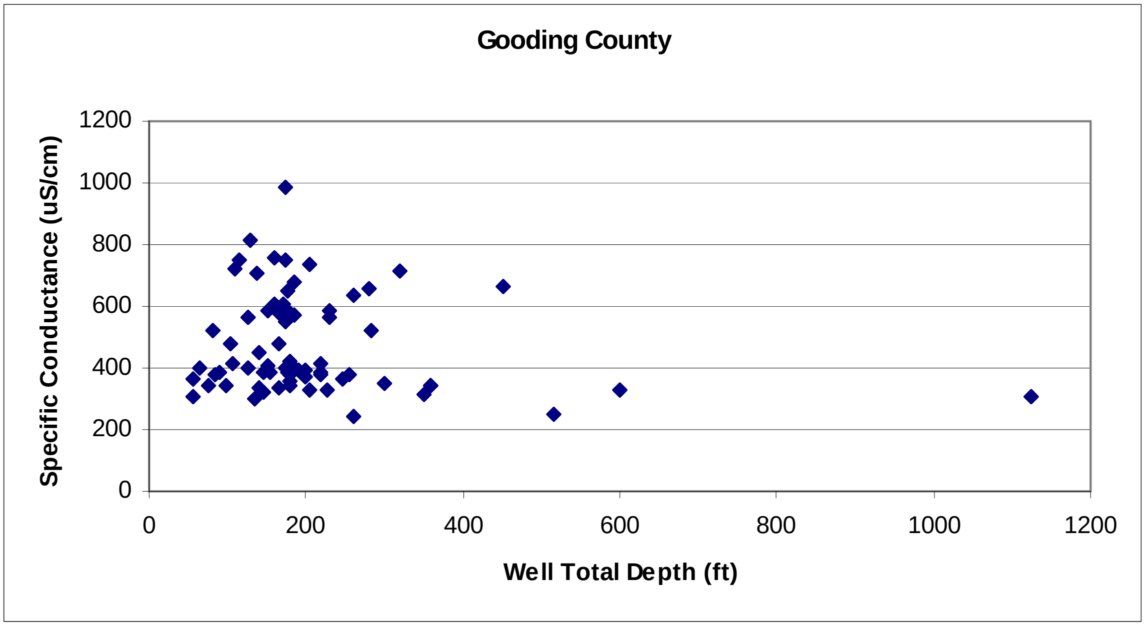
Figure 14. August 2000 field specific conductance data for springs discharging from the north canyon wall of the Snake River from Twin Falls to the Malad River. (Data collected by John and Struhs, 2000.).

National Water Information System Data Set

The second data set used to evaluate ground water chemistry in the study area was retrieved from the U.S. Geological Survey's (USGS) National Water Information System (NWIS). The data included specific conductance, nitrite-nitrate, and total dissolved solids, representing sample results from wells with total depths ranging from 10 to 770 feet and for sample dates ranging from 1947 through 2004. For wells with multiple samples, only the most recent sample result was evaluated.

Water Chemistry Stratification

Because ground water generally moves more readily in the horizontal than the vertical direction, contaminant concentrations in many aquifers are generally highest at the water table, decreasing with depth below the water table. To determine any such connection between water chemistry parameters and well depth, the NWIS data set was, evaluated to determine if there was a correlation between certain water chemistry parameters and well depth. Plots of well depth versus specific conductance were developed for each county (Figure 15 and Figure 16).



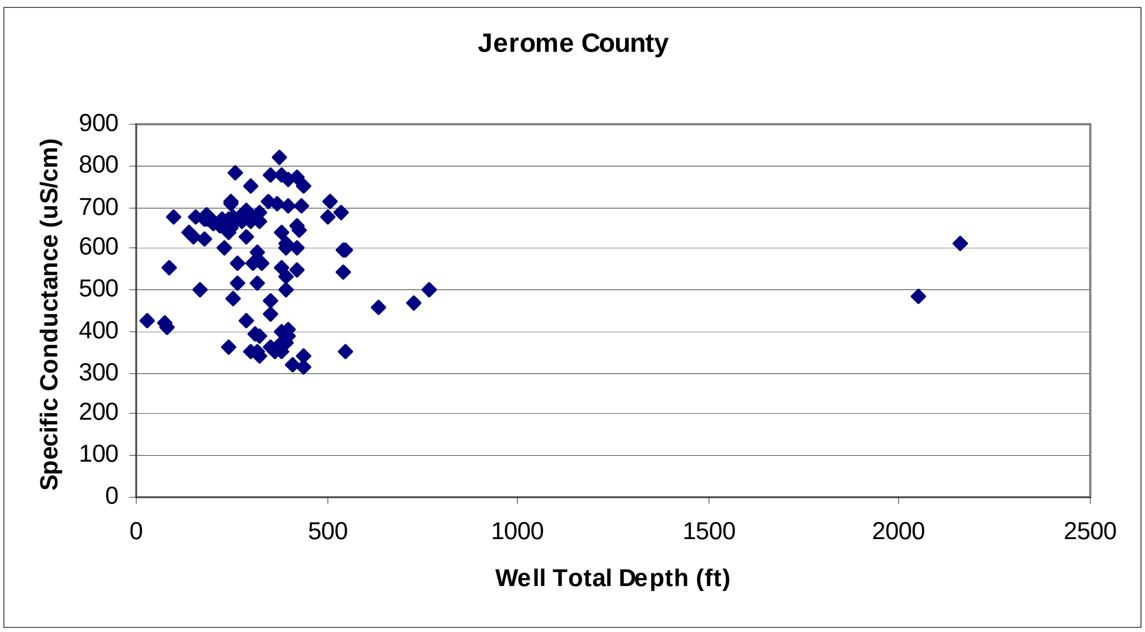
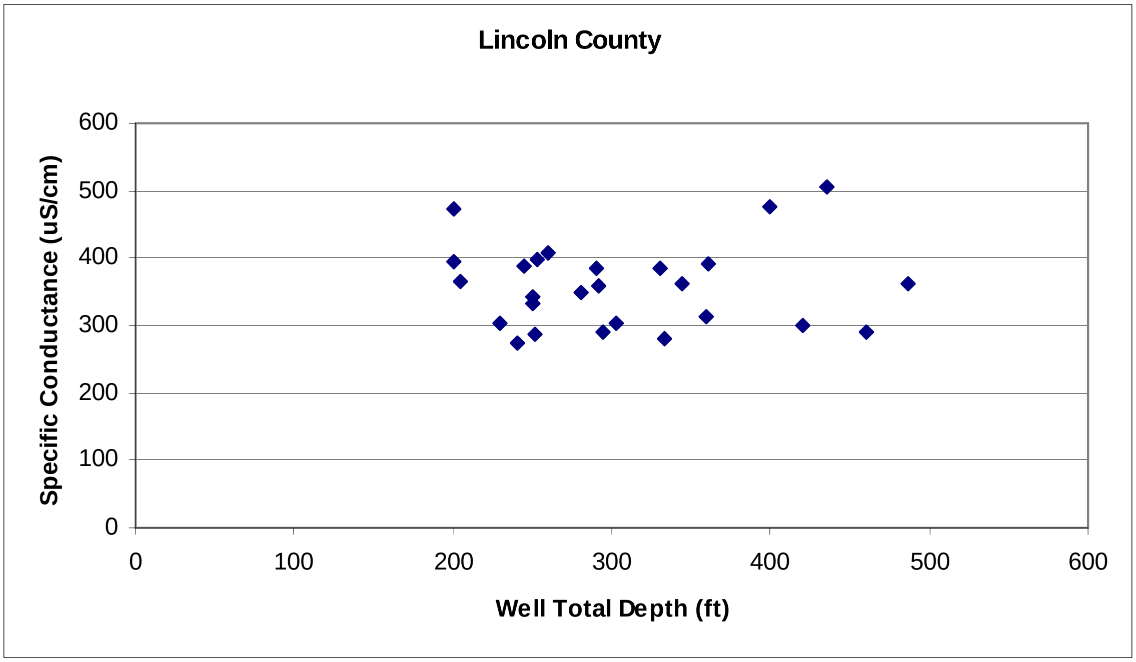


Figure 15. Well total depth, in feet versus specific conductance in µS/cm for Gooding and Jerome Counties.



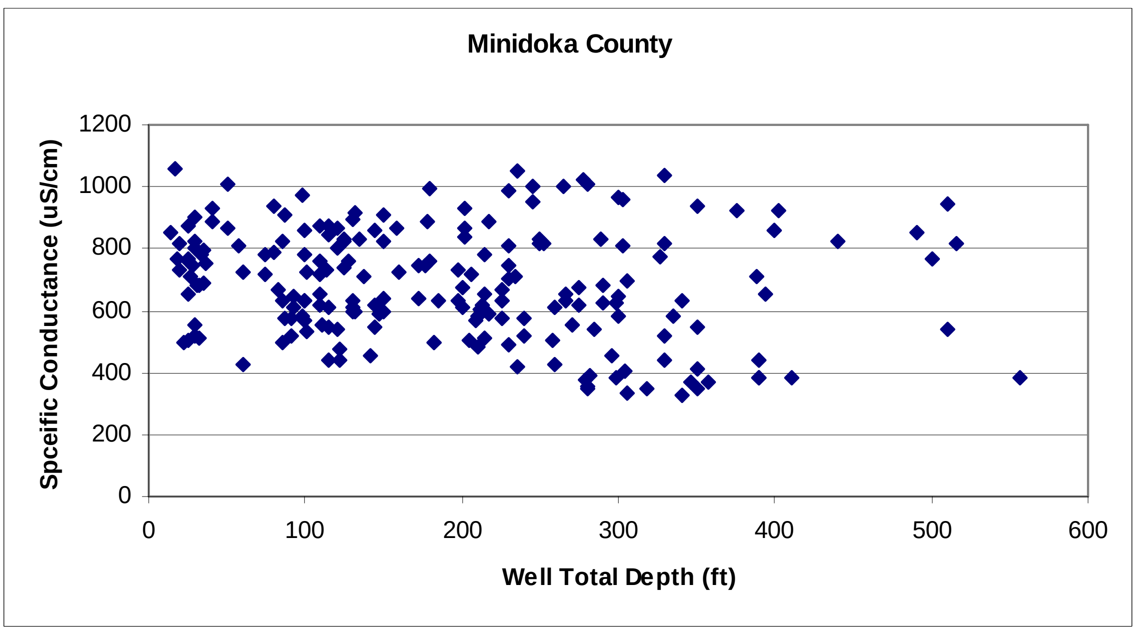


Figure 16. Well total depth, in feet versus specific conductance in µS/cm for Lincoln and Minidoka Counties.

The data show little or no correlation between total well depth and specific conductance or nitrate values. At first glance this might seem to indicate that mixing has resulted in a more or less uniform distribution of contaminants throughout the water column with little or no stratification of water chemistry within the aquifer. However, well construction probably plays an important role in the observed specific conductance data. Current IDWR rules (IDAPA 37.03.09 – Well Construction Standards Rules) require that wells be cased to a depth of 18 feet below land surface. A review of drillers logs show that most wells in the study area are only cased for the first 18 feet and the remainder of the well is left as an open hole completion. Perched water can cascade into these open hole sections, with the result that wells of all depths can be impacted by locally occurring contaminated perched aquifers. A good correlation probably doesn't exist between specific conductance and well depth within the study area due to these well construction practices. On the other hand, spring specific conductance data, to be discussed, indicate that the uppermost part of the aquifer can be degraded relative to deeper zones.

Water Quality Regions

The NWIS specific conductance data were also used to evaluate water chemistry in the study area, based on specific conductance values less than and greater than 500 µS/cm.

The 500 µS/cm value was chosen for the following reasons:

- The plot of specific conductance versus river mile (Figure 14) shows that the 500 µS/cm value occurs at approximately the midpoint in the range of specific conductance values for springs along the river.
- The 500 µS/cm value coincides with the location where the Snake River changes from a westerly to a northerly course (i.e. Briggs Spring at River mile 591 –Table 3).
- The change in river direction coincides with the position where ground water flow follows long flow paths that originate in the Idaho Falls area versus short flow paths that originate in the Burley area (Figure 11). A visual fit line of the data shows two regions with distinct water differences (Figure 17). The line delineating the two areas trends east from the Snake River, starting at Briggs Spring, passes north of Jerome, and continues east and then back south to the river north of Acequia.

Figure 17 shows that some wells east of Bliss have specific conductance values greater than 500 µS/cm. These wells are associated with a perched aquifer that has been the focus of an investigation by the Idaho Department of Agriculture (Bahr, et al, 2000) and are not part of the regional Snake Plain aquifer.

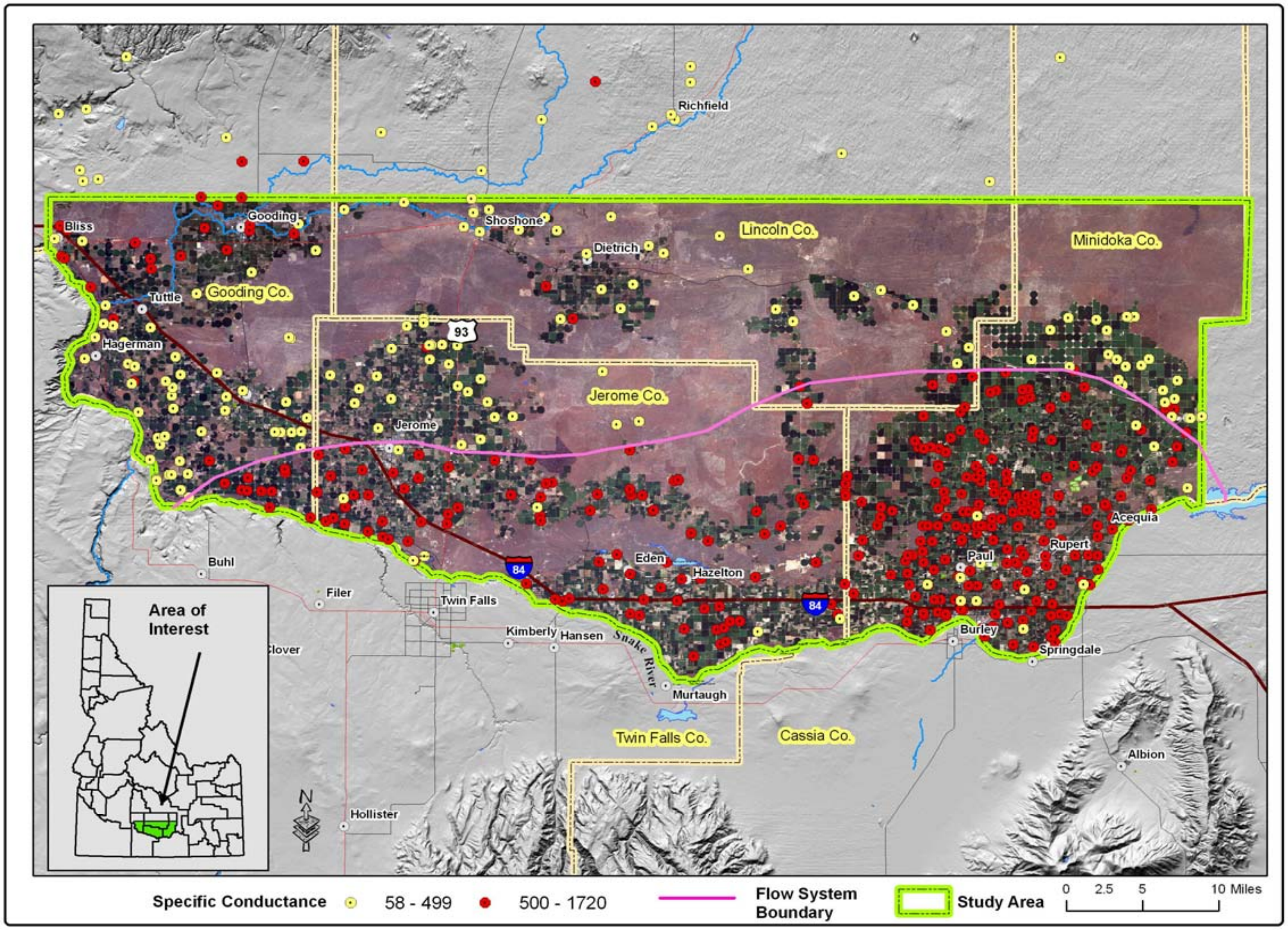


Figure 17. Wells used in flow system delineation, showing specific conductance values less than and greater than 500 µS/cm.

Statistical measures for the data points north and south of the line, including mean, median, mode, range, and number of observations for the two areas are shown in Table 4. The mean specific conductance value for the southern area is 715 µS/cm (n=356), while the mean specific conductance value for the northern area is 417 µS/cm (n=170).

Ground water nitrate data from the NWIS database also were evaluated, using the same wells as for the specific conductance evaluation. The mean nitrate concentration for the southern area wells was 4.27 mg/L (n=228), while the mean nitrate concentration for the northern area wells was 1.29 mg/L (n=125).

Table 4. Statistical summary of regional aquifer and local aquifer specific conductance and nitrate data.

Statistical measurement	Specific Conductance		Nitrate	
	Local aquifer	**Regional aquifer**	**Local aquifer**	**Regional aquifer**
Mean	715 µS/cm	417 µS/cm	4.27 mg/L	1.29 mg/L
Median	677 µS/cm	384 µS/cm	2.53 mg/L	0.93 mg/L
Mode (most frequent value)	500 µS/cm	381 µS/cm	2.0 mg/L	0.55 mg/L
Std Deviation	213	125	1.19	6.03
Variance	45,300	15,730	1.42	36.37
Minimum value	58 µS/cm	226 µS/cm	0.03 mg/L	0.01 mg/L
Maximum value	1720 µS/cm	877 µS/cm	67.9 mg/L	9.11 mg/L
Number of observations	356	170	228	125

Oxygen and Deuterium Isotopes

Analysis of ^{18}O and deuterium involves measuring the ratio of ^{2}H/^{1}H and ^{18}O/^{16}O to determine the *fractionation* (isotope partitioning) that has occurred as a result of natural meteorological (meteoric) processes. Fractionation is measured by comparing a known standard ratio concurrent with a sample ratio. Isotope ratios are expressed in delta units (δ) as *permil* (parts per thousand or $^{o}/_{oo}$) differences relative to the standard.

Six samples were collected from NFH 15 and Crystal Springs 1A springs, from November 2003 through March 2004, for analysis of ^{18}O and deuterium isotopes. The samples were collected to compare isotope characteristics in the local and regional aquifers and to evaluate isotopic changes over time.

Sample results, listed in Table 5 and plotted in Figure 18, show that waters from the regional and local aquifer systems have distinctly different isotope signatures and some variability over the sampling period. Upstream springs have more positive deuterium (^{2}H) and ^{18}O values compared to deuterium and ^{18}O values in the downstream springs.

These results, shown on a scatter plot on Figure 19, agree well with stable isotope results presented by Clark and Ott (1996). Deuterium and ^{18}O values that plot in the upper right part of the diagram (upstream springs) are indicative of water that has mixed with recharge from a surface water source, while values that plot in the lower left part of the diagram are indicative of water that has recharged the aquifer at higher elevations and/or under cooler climatic conditions.

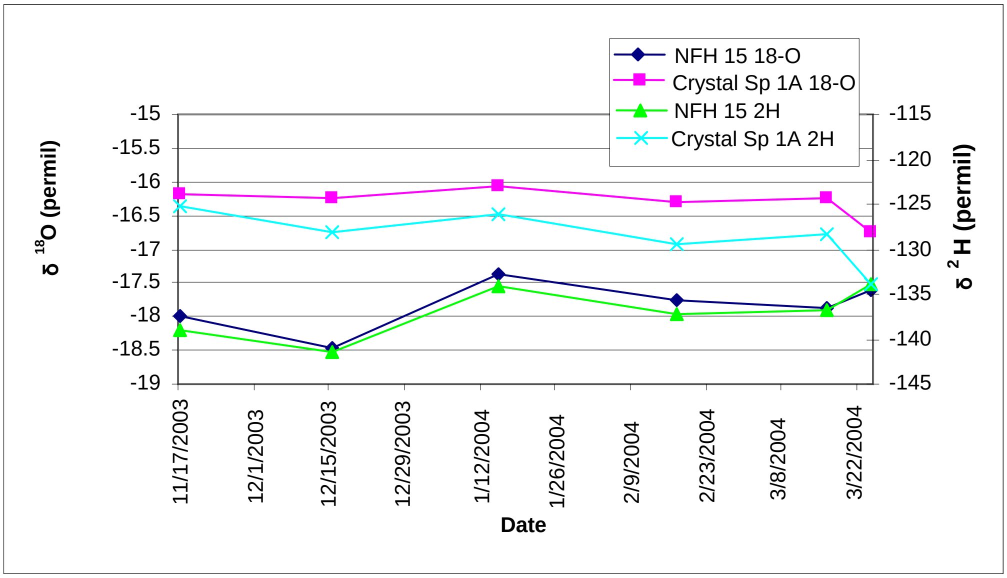


Figure 18. ^{18}**O and deuterium results for National Fish Hatchery 15 (NFH 15) and Crystal Springs 1A isotope samples collected from November 2003 through March 2004.**

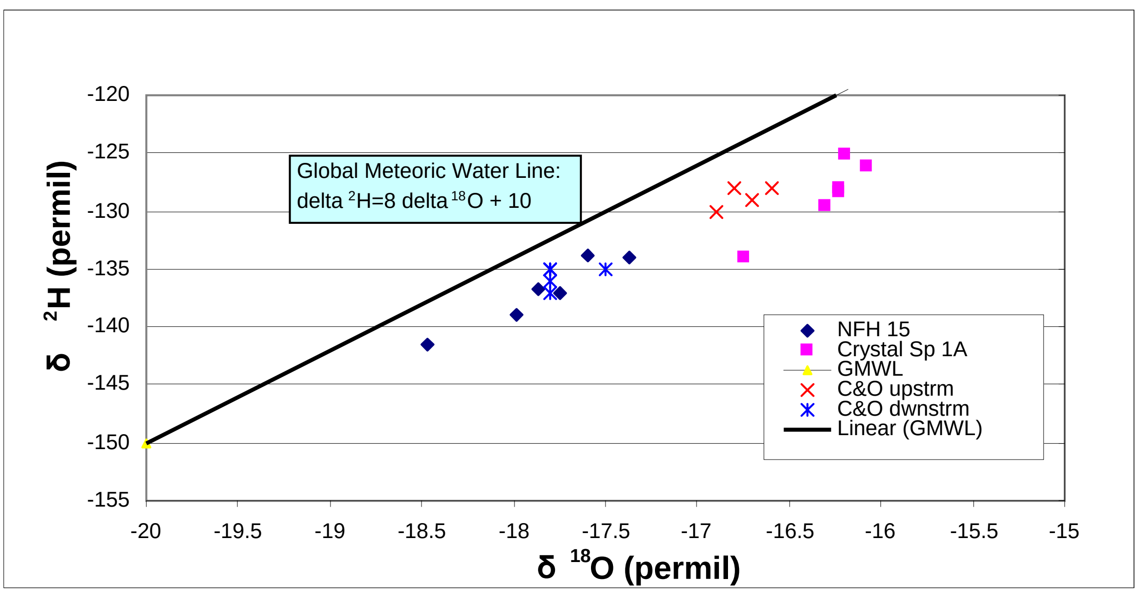


Figure 19. Plot of ^{18}**O versus deuterium for springs NFH 15 and Crystal Springs 1A. Samples collected from November 2003 through March 2004. C&O refers to Clark and Ott (1996) isotope results.**

Table 5. ^{18}O and deuterium isotope results for NFH 15 and Crystal Springs 1A, November 2003 through March 2004.

Station	Date	^{18}O	^{18}O duplicate	deuterium	deuterium duplicate
		(permil)	(permil)	(permil)	(permil)
Crystal Sp 1A	11/17/2003	-16.2		-125.16	-126.24
Crystal Sp 1A	12/15/2003	-16.23		-128.1	-127.06
Crystal Sp 1A	1/15/2004	-16.08	-16.24	-126.12	-126.31
Crystal Sp 1A	2/17/2004	-16.3		-129.49	-129.34
Crystal Sp 1A	3/16/2004	-16.23		-128.32	-128.89
Crystal Sp 1A	3/24/2004	-16.75		-133.99	-133.04
NFH 15	11/17/2003	-17.98		-139.01	-138.7
NFH 15	12/15/2003	-18.47		-141.46	-141.85
NFH 15	1/15/2004	-17.37	-17.45	-134.06	-134.67
NFH 15	2/17/2004	-17.75		-137.12	-138.22
NFH 15	3/16/2004	-17.87		-136.78	-136.56
NFH 15	3/24/2004	-17.6		.133.9	-134.28

Potentiometric Data

Potentiometric contours constructed on a water table aquifer represent the upper surface of the water table. Ground water flows at right angles to potentiometric contours, from areas of high hydraulic head (high elevation) to areas of low hydraulic head (low elevation). Ground water flow paths can be constructed by drawing lines at right angles to potentiometric contours.

The 500 μS/cm line, shown in Figure 17 is considered to be a bounding ground water flow line between the local and regional aquifers. Ground water flow paths north and south of the line move parallel to the line. Although hydraulic effects of discharge or recharge can propagate across this boundary, the exchange of water across this bounding flow line is restricted because water cannot move at right angles to the general ground water flow direction.

The potentiometric contours in the southeastern part of the study area indicate that water can move from the river into the aquifer in the river reach from below American Falls Dam to the Burley area. Downstream of Burley, ground water flows toward the west, where it discharges back to the river beginning at Twin Falls (Figure 11). Discharge to the river from the aquifer in the reach from Burley to Twin Falls is limited because ground water is moving nearly parallel to the river, and there is limited opportunity for discharge points. At Banbury Spring, the course of the river turns to the north, more or less at right angles to the ground water flow direction, and all ground water is forced to discharge from the canyon walls into the river.

As noted, the area south of the 500 μS/cm line can be considered a discrete compartment or local ground water flow system separated from the main ESRP aquifer. Ground water flow paths move parallel to the boundary on both sides, but water chemistry impacts cannot move from one area to another north or south of the line. This is in contrast to effects of ground water withdrawals, which can propagate in all directions, up-gradient, down-gradient, and cross gradient from an extraction area. Under similar loading conditions, the local ground water flow system should be more susceptible to contamination due to its slow flow velocity and small volume of water moving through the system, compared to the more rapid flow velocities and greater volumes of water moving through the regional flow system.

Nitrogen Loading Evaluation of Gooding, Jerome, Lincoln, and Minidoka Counties, Idaho

The purpose of this section is to present an evaluation and summary of the potential sources of nitrogen (referred to as *loads*) that may impact water resources—especially ground water resources—within the boundaries of Gooding, Jerome, Lincoln, and Minidoka Counties.

Specific Objectives

The objectives of the nitrogen loading evaluation include the following:

- Obtain data on crops grown in the county and estimate, where practical, the nitrogen requirement for the major crops for the most recent year of record.
- Estimate the amount of nitrogen that may be released when legume crops are plowed under.
- Obtain census data for the counties and estimate the potential nitrogen loading from domestic waste water treatment systems.
- Obtain livestock data for the counties and estimate the potential nitrogen loading from animal wastes.
- Estimate the nitrogen loading from any permitted industrial wastewater land application sites in the counties.
- Estimate nitrogen loading to the hydrologic cycle from atmospheric contributions in the form of precipitation for the counties.

Limitations of the Data Used in the Evaluation

The following limitations apply to the data used in this evaluation of nitrogen loading:

- Some subtotals and totals are rounded. Therefore, the sum of individual values in the text will not always add up to the values in the tables.
- Data sources spanned 2002 to 2004, but data for all of the objectives listed above were not always available for the same year for all of the sources of nitrogen tabulated in this evaluation.
- Although the population in the counties continues to grow, areas under cultivation vary year by year for the crops noted, with the variation often highly dependent upon the predicted availability of irrigation water.
- Livestock numbers also vary and are dependent upon a number of factors, including international marketing.

- The data for the nitrogen sources falls within a two year time span (2002-2004) that is believed to provide reasonably comparable data.

General Information

Gooding, Jerome, Lincoln, and Minidoka Counties are combined in this evaluation of the potential nitrogen loading. This combination is created to better assess the potential nitrogen loading along the ground water flow paths that lead to the Thousand Springs discharge area where the Eastern Snake River Plain Aquifer discharges to the Snake River.

Land ownership and use is distributed differently between the four counties Table 6. Federal and State land ownership constitute large portions of the land area and, as expected, agriculture dominates land use.

Table 6. Distribution of land ownership and use.

	Jerome County (acres)	Gooding County (acres)	Lincoln County (acres)	Minidoka County (acres)	Total Area (acres)
Total, all owners	383,936	467,712	771,584	486,208	2,109,440
Federal	96,510	237,503	584,486	174,649	1,093,148
State	7,951	20,124	22,851	7,720	58,646
Agriculture	200,700	126,900	100,800	229,300	657,700
Range	70,000	246,200	268,200	168,300	752,700

Note: Source is ***County Profiles of Idaho***

Findings

Estimated nitrogen loadings for each of the categories identified in the study objectives are presented in the following sections.

Nitrogen Loading from Crop Fertilization

Estimates of nitrogen loading from crop fertilization Table 7 were compiled using acreage data and recommended fertilization rates. Important information regarding the sources used for these estimates includes the following:

- Actual commercial fertilizer application rates are not available for Idaho, but the 2002 Census of Agriculture County Data states that 441,693 acres in the counties were treated with commercial fertilizer, lime, and soil conditioners.
- An alternative approach can be used to estimate the amount of nitrogen that may have been applied to crops. Nitrogen application rates can be estimated by calculating the amount of nitrogen fertilizer that is recommended for application by using guidelines recommended by the University of Idaho (Tindall, 1991).
- Corn and oats are divided into two categories unlike the other crops. These crops are listed as grain and silage (corn) and grain and hay (oats) to allow the separation of the potential nitrogen loading because silage and hay are fed to livestock where the potential nitrogen loading also is estimated. The census only reports oats harvested as grain so it is assumed the balance is harvested as hay for livestock feed. This approach minimizes the double counting of nitrogen loading as fertilizer and again as animal waste. It is recognized that some portion of the locally grown grain will be used as livestock feed but the amount used in this manner is not known. Further complicating this aspect of the potential loading is the importation of grain and other

protein supplements for livestock feed but this aspect of the evaluation is believed to be accounted for in the livestock waste estimates.

- The estimates of crops grown in the counties are based on summaries provided by Idaho Agricultural Statistics Service (IASS) from summaries released for 2003 and 2004. It should be noted that the Census reports changes in the acreages of some of the crops noted below compared to the previous census.
- The values presented in Table 7 are presented for estimating the potential nitrogen load.
- Estimates of nitrogen fertilizer applied in other agricultural related enterprises are not readily quantifiable given the availability of data and variety of crops raised. For instance, about 1,465 acres are used in counties for nurseries, greenhouses, floriculture, aquatic plants, mushrooms, flower seeds, vegetable seeds, and sod. The types of fertilizers used and the applications rates are not known for these enterprises.

Table 7. Nitrogen loading from crop fertilization.

	Crop Year	Acres Harvested (Acre)[a]	Avg. County Yield (units/area)	U of I Guidelines (lbs/acre)	N - Total Required (lbs)
Alfalfa	2004	111,150	5.35 tons/ac	0	0
Barley	2004	78,200	118 bushels/ac	180	14,076,000
Bean	2004	16,650	2,200 lbs/ac	30	499,500
Corn - grain	2004	14,000	150 bushels/ac	135	1,890,000
Corn - silage[b]	2004	54,050	25.6 tons/ac	120	6,486,000
Oats - grain	2004	550	101 bushels/ac	180	99,000
Oats - hay[b]	2004	6,650	unknown	180	1,197,000
Potatoes	2003	43,700	370 Cwt[c]/ac	160	6,992,000
Sugar Beets	2004	71,600	27.0 tons/ac	110	7,876,000
Wheat[d]	2004	65,500	109 bushels/ac	180	11,790,000
Total		146,154			43,222,500

Notes:

a Acreages obtained from Idaho Agricultural Statistics Service, Idaho County Estimates 2003 and 2004; U.S. Department of Agriculture, National Agricultural Statistics Service, 2002 Census of Agriculture - County Data (acreages include 50% of reported values for Lincoln County as an estimate of land overlying ground water flow paths affecting discharge areas under study)

b Corn raised for silage and oats raised for non-grain uses is assumed to be used locally for feed for livestock; nitrogen applied as fertilizer is not counted in this table because nitrogen also is accumulated in livestock waste in a later table.

c Cwt = hundred-weight.

d All wheat, includes only irrigated acreage.

Nitrogen Loading from Plowing Down Of Legume Crops

Nitrogen is released to the soil when legume crops are plowed down. This estimated nitrogen load is based on the plowing down of alfalfa, pea, and bean acreages and is shown in Table 8.

Table 8. Nitrogen loading from plowing down legume crops.

Crop	Acres[a]	N contribution (lbs/acre)[b]	Total Nitrogen (lbs)
Alfalfa	27,788	200	5,557,600
Beans	16,650	100	1,665,000
Total			7,222,600

Notes: a Acreage reported in Idaho Agricultural Statistics Service, Idaho County Estimates 2004
b Nitrogen contribution is based on research conducted by Carter (1990, 1991a and , 1991b).

Values shown in Table 8 were estimated by multiplying the acreage for each crop by a factor of 200 pounds per acre for alfalfa and 100 pounds per acre for peas and beans. These nitrogen contribution factors are based on research conducted by Carter (1990, 1991a, 1991b), Meek, et al (1994), Meek, et al (1995) and Robbins and Carter (1980). These studies all reflect a significant increase in nitrogen contribution at plow down compared to previous estimates (Tindall, 1991). It is further assumed that one quarter of the alfalfa acreage is rotated out of production each year, so the potential nitrogen loading is based on one quarter of the potential total nitrogen load of alfalfa. Beans, in contrast, are an annual crop, so the total acreage is assumed to be plowed down each year. Total nitrogen loading is then as follows:

- Of the 111,150 acres of alfalfa in the counties, about 27,788 acres are assumed to be plowed down each year. The estimated release of nitrogen is therefore 5,557,600 pounds, based on the 200 pounds per acre noted above.
- About 16,650 acres of beans are raised in the counties; if the entire acreage is assumed to be plowed down, the estimated release of nitrogen is, therefore, about 1,665,000 pounds.

Nitrogen Loading from Domestic and Urban Sources

Domestic waste water also contributes to nitrogen loading as shown in Table 9. Notes regarding the data used in the estimate include:

- The current county profiles delineate the distribution of population for the year 2002. The population of the counties in 2002 was 56,682; 36,498 from that figure are attributed to rural areas.
- The U.S. Environmental Protection Agency (1980) compiled data from various studies of residential wastewater flows and found the average flow rate is 68.6 gal/person/day. The estimated rate of nitrogen loading that can occur to ground water has been updated to reflect studies of wastewater systems that include Total Kjeldahl Nitrogen (TKN) and nitrate as effluent from the septic tank and soil water at 1.97 ft (0.6 meters) and 3.94 ft (1.2 meters) depths. The TKN concentration decreases with depth, and the nitrate concentration increases with depth, due to conversion processes that occur in situ. The nitrate concentration at 3.94 ft depth averaged 13.0 mg/L in the studies, and this value is assumed to percolate to ground water in the aquifer with minimal changes.

- It should be noted that nitrogen from domestic waste is applied through drain fields below the crop root zone; little or no nitrogen is removed by plants, and it is assumed to be available to migrate to ground water.

Table 9. Nitrogen loading from domestic and urban sources.

	Area Population	Human Nitrogen Contribution (lb/gal)[a]	Individual Nitrogen Contribution (lb/day)[b]	Total Human N Contribution (lbs/day)	Total Human N Contribution (lbs/yr)
Rural counties	36,498	0.0001085	0.007	272	99,155
Urban[c]	20,184	0.0001085	0.007	150.232	54,835
Total					153,990

Notes:
a Human nitrogen contribution is 13.0 mg/L (EPA 2002) for residences.
b For the rural and urban populations, multiply the Human Nitrogen Contribution by 68.6 gallons per day.
c It is assumed that all urban residents are on septic systems even though some towns such as Gooding and Jerome have sanitary sewers and treatment facilities.

The total nitrogen loading from rural and urban sources is the sum of the 99,155 pounds and the 54,835 pounds shown in Table 9, which is 153,990 pounds. The value for urban sources is very conservative because the estimate assumes all residents in the towns use septic systems which is not the case. Several towns such as Gooding and Jerome have sewer systems and treatment facilities that reduce the potential nitrogen loading to ground water.

Nitrogen Loading from Livestock/Animal Waste

The nitrogen load in animal waste in the four counties (Table 10) was estimated using animal numbers obtained for each county from the Idaho Agricultural Statistics Service (http://www.nass.usda.gov/Statistics_by_State/Idaho/Publications/County_Estimates/) and guidelines for nitrogen residual in animal waste developed by various university extension services in the U.S.

- The estimates for nitrogen in livestock waste assume the waste is applied directly to the land, except where the livestock would normally be confined and the wastes stored before application.
- In the case where wastes are stored before application to the land, the residual nitrogen is estimated using guidelines developed by the university extension services. These guidelines account for losses of nitrogen during storage (30%) and losses that occur during handling and spreading (20%).
- In some cases, the estimated amount of nitrogen generated by a species was not available, so the value for an animal of the nearest weight was used for this estimation (such as beef for elk, and turkeys for geese).

Table 10. Nitrogen loading from livestock/animal waste.

Livestock Type	# of Animals[a]	Estimated Nitrogen (lbs/animal/yr)	Total Nitrogen (lbs/yr)
Dairy[b]	198,855	129	25,652,295
Beef[b]	40,034	55	2,201,870
Other cattle[b, 1]	202,207	55	11,121,385
Subtotal			38,975,550
Horses & Ponies[c]	6,009	110	660,990
Sheep	43,425	9.2	399,510
Hogs & Pigs[b]	818	14	11,452
Goats[f]	1,474	23	33,902
Llamas[d, f]	228	23	5,244
Layers, Pullets, Meat[b]	2,870	0.56	1,607
Ducks	302	99	29,898
Geese[e]	83	1.6	133
Subtotal			1,142,736
Total			40,118,286

Notes: a Source is U.S. Department of Agriculture, National Agricultural Statistics Service, 2002 Census of Agriculture – County Data.

b Animals are assumed to be confined and waste collected and stored before application.

c Numbers of horses and ponies summed without regard to weight difference.

d Value assigned to llamas is from data for goats.

e Value assigned to geese is from data for turkeys.

f Numbers for Lincoln County are not available

Note: 1. “Other cattle” is heifers and heifer calves, steers, steer calves, bulls, and bull calves.

Nitrogen Loading from Industrial Sources

Nitrogen can be applied to the ground at thirteen wastewater land application sites in Jerome, Gooding, Lincoln, and Minidoka Counties (Table 11). These thirteen sites range from municipal to industrial sources and the nitrogen data are based on annual performance reports provided by the facilities to the Idaho Department of Environmental Quality.

Not all sites apply waste water every year so the nearest year of records was used in this estimation of nitrogen loading. For instance, the City of Gooding did not apply waste water in 2003 so the records for 2002 are used in this estimation (the records for 2004 are not available at the time of preparation of this report). The total nitrogen applied was summed for the acreages under application, using the amount of nitrogen stated as being applied to those acreages. (It should be noted that these facilities routinely report the amount of wastewater and nutrients applied to their land application sites and the amount of nutrients removed by cropping the acreage. The net balance for nitrogen typically is negative in that the crops remove more nitrogen than is applied to the land.)

Table 11. Nitrogen loading from industrial sources.

	Year	Acreage (ac)	Total Nitrogen Applied (lbs/year)
Crossroads of Idaho	2004	14.50	4,002
Eden, City of[a]	2000	4	123
Glanbia Foods - Gooding	2003	918	612,656
Glanbia Foods - Richfield	2004	478	160,927
Gooding, City of	2003	55	4,957
Hazelton, City of	2004	16.5	2,524
Jerome Cheese Co.[b]	2003		
Jerome, City of[c]	1995	11.3	
Paul, City of	2002	114	1,583
Rupert, City of	2003	261	39,183
TASCO	2004	833	36,736
Wendell, City of	2004	45.3	3,293
Western Idaho Potato[d]	1998		
Total			865,984

Notes: a Data submitted for 2000, no waste water discharged in 2003 & 2004; LA-173

b Data not submitted for 2003; LA-151

c Missing reports; LA-149

d No waste water discharged

Nitrogen Loading from Precipitation

Total nitrogen deposited by precipitation can be estimated for the four counties using the same methods employed by Rupert (1996) for the upper Snake River Basin. The following equation defines the approach for developing this estimate:

$$B = (E \times Q \times I) \times D,$$

Where:

B = total nitrogen input from precipitation (kg),
E = total nitrogen concentration in precipitation (mg/L),
Q = annual rainfall (m),
I = land area within the county (m^2), and
D = dry deposition constant (unitless).

Values used for this evaluation are as follows:

- Maupin (1995) estimated the total nitrogen in precipitation (E) for the upper Snake River Basin to range from 0.18 to 0.27 mg/L. The midrange concentration (0.23 mg/L) total nitrogen is used to calculate the nitrogen contribution from precipitation for this evaluation.
- Average annual precipitation (Q) is 9.48 inches (0.241 m) at Jerome, Gooding, Rupert, and Minidoka, based on records from 1919 to 2004 (Western Regional Climate Center).

- Gooding, Jerome, Lincoln, and Minidoka Counties covers (I) 1,723,648 acres (6.975 E+09 m^2) (State of Idaho, 2005) [Assumes only half of acreage in Lincoln County contributes to portion of Snake River Plain Aquifer of interest.]
- Rupert (1996) used a dry deposition constant (D) of 1.444 to convert the wet deposition value to total nitrogen supplied by wet and dry deposition.

Applying these values the following:

$$B = \{(0.23 \text{ mg/L}) (0.241 \text{ m}) (6.975\text{E+09m}^2) (1.444) (1{,}000 \text{ L/m}^3)\} \div (1\text{E+06 mg/kg})$$
$$B = 558{,}000 \text{ kg}$$
$$B = 1{,}230{,}000 \text{ lbs}$$

Total Estimated Nitrogen Loading

The total nitrogen loading that potentially is applied to the land surface in Jerome, Gooding, Lincoln, and Minidoka Counties (Table 12) can be estimated by combining the subtotals of the six[1] categories of sources described above. Figure 20 presents this information graphically.

Table 12. Total estimated nitrogen loading for four county study area.

Source	Nitrogen Contribution (lbs)	Percent Contribution
Fertilizer	43,222,500	46.6
Legume crop plowdown	7,222,600	7.8
Domestic/urban	153,990	0.2
Dairy	25,652,295	27.7
Beef	2,201,870	2.4
Other cattle[1]	11,121,385	12.0
Other livestock[2]	1,080,000	1.2
Industrial	865,984	0.9
Precipitation	1,230,000	1.3
Total	92,750,624	100

Note: 1. “Other cattle” is heifers and heifer calves, steers, steer calves, bulls, and bull calves.
2. “Other livestock” includes all livestock listed in Table 5 except for cattle.

[1] Because of the relative magnitude of the nitrogen loading contributed by animal waste, this category is presented using data from four subcategories: dairy, beef, other cattle, and other livestock.

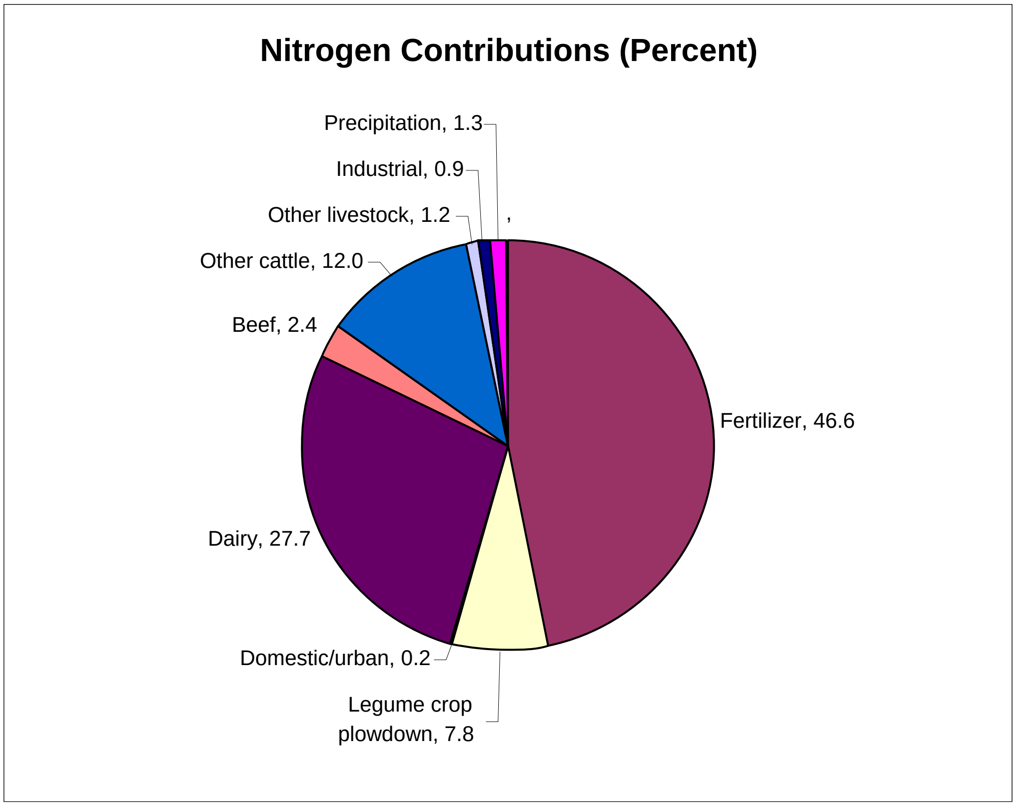


Figure 20. Estimated nitrogen loading for Gooding, Jerome, Lincoln, and Minidoka Counties by source.

Discussion

It is apparent that the largest potential source of nitrogen that could impact ground water in Gooding, Jerome, Lincoln, and Minidoka Counties is nitrogen from fertilizer applications (46.6%). The second largest potential source of nitrogen is from dairy, beef and other cattle operations (43.3% overall). The remaining 10.1% of the potential nitrogen sources can be attributed to domestic/urban waste (0.2%), legume crops plowed down (7.8%), industrial sources (0.9%), and precipitation sources (1.3%).

This does not mean the results of this evaluation should be interpreted to indicate that localized problems cannot occur from the smaller sources of nitrogen. What it does mean is that the bulk of the potential nitrogen loading that can occur to ground water in the counties can be expected to come from farming and livestock operations within the county.

The total nitrogen loads from Table 12 are listed in Table 13, along with the nitrogen load estimated from Baldwin et al. (2000). For the most part, the percent nitrogen contribution from each source is comparable for the two studies. Differences in nitrogen loads for dairy sources and beef/other cattle sources between the two studies can be attributed to the greater amount of range land acreage in northern Gooding and Minidoka Counties and all of Lincoln County. A greater percentage of beef cattle is raised on this rangeland acreage, in contrast to the higher percentage of dairy cattle recorded in the 2000 study area. The total nitrogen load for the four-county study area is approximately 80,000,000 pounds per year, of which 95 percent is from commercial fertilizer and livestock sources.

Table 13. Summary of nitrogen sources and loads from Baldwin, et al (2000) and the current four-county study area. Nitrogen loads are larger for the current study due to the larger acreage in the study area compared to the 2000 study area.

Nitrogen source	2000 Study area (Baldwin, et al)		2004 Four-County study area	
	Nitrogen load, lbs	Percent of total	Nitrogen Load, lbs	Percent of Total
Fertilizer	15,220000	54	43,222,500	49
Human waste	324,800	1	153,990	0.1
Dairy	11,129,000	40	26,652,295	30
Beef/other cattle/livestock	1,185,000	2	14,465,991	16
Precipitation	201,700	1	1,230,000	1
Legumes	608,700	2	7,222,600	3
Industrial[1]	NA	NA	865,984	1
Total	28,670,100		92,813,360	

[1] Industrial sources in the four-county study area are 13 wastewater land application sites

An estimate of the annual nitrogen load in springs discharging from the north side of the river can be made using average nitrate concentrations in local and regional ground water (1.29 and 4.27 mg/L, respectively, Table 4) and estimated discharge from local and regional springs on the north side of the river (Kjelstrom, 1995). Kjelstrom's analysis indicates that in 1980 discharge to the river from that portion of the aquifer identified in this report as the local aquifer amounted to about 20 percent of the total. Discharge to the river from what is termed the regional aquifer amounted to about 80 percent of the total.

The combined discharge from the local and regional aquifers is currently estimated to range from 5,000 to 5,500 ft3/sec. Table 14 shows estimated annual nitrogen loads from local and regional springs for the two discharge estimates and various discharge percentages from the local and regional aquifers. The table also shows the estimated value of nitrogen in the discharge, based on a 2005 nitrogen cost of $0.39 per pound for south central Idaho (Patterson and Smathers, 2005). The nitrogen load in spring discharge to the river from the local and regional aquifers ranges from about 18,500,000 to about 25,000,000 pounds per year. This amounts to about 25 percent of the estimated 80,000,000 pounds per year of nitrogen input into the system. The value of this nitrogen ranges from about $7,200,000 to about $9,800,000 per year.

Table 14. Estimated annual NO_3 load for springs discharging to the Snake River from the north side and value of this nitrogen, based on 2005 nitrogen cost.

Local/Regional Discharge (percent)	Total Spring Discharge (ft^3/sec)	Aquifer Discharge (ft^3/sec)		Nitrate Load (lbs/yr)		Total NO3 load (lbs per year)	Value of N in spring discharge
		Local	Regional	Local aquifer (4.27 mg/L)	Regional aquifer (1.29 mg/L)		
35/65	5000	1,750	3,250	14,712,156	8,254,361	22,976,518	$8,960,842
35/65	5,500	1,925	3,575	16,183,372	9,079,798	25,274,170	$9,856,926
30/70	5,000	1,500	3,500	12,610,420	8,889,312	21,509,732	$8,388,796
30/70	5,500	1,650	3,850	13,871,462	9,778,244	23,660,705	$9,227,675
25/75	5,000	1,250	3,750	10,508,683	9,524,263	20,042,946	$7,816,749
25/75	5,500	1,375	4,125	11,559,551	10,476,690	22,047,241	$8,598,424
20/80	5,000	1,000	4,000	8,406,947	10,259,214	18,576,161	$7,244,703
20/80	5,500	1,100	4,400	9,247,641	11,175,136	20,433,777	$7,969,173

Notes: Local discharge = estimated percentage of spring discharge from local ground water flow system
Regional discharge = estimated percentage of spring discharge from regional ground water flow system

Nitrate Statistical Analysis

At the end of 1999, nitrate concentration trends in five major springs discharging to the Snake River were increasing and were projected to reach concentrations of 5 mg/L if trends continued (Baldwin et al, 2000). Four of the five springs evaluated in the 2000 report were revisited in this study including Box Canyon, Niagara Spring, and Crystal Spring 1 and Crystal Spring 2.

Data from the Snake River Farm spring were available from June 1994 through December 2004 and were also evaluated for this study. Sampling frequency in Box Canyon, Snake River Farm and Crystal Springs 1 and Crystal Springs 2 were reduced from weekly to monthly since 1997.

The locations of the five springs evaluated for this study are shown in Figure 21, and plots of the raw data for the five springs are shown in Figure 22 through Figure 26.

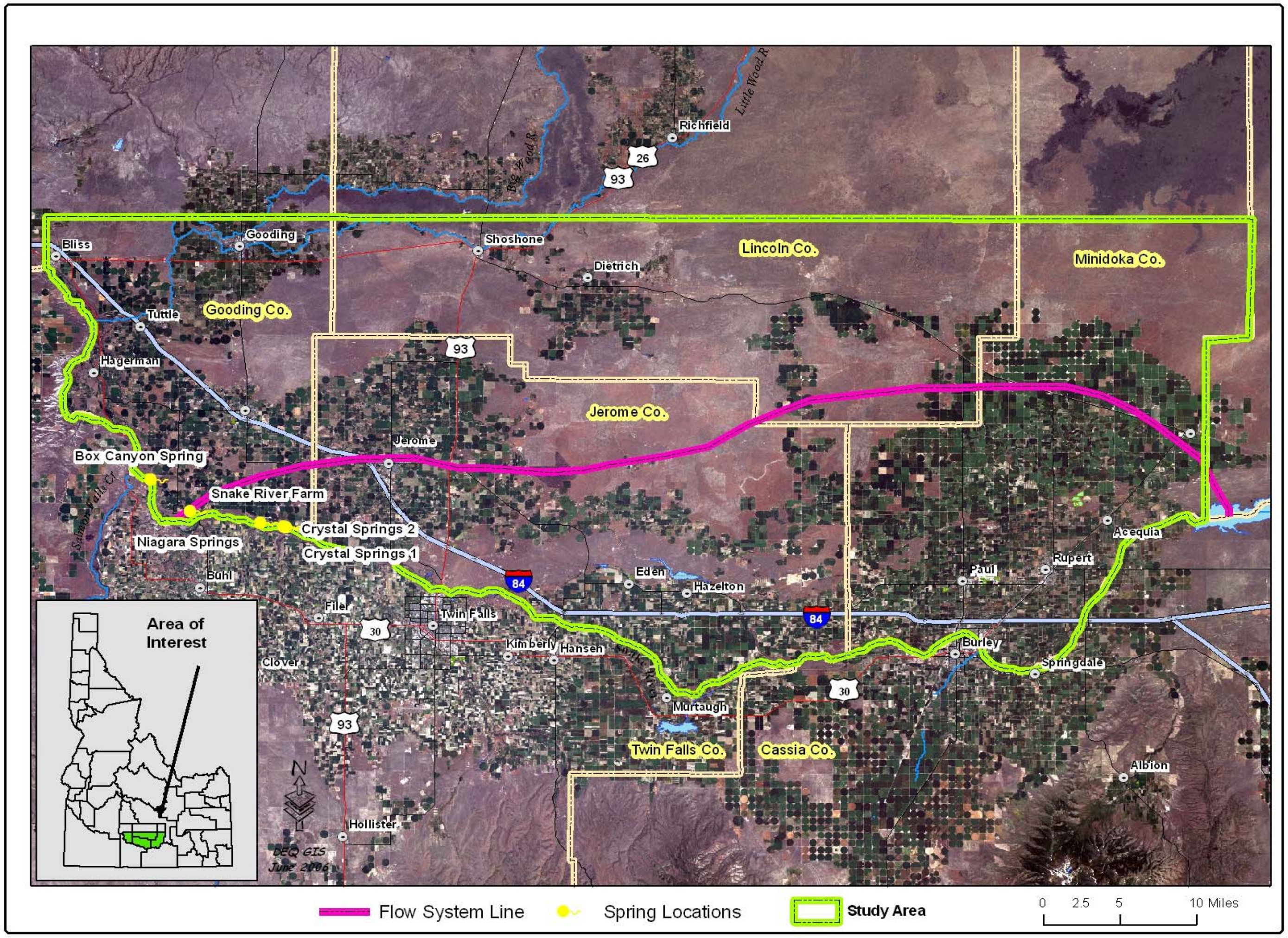


Figure 21. Location of five springs used for nitrate statistical analysis. (Crystal Springs 1 and Crystal Spring 2 are located adjacent to one another and appear as one on this map. Of the remaining three, Box Canyon Spring is further west and Niagara Springs furthest east.)

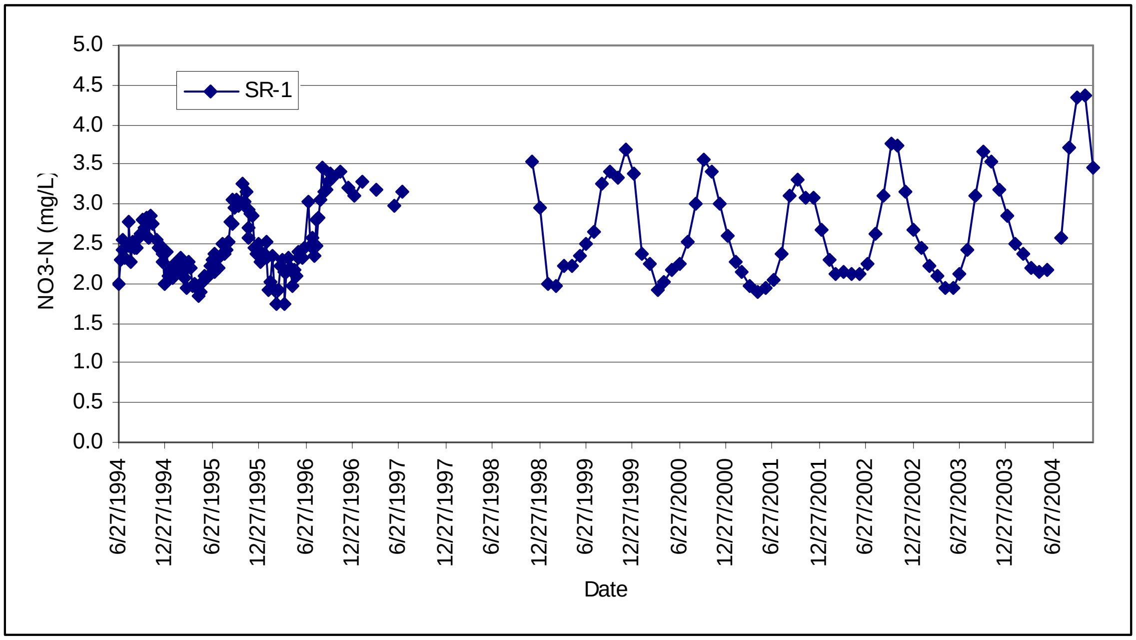


Figure 22. Plot of raw data for Snake River Farm spring (SR-1).

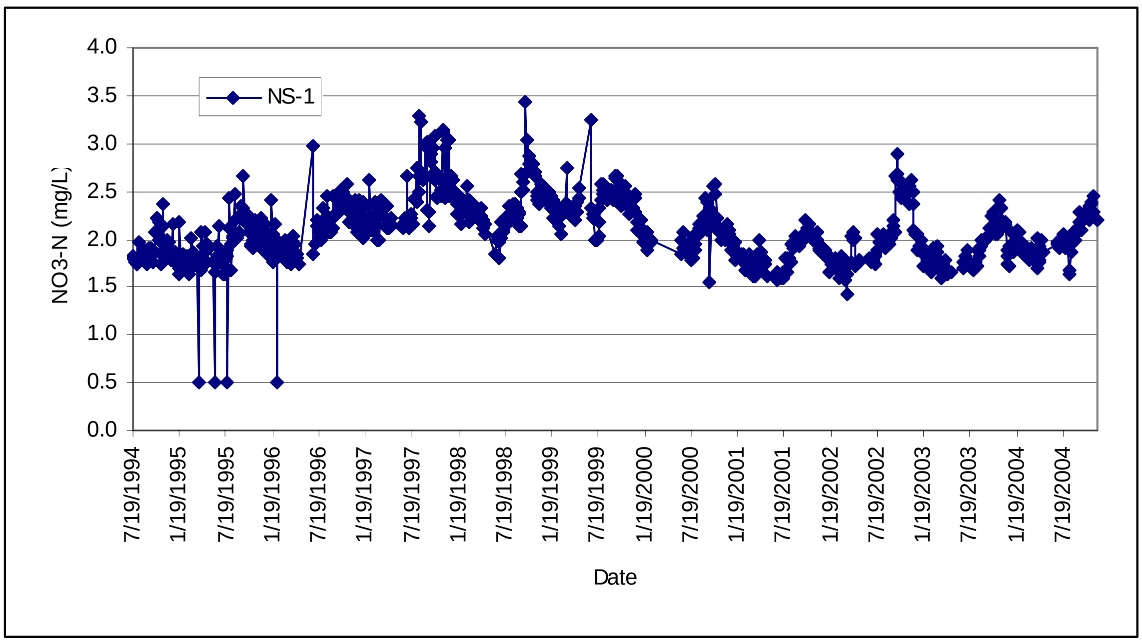


Figure 23. Plot of raw data for Niagara Springs (NS-1).

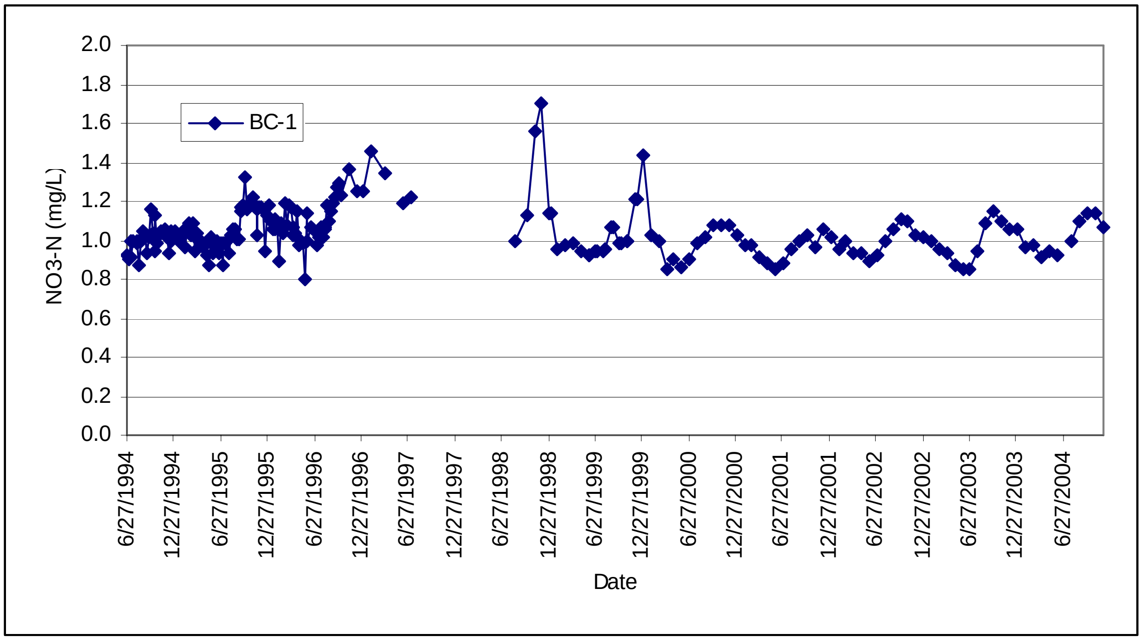


Figure 24. Plot of raw data for Box Canyon spring (BC-1).

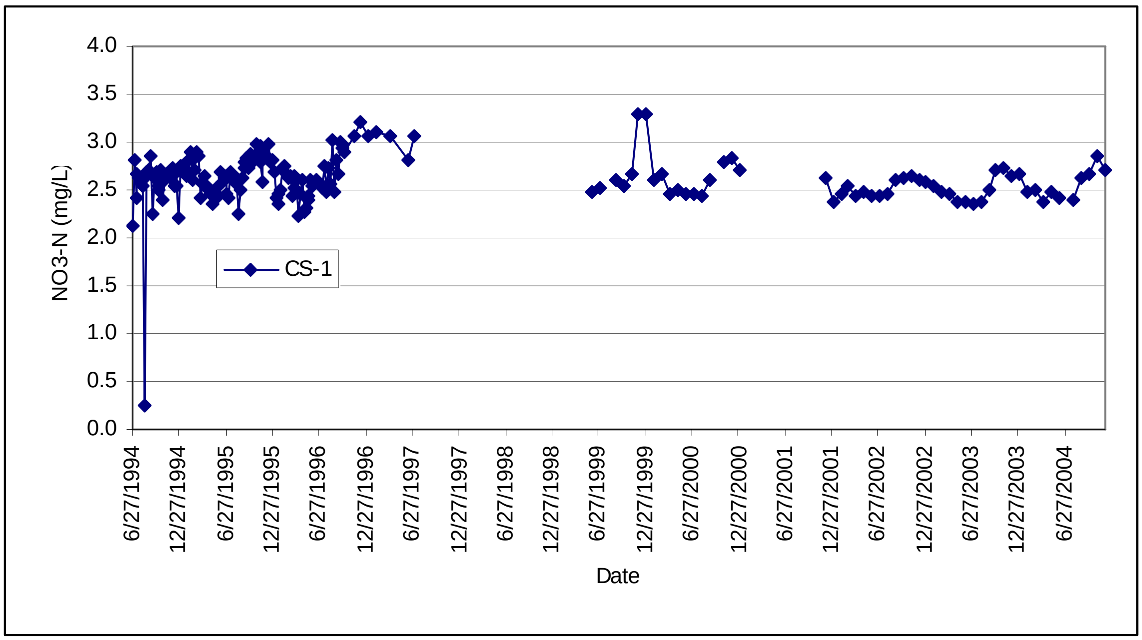


Figure 25. Plot of raw data for Crystal Springs 1 (CS-1).

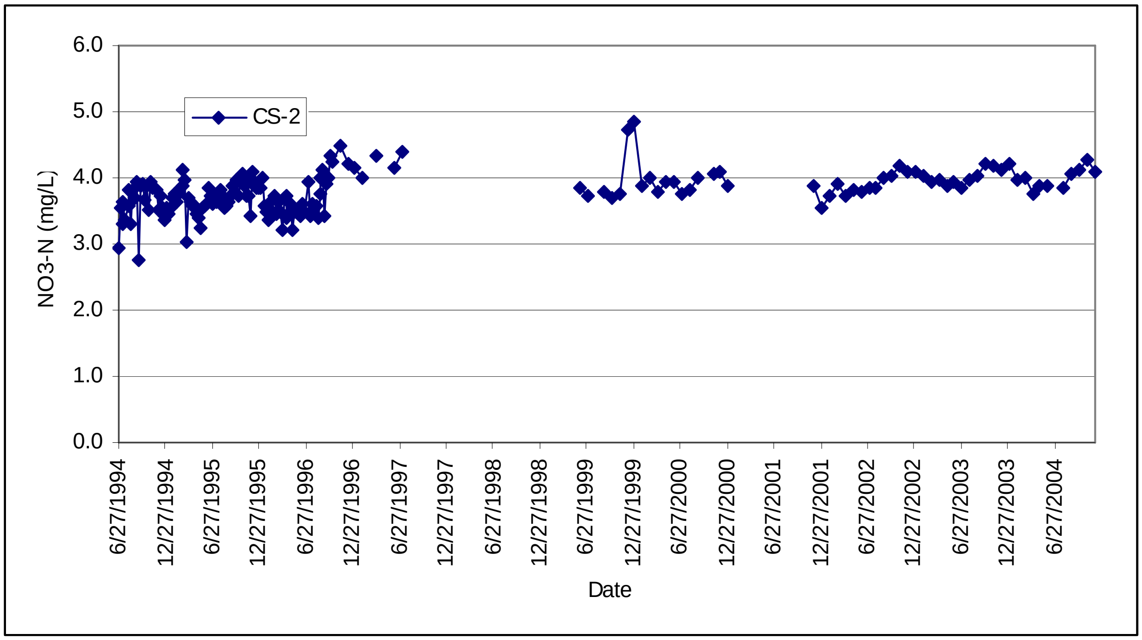


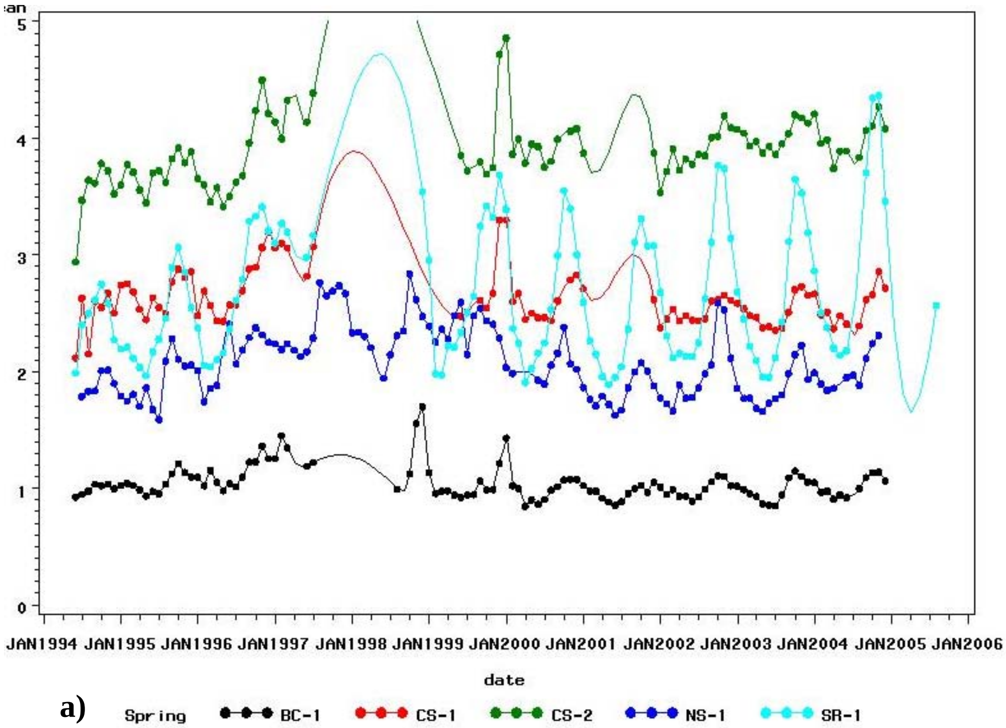
Figure 26. Plot of raw data for Crystal Springs 2 (CS-2).

Seasonality

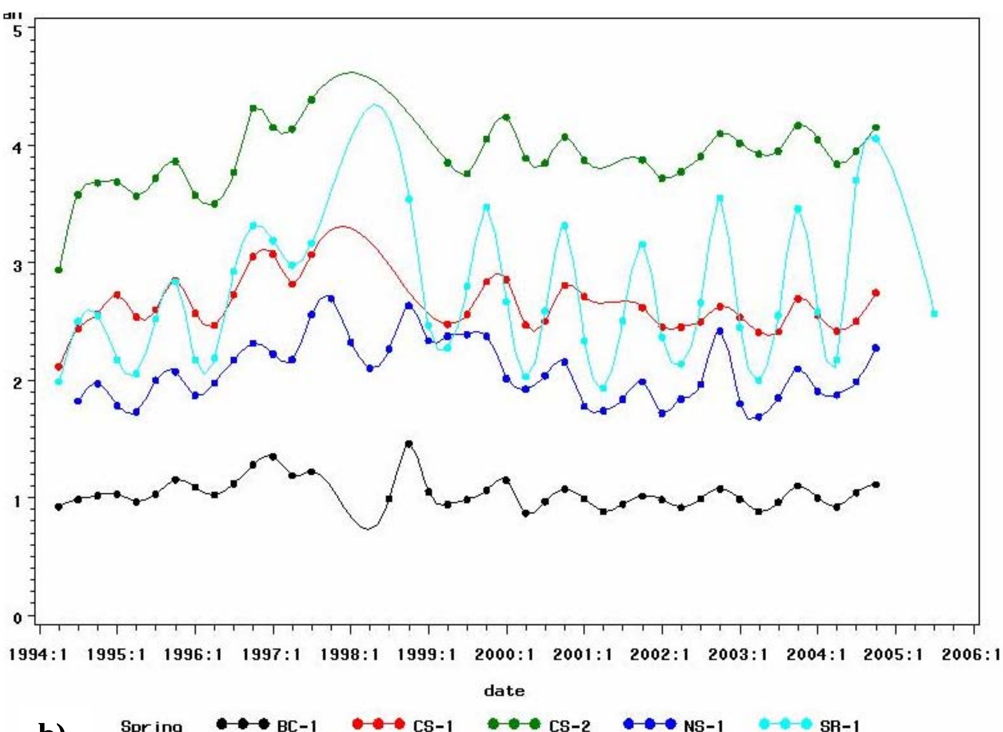
The trend and seasonality of spring data at monthly and quarterly intervals for 1994 through 2004 are illustrated in Figure 27. Seasonality is the component of variation in a time series which is dependent on the time of year. Both monthly and quarterly reoccurring patterns indicate seasonality is present in the data.

The plots show that nitrate concentrations in the springs are lowest during the first quarter of the growing season from April to June. The monthly seasonal plot shows that nitrate concentrations increased from September and stayed at relatively high concentrations until the next growing season in April. Compared to the other four springs, Snake River Farm Spring has a different seasonal behavior in that nitrate increased dramatically during the 3rd quarter; its average 4th quarter nitrogen concentration is 0.73 mg/l higher than in the 1st quarter.

Trend evaluation using *ordinary least square* (OLS) regression may be misleading when seasonality is present in the data. When a trend is inferred by OLS regression, it may actually be due to regular seasonal patterns. Seasonal decomposition for the spring data were performed using the SAS (SAS Inc., NC) procedure TIMESERIES. A multiplicative model is used if the series are strictly positive, a pseudo-additive model is used if the data series are nonnegative, and an additive model is used if the series are negative. Figure 28 shows the time series after seasonality was removed from the data. The de-seasonalized series do not show the periodic seasonal pattern and have less variability.



a)



b)

Figure 27. Time plots (without seasonal adjustments) of nitrogen concentrations in five springs: a) monthly spring nitrogen concentration time plot; b) quarterly spring nitrogen concentration time plot.

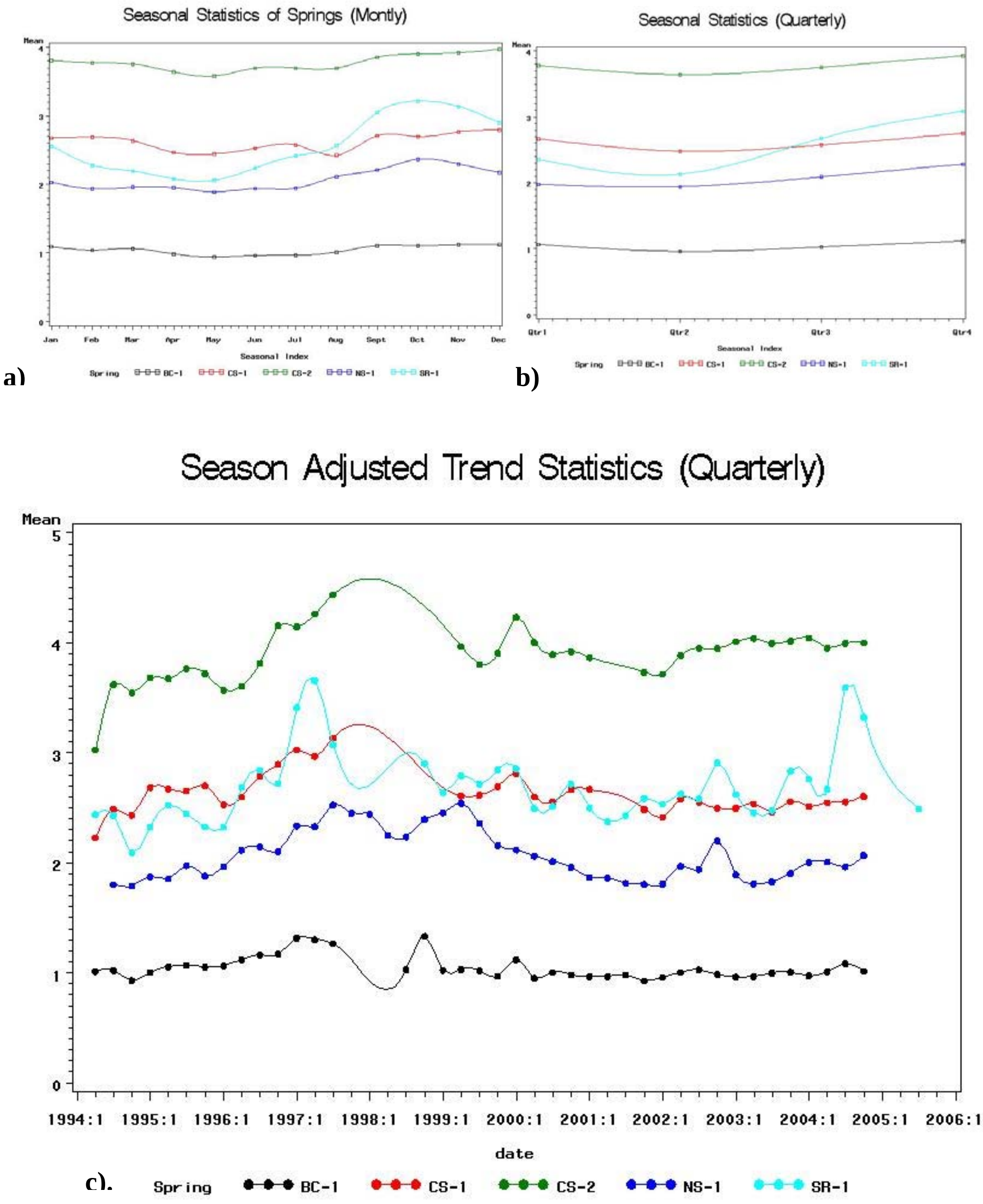


Figure 28. Quarterly and monthly seasonal patterns and seasonal-adjusted time plots for the nitrogen concentrations in the five springs. a) monthly pattern of nitrogen concentrations in the springs; b) quarterly pattern of nitrogen concentrations in the springs; c) seasonal-adjusted (quarterly) time plot of nitrogen concentrations in the springs.

Autocorrelation

Serial dependency, also referred to as autocorrelation, is the tendency for a value in a time series to be correlated to nearby values. Partial autocorrelation function plots (PACF) for the five springs are shown in Figure 29. The PACF plots represent the correlation coefficients of the i^{th} observations compared with $(i+k)^{th}$ nearby observations, where k is the temporal separation or lag between pairs of points in a time series (k = 0 for no lag; i.e., when a point is compared to itself). The first groups of graphs are the PACF plots for the original (unadjusted) nitrate data in springs. The bars represent the values of the correlation coefficient at each lag; the red lines represent two standard errors of the coefficients for k > 0. Any lag with a correlation coefficient outside the red lines is considered to have significant serial dependency.

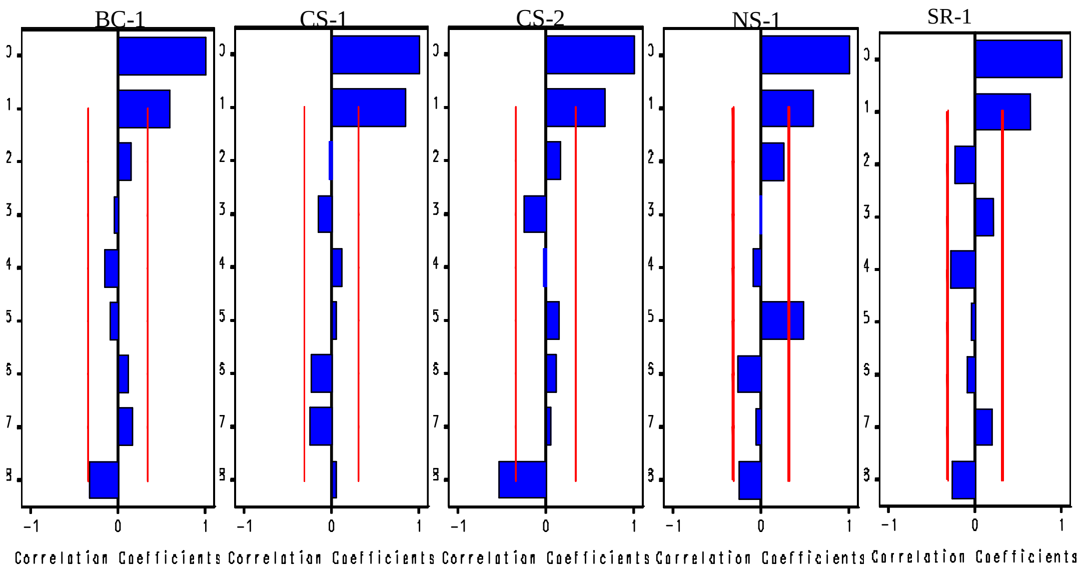


Figure 29. Partial autocorrelation plots of the original (unadjusted) nitrate data in springs. Red lines represent 95 percent confidence interval for correlation coefficient if no serial correlation exists.

The graphs indicate that the serial autocorrelations are all significant at lag 1, the second bar from the top in Figure 29. This means that each observation is highly correlated to nearby observations. When serial dependency exists in the data, conclusions based on OLS regression may be incorrect. The serial dependency biases the estimate of standard error of the slope, which is used to calculate the statistics to test the significance of the slope. Consequently, OLS regression may lead to a biased inference of trend.

Figure 30 shows PACF plots of deseasonalized series after removing the effects of first order autocorrelation (AR(1)). Following this adjustment, serial dependency was not significant at any lags.

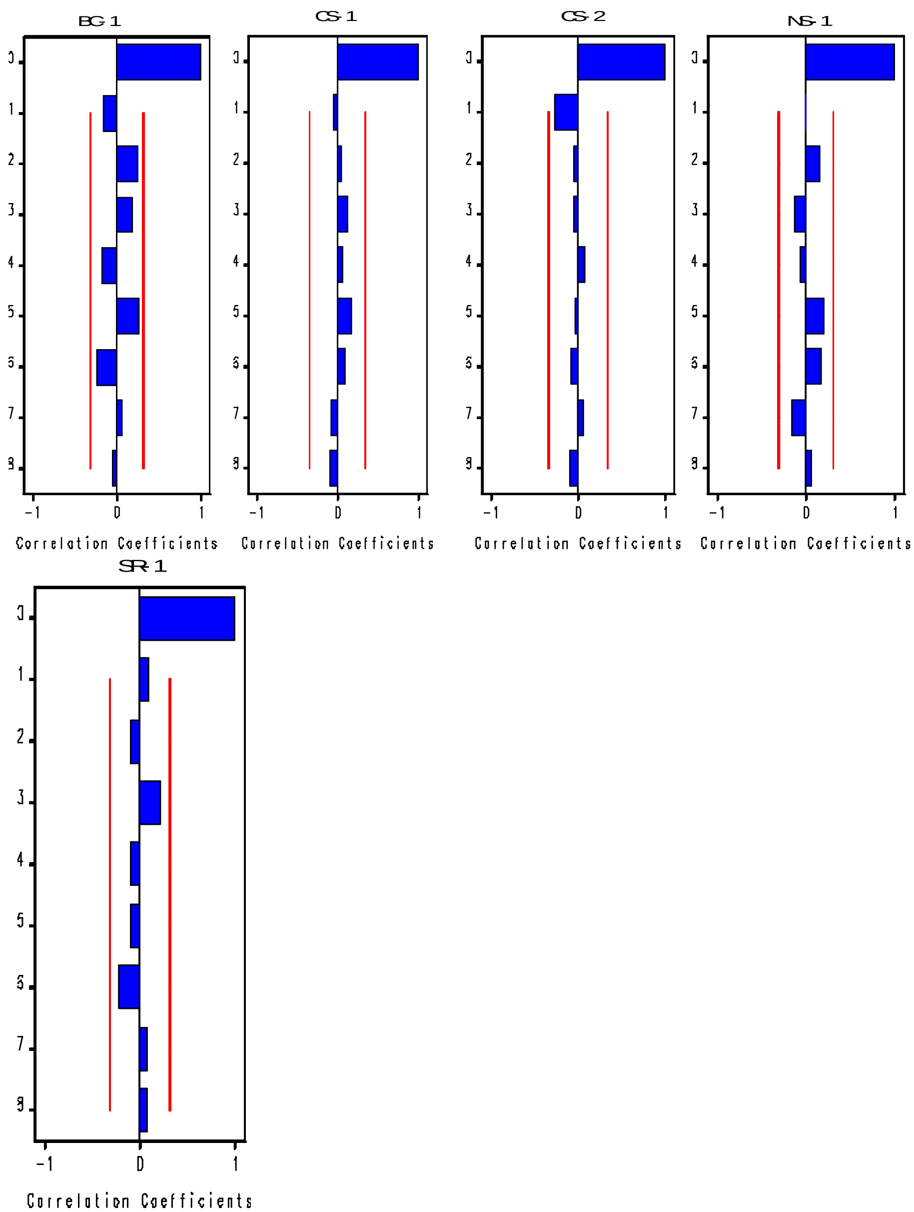


Figure 30. Partial autocorrelation plots of the first order autocorrelation corrected data. Red lines represent 95 percent confidence interval for correlation coefficient if no serial correlation exists.

Trend Analysis

Before trend analysis was performed, the data were de-seasonalized and corrected for first-order autocorrelation using the Time Series Forecasting System (TSFS) in SAS. Comparison of recent (1999-2004) and old data (1994-1998) revealed different mean and variability of spring nitrogen concentrations. The trend analyses in this report reflect only the quarterly data from 1999-2004; analysis of previous data was presented by Baldwin, et al (2000). Table 15 summarizes the trend analysis results. No linear and quadratic trends were observed because nitrate concentrations first decreased and then increased.

Trends were tested at a significance level of 0.05; an asterisk indicates if the p-value was less than 0.05. Increasing/decreasing trends are denoted by +/- sign in the table.

The analysis indicates that trends are not uniform for the five springs. Nitrogen concentrations have been increasing in Box Canyon, Niagara and Snake River Farm Springs. The nature of the increasing trends at these springs is quadratic, that is, nitrate concentrations first decrease then increased. A linear trend also exists for Snake River Farm Spring. There is neither a linear or quadratic trend for Crystal Springs #2, as denoted by N/A.

Table 15. Nitrogen concentration trends in the five springs for 1994-2004. P-values with an asterisk indicate that trends are significant at 95% confidence.

Waters	Trend Analysis			
	Linear p-value	Y/N	Quadratic p-value	Y/N
Box Canyon (BC-1)	0.7797	N	0.0113*(+)	Y
Crystal Spring (CS-1)	0.0124*(-)	Y	N/A	N/A
Crystal Spring (CS-2)	0.5383	N	N/A	N/A
Niagara Spring (NS-1)	0.9338	N	0.0003*(+)	Y
Snake River (SR-1)	0.0067*(+)	Y	0.0005*(+)	Y

Comparison of Nitrogen Concentrations before and after 1999

A closer look at the time plots of the five springs shows variations in nitrate concentration patterns for the five springs. Figure 31 through Figure 35 show that a considerable decrease of average annual nitrate occurred from 1998 to 1999 at all five springs.

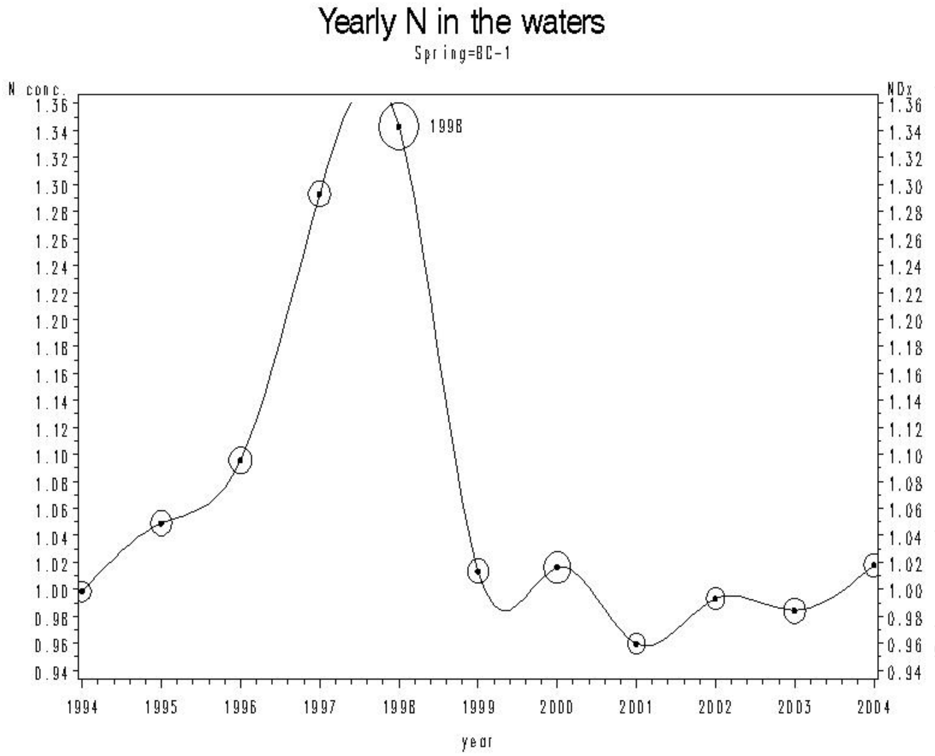


Figure 31. Variation of annual average nitrogen concentrations in spring BC-1. The bubbles represent the variability of the data: the larger the bubble, the more variable the data.

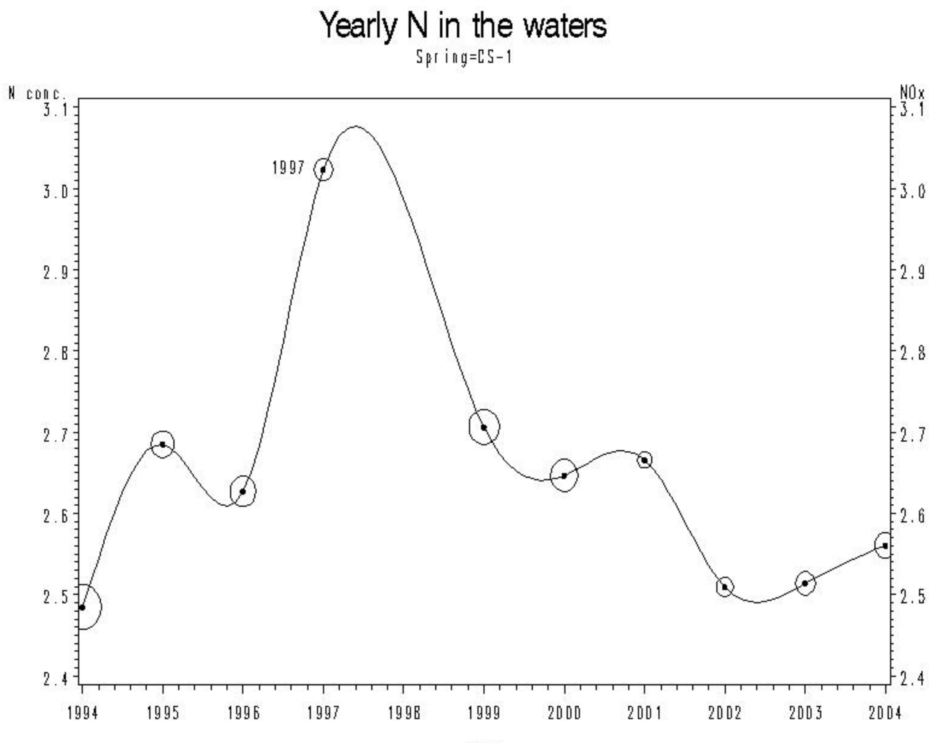


Figure 32. Variation of annual average nitrogen concentrations in spring CS-1. The bubbles represent the variability of the data: the larger the bubble, the more variable the data.

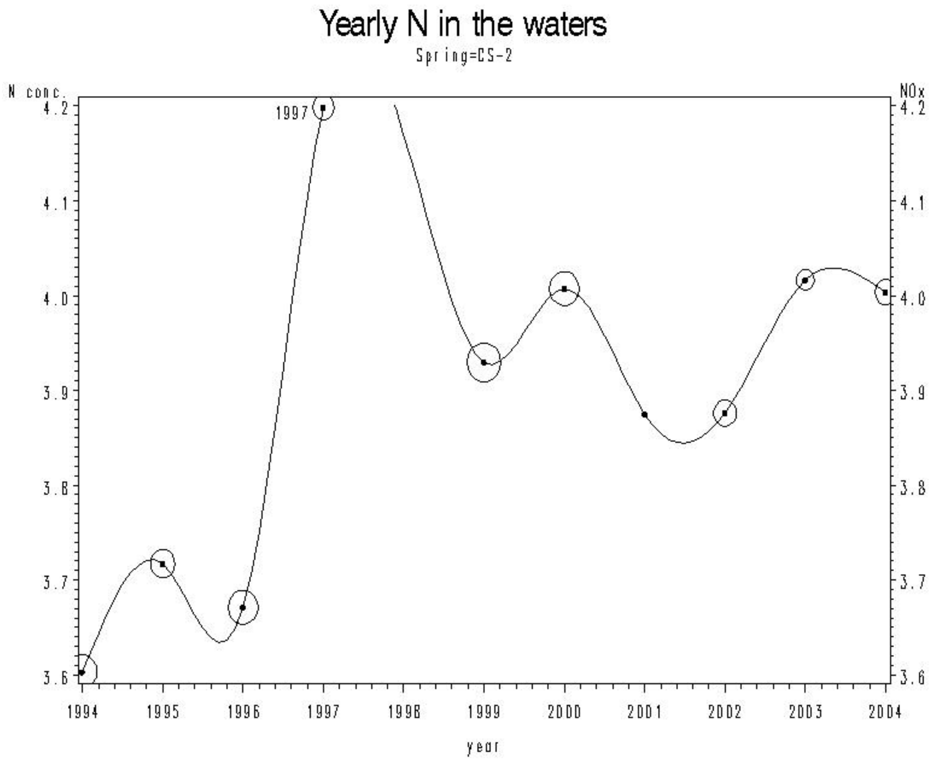


Figure 33. Variation of annual average nitrogen concentrations in springs CS-2. The bubbles represent the variability of the data: the larger the bubble, the more variable the data.

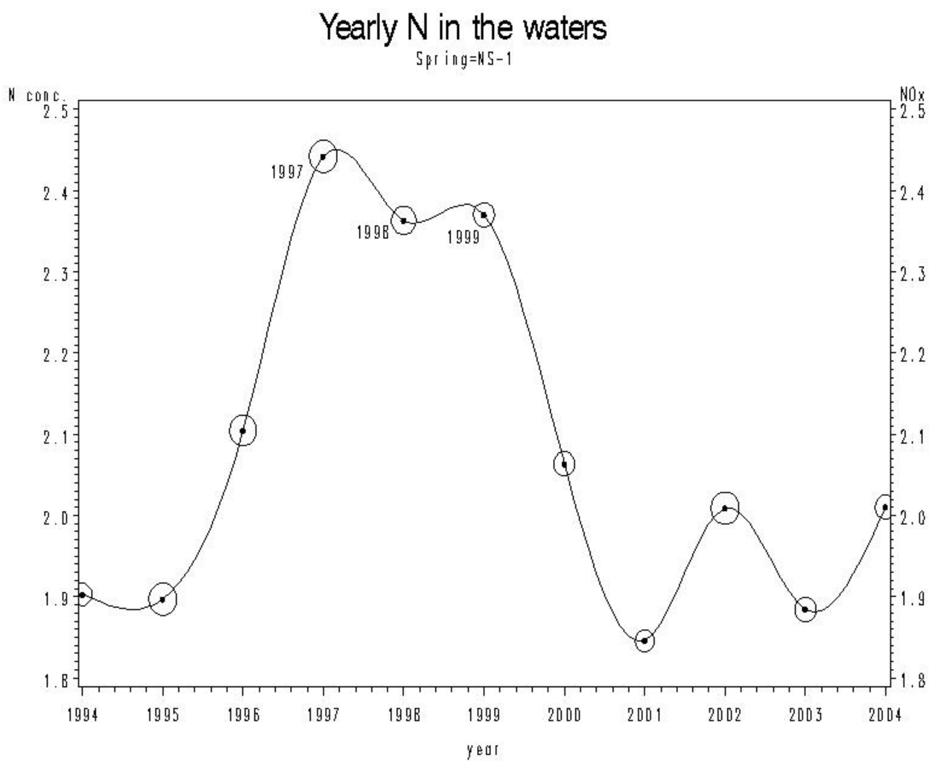


Figure 34. Variation of annual average nitrogen concentrations in spring NS-1. The bubbles represent the variability of the data: the larger the bubble, the more variable the data.

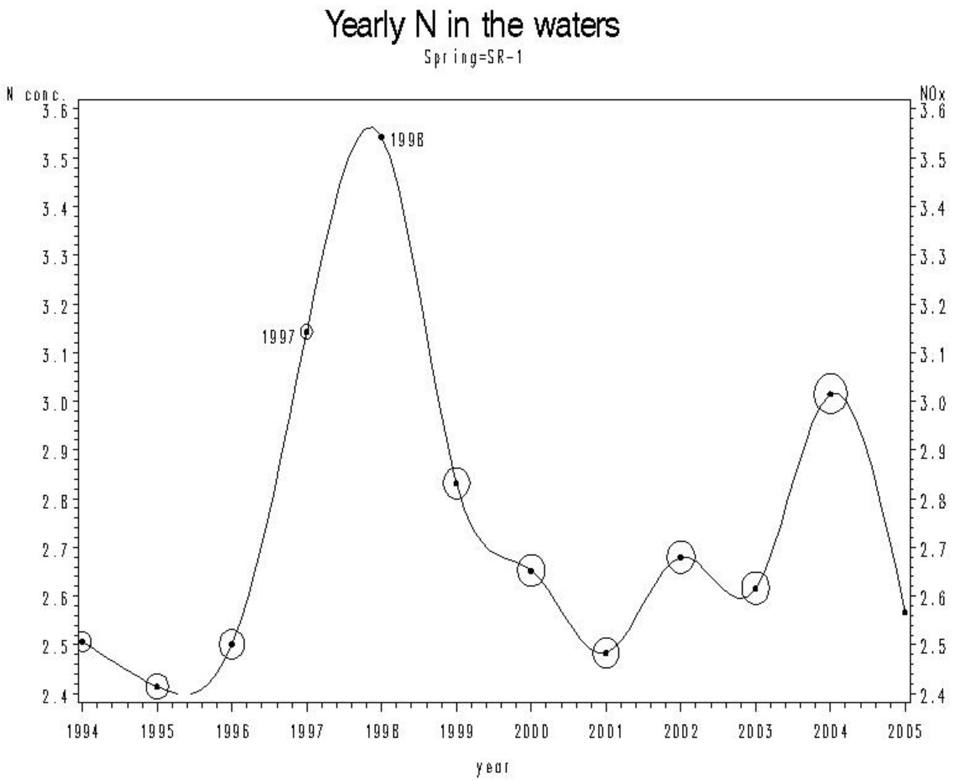


Figure 35. Variation of annual average nitrogen concentrations in spring SR-1. The bubbles represent the variability of the data: the larger the bubble, the more variable the data.

Box plots in Figure 36 through Figure 40 show unequal variations between current observations (1999-2004) and previous observations (1994-1998).

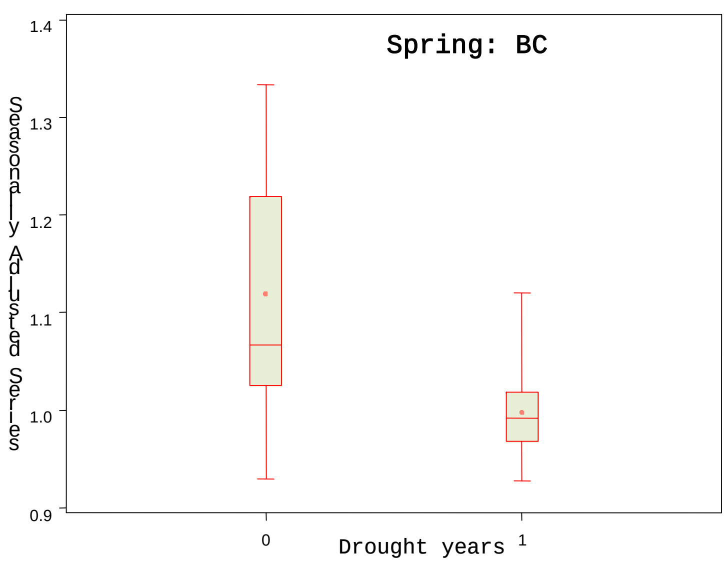


Figure 36. Box plots of nitrogen concentrations in Spring BC, comparing 1994-98 (denoted by 0) and 1999-2004 (denoted by 1) data.

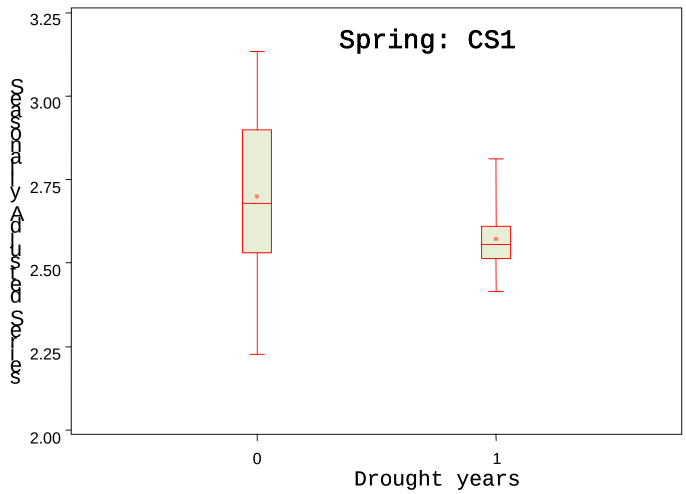


Figure 37. Box plots of nitrogen concentrations in Spring CS1, comparing 1994-98 (denoted by 0) and 1999-2004 (denoted by 1) data.

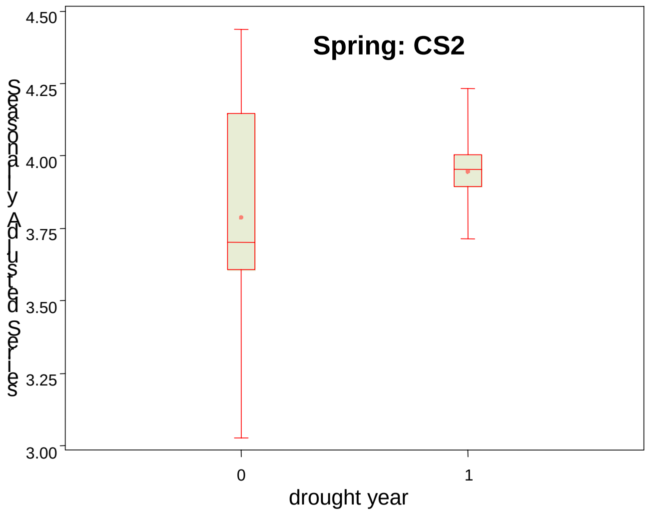


Figure 38. Box plots of nitrogen concentrations in Spring CS2, comparing 1994-98 (denoted by 0) and 1999-2004 (denoted by 1) data.

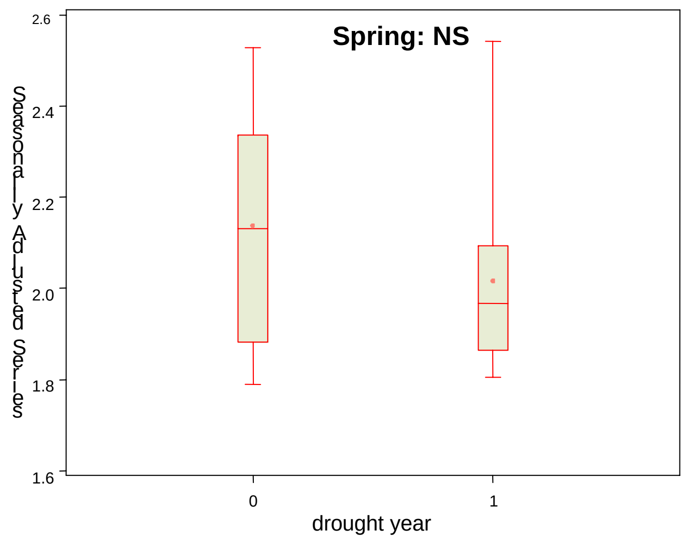


Figure 39. Box plots of nitrogen concentrations in Spring NS, comparing 1994-98 (denoted by 0) and 1999-2004 (denoted by 1) data.

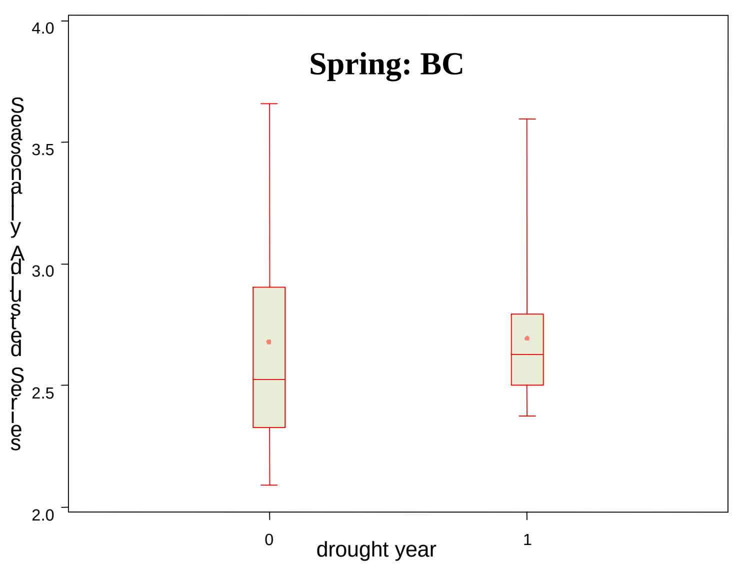


Figure 40. Box plots of nitrogen concentrations in Spring BC, comparing 1994-98 (denoted by 0) and 1999-2004 (denoted by 1) data.

Comparison of mean and variability of spring nitrogen

Statistical tests on similarity of mean and variability are shown in Table 16. Although the box plots indicate that there is a difference in nitrate concentrations, mean nitrogen concentrations are not different for the springs before and after 1999 except for Box Canyon (p=0.0016), which has lower nitrate concentrations after 1999.

Levene’s test shows that current observations (1999-2004) are significantly less scattered than observations for the period 1994-1998 as shown by smaller range in the 1999-2004 box plots compared to the range for the 1994-1998 box plots.

Table 16. Comparison of mean nitrogen concentrations in spring discharge before and after 1999. P-values with an asterisk indicate significance at the 0.05 level.

Waters	Mean N (mg/l)		Std Dev (mg/l)		Levene's test	t-test	Different
	<1999	≥1999	<1999	≥1999	p-value	p-value	(Y/N)
Box Canyon (BC-1)	1.13	1.00	0.13	0.04	0.0002*	0.0016*	Y
Crystal Spring (CS-1)	2.70	2.57	0.25	0.09	0.0039*	0.0826	N
Crystal Spring (CS-2)	3.79	3.95	0.36	0.11	0.0084*	0.1315	N
Niagara Spring (NS-1)	2.14	2.02	0.24	0.20	0.3672	0.0989	N
Snake River (SR-1)	2.68	2.69	0.43	0.28	0.1386	0.9135	N

Causes for the difference

Potential causes for the observed decrease of nitrate concentration in the springs were investigated. We evaluated irrigated crop acreage and crop types, CAFO animal numbers and precipitation before and after 1999.

Precipitation and Irrigation Diversions

Long term changes in precipitation could potentially result in variations in deep percolation and therefore have an effect on nitrogen movement from agricultural land. Figure 41 shows precipitation at Jerome for the period 1950 through 2004 along with North Side Canal Company irrigation diversions for 1990 through 2004 (Pennington, April 2005). The annual average precipitation at Jerome for the period 1950 through 2004 is 10.30 inches (National Weather Service records). Figure 42 shows the change in annual precipitation for the period 1994 through 2004. Average precipitation from 1994-1998 was 12.8 inches/year while it was 8.2 inches/year for 1999 through 2004. The drought period that began in 1999 could be one reason for lower nitrogen concentrations in the springs. However, recharge from precipitation within the study area is probably small when compared to leakage from irrigation canals and deep percolation of irrigation water.

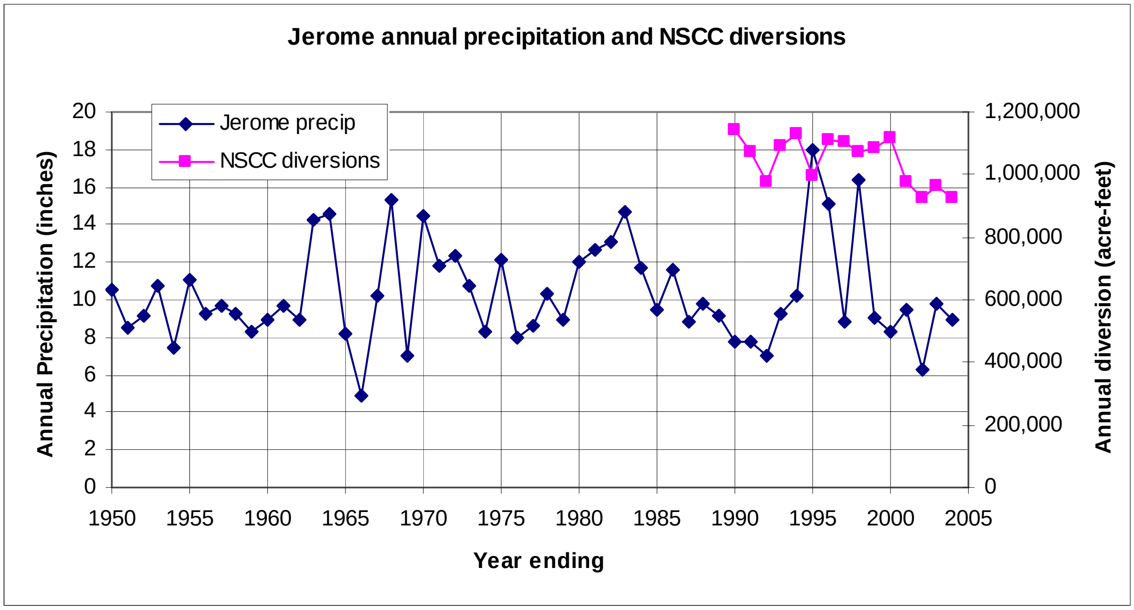


Figure 41. Annual precipitation for Jerome for the period 1950 through 2004, and North Side Canal Company (NSCC) irrigation diversions for the period 1990 through 2004.

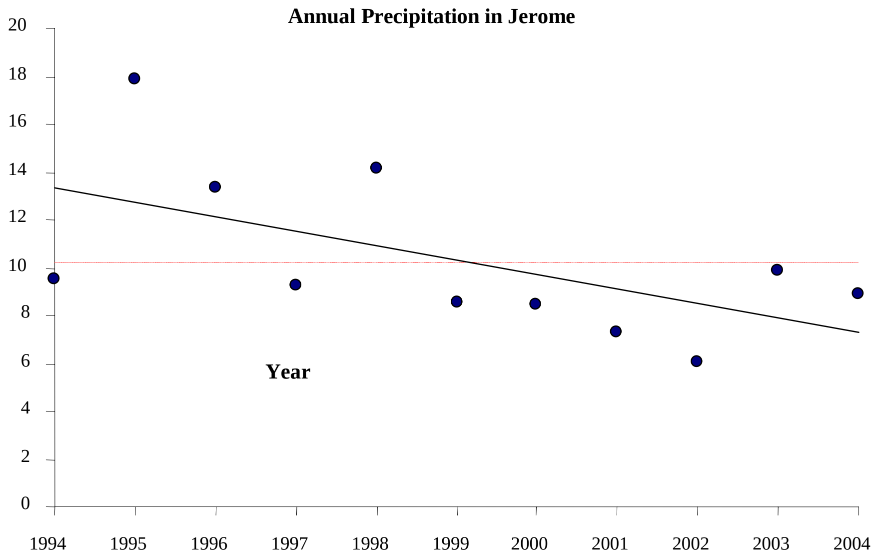


Figure 42. Precipitation at Jerome for 1994 through 2004. The dashed red line shows long term precipitation at Jerome, which is 10.30 inches for the period 1950 through 2004.

Although irrigation diversions track Jerome precipitation to a certain extent (Figure 41) a better measure of water available for irrigation diversion would be flow in the Snake River. When river flow is low less water is available for irrigation diversion. The nearest USGS gauging station above the NSCC diversion point is the Snake River at Neeley.

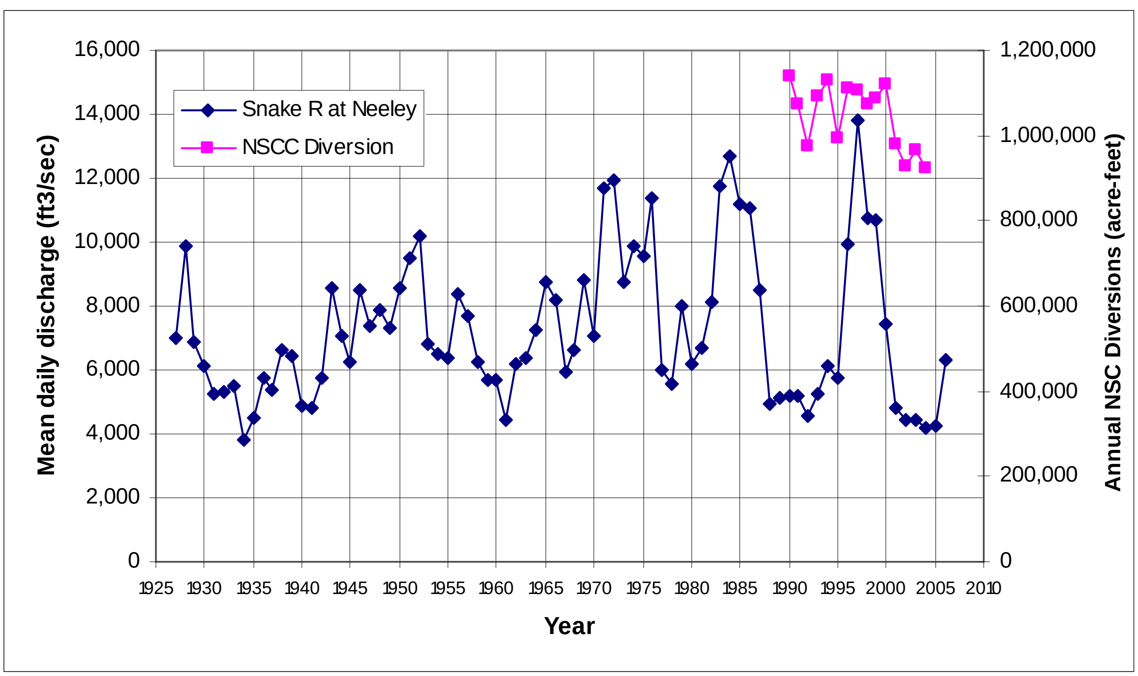


Figure 43. Mean daily discharge for the Snake River at Neeley (USGS gauging station 13077000).

Figure 43 shows mean daily discharge for the Snake River at Neeley for the period 1927 through 2006. Although data are limited, NSCC diversions more closely track flow in the river. Total irrigation diversions have been about 12 percent smaller for 2001 through 2004, compared to the period 1990 through 2000. There does not appear to be a good correlation between irrigation diversions and nitrate concentrations at springs

Agricultural Factors

Comparisons of agricultural factors before and after 1999 are summarized in Table 17. Confined Animal Feeding Operation (CAFO) animal units (AU) have steadily increased in both Gooding and Jerome Counties. Corn acreage has increased while potato acreage has decreased since 1997. These changes are significant at the 0.05 significance level (Table 17). At the same time, a significant decrease in nitrate concentrations has occurred at Box Canyon Springs (Table 16). The two factors are highly correlated (ρ=0.9), based on a T-test on the correlation coefficient. However, a positive correlation between two factors doesn't imply a cause and effect relation ship. In this case the decrease in potato acreage probably hasn't resulted in a large enough decrease in nitrogen fertilizer use that would translate in a decrease in nitrate concentration at springs discharging to the river.

Table 17. Difference of agricultural factors before and after 1999 in delineated area. CAFO = Confined Animal Feeding Operation; AU = animal units where one AU equals 1,000 pounds of live animal weight. P-values with an asterisk indicate significance at the 0.05 level.

	Gooding County			Jerome County		
	CAFO (AU)	Corn (Acreage)	Potato (Acreage)	CAFO (AU)	Corn (Acreage)	Potato (Acreage)
Mean (<1999)	130,800	17,400	12,880	114,800	12,160	19,260
Mean >1999	174,000	27,680	6,700	153,584	23,400	12,240
p-value	0.0073*	0.00378*	0.0002*	0.0007*	0.0005*	0.0025*

Discussion

Increasing nitrate trends were found in Box Canyon, Niagara, and Snake River Farm Springs. The trend is nonlinear of quadratic nature. A linear decreasing trend was found in Crystal Springs #1.

A seasonality pattern is significant in the spring nitrate data. The nitrate concentration in the springs is low during the growing season and increases during non-growing season. Spring nitrate concentrations are lowest from April to June and highest during October.

One possible explanation is that during the growing season plants efficiently remove nitrogen from the soil. A peak removal rate is reached at a certain stage of plant growth and after this time the rate of nitrogen use decreases until the crop is harvested or freezing conditions occur. After this point, any nitrogen remaining in the soil may move downward if sufficient soil moisture is available. This could explain elevated ground water nitrate concentrations that occur each fall.

Trends

The following points can be made regarding nitrate trends in the springs:

- Springs in both the regional aquifer and the local aquifer exhibit seasonality in nitrate concentrations. Concentrations vary on an annual basis, with the smallest concentrations occurring April through June and the largest occurring October through December. These same seasonal nitrate variations repeat from year to year.

- Box Canyon spring, which discharges from the regional ground water flow system, has the lowest nitrate concentration and the smallest annual fluctuation in nitrate concentration of the five springs. This spring, which is down-gradient of the highest density of dairies in the study area is the only spring with long-term nitrate data from the regional ground water flow system. The small annual fluctuations and low nitrate concentrations are most likely due to greater dilution (larger volume of water flowing through the aquifer) compared to smaller flow volumes moving through the local flow system.

- Peaks in nitrate concentration in any one year may represent nitrogen that entered the aquifer during that same year, after the end of the growing season. Travel times for water moving down through the unsaturated fractured basalt and laterally through the regional ground water flow system to spring discharge points are rapid, so variations in water chemistry, especially near spring discharge areas, are transmitted to the discharge points within the same year.

- Nitrate that enters the local flow system on the eastern side of the study area (Minidoka County) probably takes several tens of years to travel to discharge points on the west.

- Nitrate concentrations in the four springs discharging from the local aquifer vary in space and time: nitrate trends at some springs increase while some decline over the long term, and springs in close proximity to each other have statistically different nitrate concentrations (Crystal Springs 1 versus Crystal Springs 2).

  These differences can be attributed to differing land use activities, aquifer properties up-gradient of each spring or spring discharge elevations. For instance, improper land use activities practiced over an area of the aquifer with low hydraulic conductivity could result in degraded water quality at one spring compared to an adjacent spring with similar land use practices but higher hydraulic conductivity. Discharge from a high elevation spring probably represents water from the upper part of the aquifer while a spring discharging from a lower elevation may represent water from lower in the aquifer, or it may represent a mixture of water from upper and lower parts for the aquifer.

- Long-term observations, combined with the specific conductance data collected by Johnson and Struhs (2000), demonstrate that water chemistry throughout the local aquifer is not uniform. For instance, specific conductance values ranged from 642 to 709 μS/cm during the August 2000 sample collection event at the Crystal Springs complex (Crystal Springs 9 and Crystal Springs 1a, Table 3). These two springs, which represent the most up-and down-gradient springs at the complex, are approximately one half mile apart. The Johnson and Struhs (2000) data indicate that water chemistry within the regional aquifer is also variable, but Box Canyon spring is the only spring with long-term nitrate data.

- The upward trend in nitrate concentrations noted in Baldwin et al. (2000) flattened out beginning in 1999 for all springs. Changes in crop acreage, a decrease in surface water diversions for irrigation starting in 2001 (Figure 10), and a steady increase in animal numbers in Gooding County also have occurred during this period. Ground water levels have been declining since the 1950s and spring discharge has decreased during the same period. None of the above factors provide any one set of conditions that can explain changes in ground water nitrate concentrations at all springs.

Decreased ground water nitrate concentrations may be the result of nitrogen storage in soils and the vadose zone due to a more efficient use of irrigation water during drought conditions. If nitrogen is being stored in the vadose zone, a return to normal or wetter than normal conditions may result in this stored nitrogen being transported to the aquifer. At the same time, the use of manure as a fertilizer source has likely increased as the number of animals in the study area has increased. Nutrient management plans that are required for all dairies may result in better management of nutrients from both manure and commercial fertilizer sources.

The above evaluation highlights the difficulty in the determination of land use factors that can impact area-wide ground water quality. Ground water flow paths through the basalt aquifer are probably strongly laminar, i.e., limited dispersion occurs when contaminants enter the flow system. This means that contaminant plumes emanating from a source tend to be long and narrow and although two springs may be adjacent water chemistry may be different.

Nitrogen Mobility

The mobility of the two general nitrogen sources (inorganic and organic) is fundamentally different:

- The forms of nitrogen fertilizers are anhydrous ammonia (82 % N), urea (46.4 % N), nitrogen solutions (28-32 % N) ammonium sulfate (21 % N) and ammonium nitrate (34 % N). These nitrogen forms are plant available, meaning that the nitrogen can be directly absorbed or taken up by plants.
- Organic nitrogen, such as proteins, amino acids and urea are found in living organisms and decaying plant and animal tissues. These organic nitrogen forms must be converted to plant available nitrogen forms through the process of mineralization. Not all nitrogen in manure is plant available in the first year after application due to the slow mineralization rates of nitrogen in the organic material.

Urea, which is listed as both an inorganic and an organic nitrogen source, is a naturally occurring compound contained in the urine of animals. It also is manufactured by combining carbon dioxide with ammonia; the final product has the molecular formula $(NH_2)_2CO$. Since it has the highest nitrogen content of all solid nitrogen fertilizers it has the lowest transportation cost per unit of nitrogen. In the soil, urea from both inorganic and organic sources must be converted to ammonium ions (NH_4^+) and then to the plant available NO_3 form.

A decay series for mineralization of nitrogen in organic material might be 0.50, 0.25, 0.15, and 0.10 over a four-year period. This decay series indicates that nitrogen will continue to be mineralized from manure for several years following an initial application. For fields where manure is applied several years in succession nitrogen mineralization is additive for all the preceding years of application.

Manure Application

Information on manure application within the study area is available for 2002 for Gooding, Jerome, Lincoln and Minidoka Counties (National Agricultural Statistics Services). This information, along with animal numbers for 2002, is shown in Table 18.

The four-county acreage where manure was applied amounted to 70,983 acres, while there were 194,100 milk cows in the four-county area for the same year. The total number of cattle and calves in the four-county area for 2002 was 409,000 head. As a general rule of thumb, one to two acres are required for treatment of waste (solids and liquids) generated by one milk cow. Using this number, the acreage required for treatment of waste generated by 194,100 milk cows would range from 194,100 to 388,200 acres.

Table 18. Farm acreage treated with manure application for 2002, the only year for which data are available. Also listed are cattle numbers for the four-county area for 2002. (Source: 2002 Census of Agriculture, National Agricultural Statistics Service).

Year	County	Acres treated with manure	Milk cows	Total cattle and calves
2002	Gooding	33,628	106,000	173,000
2002	Jerome	23,048	67,000	155,000
2002	Lincoln	4,720	12,000	38,000
2002	Minidoka	9,587	9,100	43,000
Totals for 4-county area		**70,983**	**194,100**	**409,000**

One measure of manure treatment effectiveness is available from soil test phosphorus results from regulatory soil tests required by IDA. Soil test phosphorus results are available for fields in Gooding, Jerome, and Lincoln Counties, where dairy manure has been applied. Nutrient Management Code 590 lists phosphorus threshold values that are intended to be protective of either surface or ground water resources:

- If surface water runoff from a particular field is the primary resource concern, then soil samples from the 0-12” depth should meet the phosphorus threshold value of 40 mg/kg.
- If ground water beneath a field is the resource of concern, then soil samples from the 18-24” depth should meet the phosphorus threshold value of either 20 mg/kg (if the depth to fractured bedrock, cobbles or gravel is less than 5 feet) or 30 mg/kg (if the depth to fractured bedrock, cobbles or gravel is greater than five feet.)

The initial soil test phosphorus results did not identify the depth to fractured bedrock, cobbles or gravel, so for the purposes of this discussion, the 30 mg/kg soil test phosphorus threshold value will be used to evaluate areas where ground water is the resource of concern.

Figure 44, Figure 45 and Figure 46 show IDA soil test phosphorus values for fields in Gooding, Jerome, and Lincoln Counties where dairy waste is applied according to a nutrient management plan. Soil test phosphorus data were not available for Minidoka County. In Gooding County, soil test phosphorus values are less than the 40 mg/kg threshold value for 72 percent of the samples where surface water resources are a concern. Soil test phosphorus values are less than the 30 mg/kg threshold value for 73 percent of the fields where ground water resources are a concern.

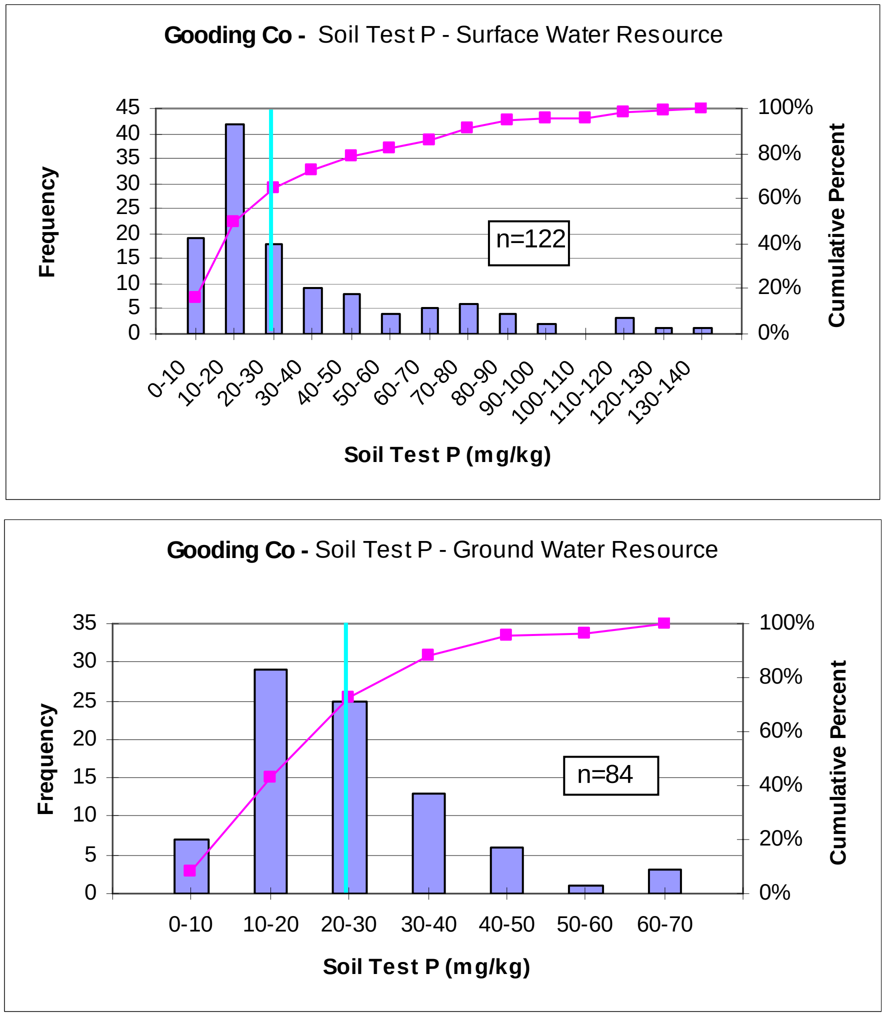
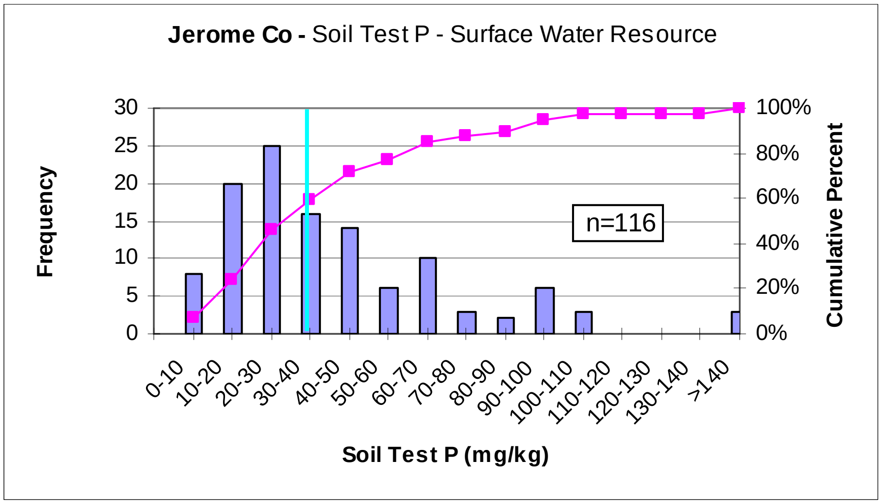


Figure 44. Histograms and cumulative frequency plots showing Gooding County soil test phosphorus results for surface water and ground water resource concerns. Blue lines indicate phosphorus threshold limits.



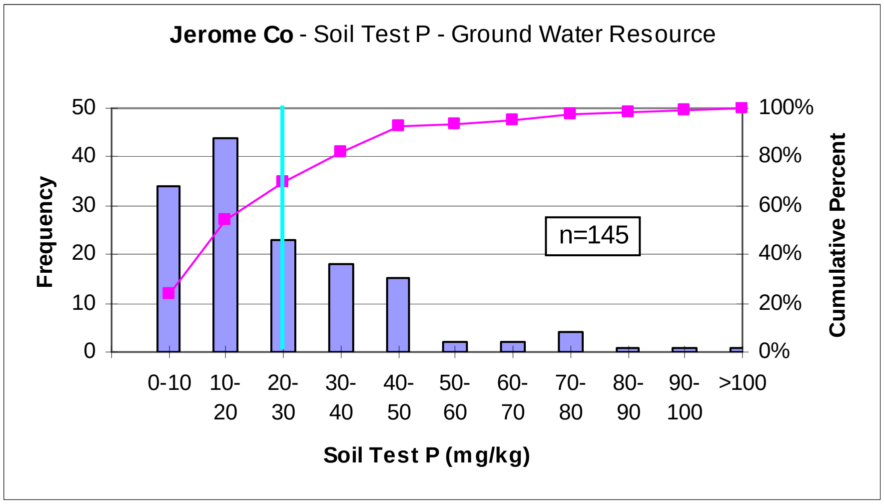
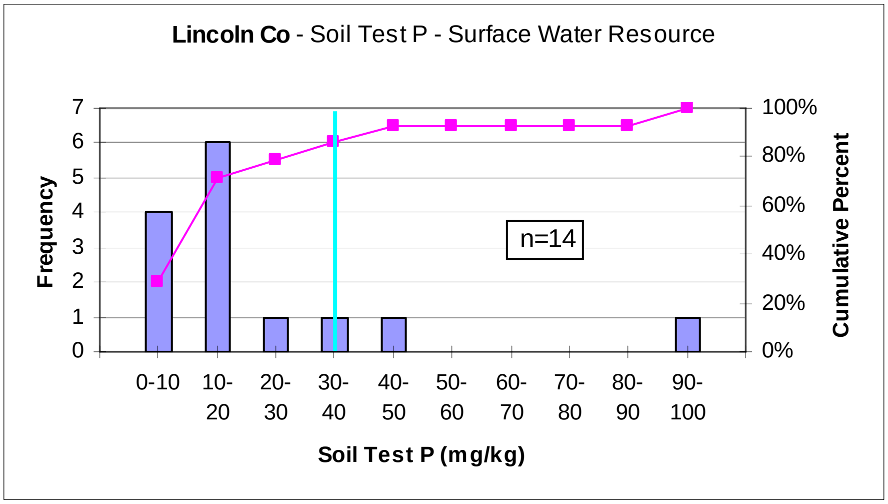


Figure 45. Histograms showing Jerome County soil test phosphorus results for surface water and ground water resource concerns. Red lines indicate phosphorus threshold limits.



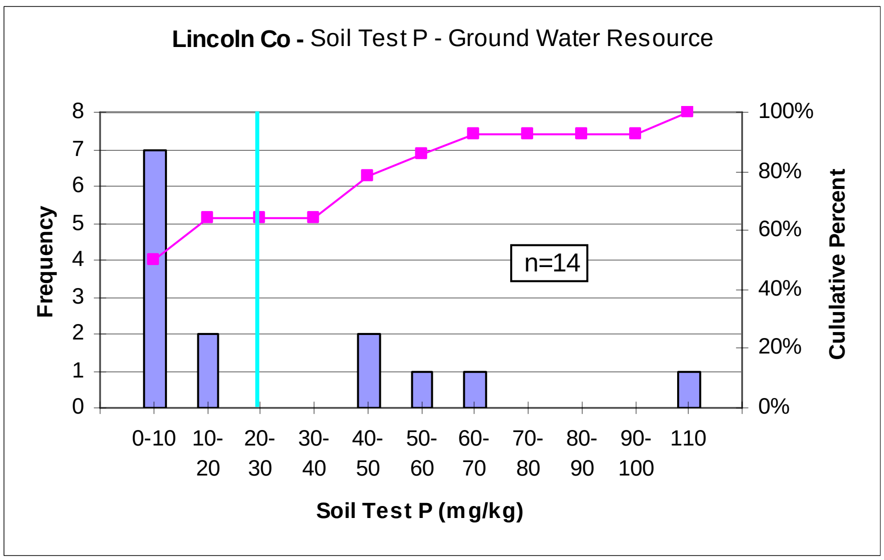


Figure 46. Histograms showing Lincoln County soil test phosphorus results for surface water and ground water resource concerns. Red lines indicate phosphorus threshold limits.

In Jerome County, soil test phosphorus values are less than the 40 mg/kg threshold value for 72 percent of the samples where surface water resources are a concern. Soil test phosphorus values are less than the 30 mg/kg threshold value for 73 percent of the fields where ground water resources are a concern.

In Lincoln County, soil test phosphorus values are less than the 40 mg/kg threshold value for 86 percent of the samples where surface water resources are a concern. Soil test phosphorus values are less than the 30 mg/kg threshold value for 64 percent of the fields where ground water resources are a concern.

A larger percentage of all samples would exceed the 20 mg/kg threshold phosphorus value for fields with a ground water resource concern or where the depth to fractured bedrock, cobbles or gravel is less than 5 feet; as noted above these conditions were not identified in the initial data set. As a general rule, nitrogen over application has occurred in fields where elevated phosphorus is present.

Conclusions and Recommendations

Conclusions and recommendations stemming from this study are as follows:

- Specific conductance, nitrate, and isotope data in wells and springs discharging from the ESRP were used to evaluate ground water flow systems and water chemistry in the study area. When combined with isotope, water chemistry and potentiometric information from previous studies, the information indicates two ground water flow systems exist in the study area: a local ground water flow system in the southern part and the regional flow system in the northern part.

- In the western part of the study area the aquifer become thinner, forcing the same volume of ground water to move through a smaller cross sectional area. This results in more rapid ground water flow velocities than in the eastern part of the study area. The thinner cross sectional area also causes ground water discharge to occur over a smaller vertical interval than would otherwise be the case.

- Water chemistry data from spring locations provides a more integrated view of region wide ground water quality in either the local or regional aquifers compared to wells. This is because spring discharge points represent ground water flow from multiple flow paths where well samples represent ground water from a single flow path. Springs discharging at high elevations represent the uppermost part of the aquifer. Water chemistry in these springs is more likely to detect impacts than low elevation springs that integrate water from a large vertical section of the aquifer.

- The local flow system is characterized by elevated specific conductance and nitrate concentrations, short ground water flow paths and limited contaminant dilution compared to the regional ground water flow system. Total dissolved solids concentrations in the local flow system are also elevated compared to ground water in the regional aquifer. The mean nitrate concentration in the eastern part of the local flow system, near the Snake River, is 1.9 mg/L. The nitrate concentration increases to 4 to 5 mg/L about ten miles down-gradient of the Snake River and remains at this concentration across the study area to where springs discharge along the Snake River. The overall mean nitrate concentration in the local aquifer is 4.27 mg/L (n=228) and the mean specific conductance is 715 µS/cm (n=356).

- The regional ground water flow system is characterized by low specific conductance, low total dissolved solids concentrations and low nitrate concentrations compared to water quality in the southern or local aquifer. The regional flow system has larger flow volumes that dilute contaminants entering ground water. The mean nitrate concentration in the regional aquifer is 1.29 mg/L (n=125) and the mean specific conductance is 417 µS/cm (n=170).

- Excess nitrogen application in the eastern part of the local aquifer results in increased nitrate concentrations. In the central and western parts of the study area irrigation canals and laterals introduce good quality water into the local aquifer through leakage. In spite of this additional water dilution does not occur but rather nitrate concentrations remain constant across the study area. This is probably due to additional nitrogen loading to the aquifer from agricultural sources in the central and western parts of the study area.

- Nutrient management plans have been developed and implemented for all dairy operations. Regulatory soil sampling by IDA is underway to verify that soil nutrient levels are protective of both surface water and ground water resources at these sites. However, nutrient management plans only cover the acreage owned or controlled by a particular dairy. Consideration should be given for development of nutrient management plans for all land where dairy waste is applied.
- Nutrient management plans have been developed for some beef operations. Consideration also should be given for development of nutrient management plans for animal waste that is applied from all beef operations.
- A nitrogen budget prepared for the four county study area determined that of the estimated 80,000,000 pounds per year of nitrogen that is available, about 98 percent is from commercial fertilizer, livestock and legume sources. Nitrogen in animal waste accounts for about 43 percent of the total, commercial fertilizer accounts for about for about 47 percent of the total and nitrogen from plow down of legume crops (alfalfa, beans and peas) accounts for about 8 percent of the estimated nitrogen load.
- Consideration should be given for development of nutrient management plans for acreage where commercial fertilizer is applied. Nitrogen from plow down of legumes has probably been an overlooked nitrogen source. The University of Idaho Fertilizer Guides should be revised to reflect nitrogen release from legumes that has been documented in field research.
- The relative percentage of crops grown in the four counties within the study area has changed over the past few years due to changing economic conditions. The acreage devoted to potatoes has decreased over the past five years in Gooding, Jerome and Lincoln counties and has increased and then declined in Minidoka County. Corn acreage has increased substantially in Gooding and Jerome Counties, mostly in response to the increased usage of this crop in dairy rations. The commercial nitrogen fertilizer usage in the four county area probably has changed as a result of changing crop acreages but data are not available to evaluate whether this nitrogen load has increased or decreased.
- Although the highest concentration of dairies occurs over the regional aquifer in southern Gooding and western Jerome Counties, ground water nitrate concentrations remain low in this part of the aquifer. This is most likely due to large volumes of ground water moving through the system that dilute nitrogen loads entering the system.
- Nitrogen contained in springs discharging to the river was estimated to range from about 18,000,000 to about 25,000,000 pounds per year. The value of this nitrogen ranges from about $7,000,000 to about $10,000,000 per year using a 1995 central Idaho nitrogen cost of $0.39 per pound.
- For five springs where long-term nitrate data are available, concentrations increased during the period 1991 or 1994 through 1999 (Baldwin et al, 2000). Nitrate

concentrations in these springs were re-examined for trends in the current study. At four springs (Crystal Springs #1, Crystal Springs #2, Niagara Springs and Clear Lakes Springs) the trend in nitrate concentration flattened out during the period 1994-2000, and, at Box Canyon Spring, nitrate concentrations decreased during the same time period.

- Long-term nitrate concentrations are relatively stable at springs although seasonal water chemistry variations occur. This apparent stability has occurred during a period in which land use and water supply conditions are constantly changing. Irrigation diversions decreased during the period 2001 through 2004, ground water levels declined and spring discharge decreased during the same period. If recharge has decreased then nitrate transported to the aquifer may also have decreased. Nitrogen storage may be occurring in the soil and vadose zone, although soils test data are not available to evaluate this. A return to average or above average recharge conditions could transport stored nitrogen, resulting in increased ground water and spring nitrate concentrations. Another factor may be that the time frame over which nitrate observations are available is simply too short to detect meaningful changes.
- Specific conductance measurements at individual springs can be used as a tool to evaluate nitrate concentrations in ground water, based on correlations established in this study.
- Land use decisions for the study area should be evaluated based on whether the activity occurs over the local or the regional ground water flow system.
- Spring water chemistry data provide information at the flow system discharge point and therefore are good indicators of total contaminant loads coming from the aquifer and entering the river. Long term nitrate data currently are being collected at four springs discharging from the local aquifer and one spring discharging from the regional aquifer. Data from three of the springs are provided by private entities. Additional spring sampling locations should be established by DEQ in both the local and regional flow systems so that trends in long-term water quality can be established.

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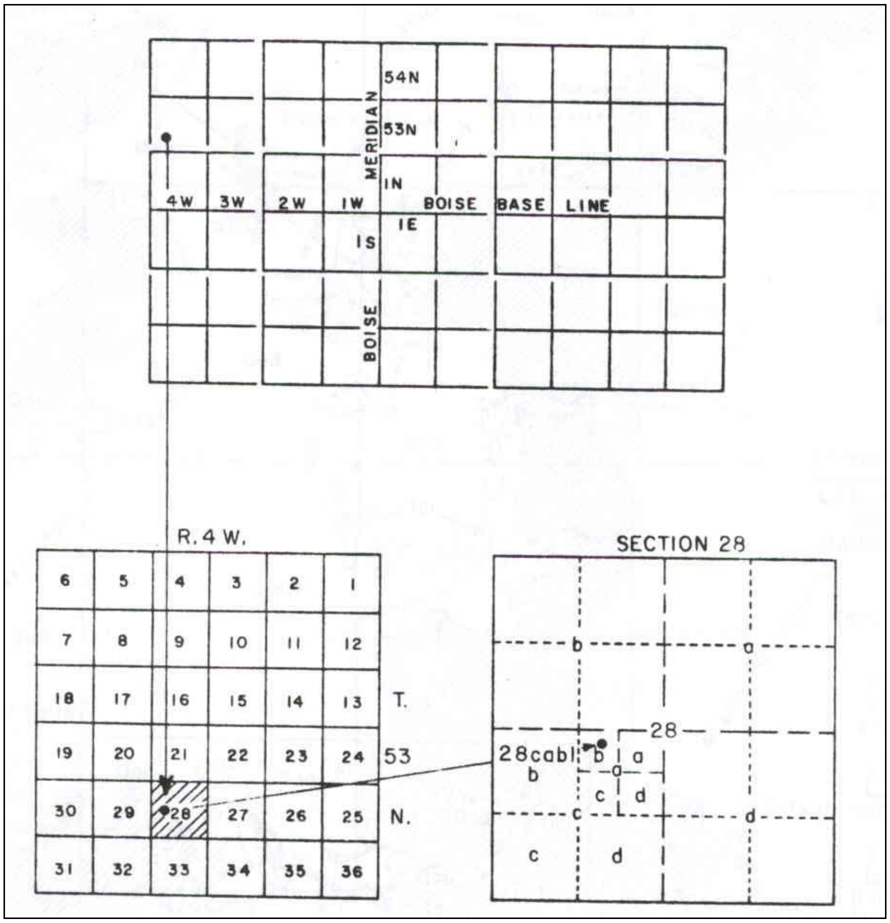
Appendix A. Well Numbering system



The well numbering system used in this report is based on the common subdivision of land into townships, ranges and sections. This subdivision of lands is called the Public Land Survey System (PLSS) and is referenced to the Boise baseline and meridian. The first two segments of a well number represent the township and range. The third segment gives the section number followed by three or four letters and a number. The letters indicate the ¼ section (160 acre tract), ¼-¼ section (40 acre tract), ¼-¼-¼ section (10 acre tract) and ¼-¼-¼-¼ section (2.5 acre tract) and the serial number of the well within the tract. Quarter sections are labeled A, B, C and D in counterclockwise order starting with the northeast quarter of the section. Successively smaller tracts are labeled in the same manner.

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