Ground Water Quality Technical Report No. 15

Ground Water Quality Investigation
and
Wellhead Protection Study
Ferdinand, Idaho

Idaho Department of Environmental Quality
Technical Services Division
July 2000

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Acknowledgments

This report, evaluating potential sources of nitrate found in public and domestic wells in the Ferdinand area, was a cooperative effort of the Idaho Division of Environmental Quality (IDEQ) and local residents. The support of the Ferdinand City Council and public water system operator Mr. Ron Riener was essential in conducting the project. Additionally, without the cooperation and assistance of local well owners who allowed IDEQ access to sample their wells, this study would not have been possible.

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1.0 ABSTRACT

Ground water in the Ferdinand, Idaho area was sampled during November 1998 to evaluate potential sources of nitrogen contributing to elevated nitrate levels in the ground water. The City of Ferdinand was one of five communities in Idaho to receive technical assistance from the Idaho Division of Environmental Quality and financial assistance from a U.S. Environmental Protection Agency 319 grant to investigate the cause of elevated nitrates in their drinking water system. The communities can use the information from the study to implement a ground water protection program.

Water quality monitoring of the City of Ferdinand public water system has historically shown nitrate levels near the drinking water standard of 10 milligrams per liter. Previous investigations established that nitrate-degraded ground water is widespread throughout the Camas Prairie. Potential sources of nitrate in the area include domestic septic systems, small cattle feedlots, fertilizer storage and distribution, and organic (manure) and inorganic chemical fertilizer application on agricultural land.

The ground water quality evaluation consisted of a review of previous water quality data, and collection and analysis of water samples from six wells and two springs located within an approximate 2-mile radius of the City of Ferdinand. Numerous laboratory analyses were performed to assess the potential sources of elevated nitrate. Water samples were analyzed for major ions, nitrate, ammonia, pesticides, and nitrogen isotope ratios. The nitrogen isotope analysis is a relatively uncommon analysis that has been utilized only recently by the Idaho Division of Environmental Quality.

Nitrate was the only chemical analyzed that was detected in concentrations greater than drinking water standards. Nitrate was detected in water samples collected from six of the eight locations. The shallow basalt aquifer underlying much of the area appears to contain the highest concentrations of nitrate. The nitrogen isotope results indicate the predominant source of nitrate is inorganic chemical fertilizer. No pesticides were detected in any water samples.

Based on the investigation results, regional ground water protection efforts should focus on management of inorganic commercial fertilizer. Other nitrogen sources may impact ground water quality on a localized scale and should be managed on a case-by-case basis.

2.0 INTRODUCTION: BACKGROUND AND PURPOSE OF PROJECT

During May of 1998, the Idaho Division of Environmental Quality (IDEQ) selected numerous communities within the state to be included in the *Wellhead Protection Viability Demonstration Project.* The project was designed to assist community water systems (CWSs) serving populations less than 10,000 impacted by nonpoint source contaminants such as nitrate. CWSs with detections of nitrate within plus or minus 25 percent of the drinking water maximum contaminant level (MCL) were selected for the project. Ferdinand, Idaho was one of the communities selected because of elevated nitrate concentrations in their municipal well as well as their commitment to protecting and managing their ground water resource. This study focused on CWSs impacted by nitrate due to the widespread usage of nitrate.

Excessive levels of nitrate can cause serious illness and sometimes death in infants under 6 months of age. The primary hazard from consuming water high in nitrate is methemoglobinemia (sometimes referred to as "blue-baby syndrome"). The condition occurs because nitrite, which is transformed from nitrate in the digestive system, causes the iron in the hemoglobin to oxidize, creating methemoglobin. This methemoglobin lacks the oxygen carrying capacity of hemoglobin. In most cases health deteriorates over a period of days, with symptoms including shortness of breath and blueness of skin.

Ground water quality data including common ions, nutrients, bacteria, pesticides, and nitrogen isotopes, were collected and interpreted to determine the source of nitrate found in the ground water. All the analyses, except for the nitrogen isotope ratio analysis, are common tests that can be conducted by most analytical laboratories. The nitrogen isotope ratio analysis is an analytical procedure that is performed primarily at universities and research laboratories. The nitrogen isotope information is extremely valuable in the evaluation of sources contributing to elevated levels of nitrate in the ground water. Numerous scientific articles have documented the benefit of employing nitrogen isotopes in environmental studies (Gormly and Spalding, 1979; Aravena et al., 1993; Exner and Spalding, 1994; Gellenbeck, 1994; and Seiler, 1996). Recently, the IDEQ used nitrogen isotope analyses to identify sources of nitrate contamination in Ada County, Idaho (Howarth, 1999).

DEQ activities during this study included the following.

(1) DEQ representatives met with city officials from Ferdinand to explain the project and to enlist them as project participants.

(2) Wells were sampled and, where feasible, water levels were measured.

(3) An inventory of potential contaminant sources was conducted.

(4) The wellhead protection area for the City of Ferdinand was delineated.

(5) All ground water quality results were received and sent to the respective well owners.

(6) This summary report was prepared.

2.1 Purpose and Objectives

The purpose of this project is to collect ground water quality and hydrogeologic information to evaluate elevated nitrate concentrations near the City of Ferdinand and to assist the local residents in protecting their ground water resources. The project should help identify sources of nitrate impacting the drinking water supply of the city and surrounding domestic wells. The specific objectives of the project include:

- Collect and analyze ground water quality data and locate potential sources of ground water contamination in the vicinity of the City of Ferdinand.
- Estimate the wellhead protection area for the City of Ferdinand using two different methods; compare the sizes of the areas and compare the number of potential contaminant sources within the different wellhead protection areas.
- Assess potential sources of nitrate contamination in the vicinity of Ferdinand and utilize nitrogen isotope and hydrochemical data to identify, where possible, the source or sources of nitrate contamination in the ground water.

2.2 Historic Water Quality Data

Available historic water quality data for nitrate, bacteria, and organic compounds including pesticides and herbicides were reviewed and summarized for any evidence of trends occurring within the last 10 to 15 years. The review was limited to the public water system monitoring data for the City of Ferdinand public drinking water system at the DEQ Lewiston Regional Office and information contained in the IDEQ Drinking Water Information Management System (DWIMS).

Nitrate results for the period 1985 through 1999 were reviewed and are shown in Table 1. The results indicate that nitrate concentrations have fluctuated between 5.6 milligrams per liter (mg/l) and 10.5 mg/l over this time period.

Laboratory tests conducted between 1990 and 1999 indicate water samples collected from the City of Ferdinand water system did not contain organic compounds. The water samples collected from the City of Ferdinand water system during this time period also did not contain inorganic compounds above the MCL. Samples collected in 1998 indicate that total coliform bacteria were present on a couple of occasions in the City of Ferdinand water system. None of the ten samples containing total coliform bacteria were found to contain detectable levels of *E-Coli* bacteria.

Table 1. Nitrate Results for City of Ferdinand Public Water System (1985-1999)

Sample Date	Well	Nitrate Concentration (mg/l)
8/27/85	#1	5.95
3/31/87	#1	5.84
8/17/88	#1	10.5
4/6/89	#1	5.8
3/17/94	#1	8
7/11/94	#1	9.7
9/19/94	#1	6.33
8/28/95	#1	6.41
4/23/96	#1	8.5
10/02/97	#1	5.6
9/15/98	#1	6.7
10/14/98	#2	6.0
11/12/98	#1	6.49
12/16/99	#2	5.6

2.3 Study Area

The study area is located in northwest Idaho County within the boundaries of the Nez Perce Tribe Reservation and encompasses the City of Ferdinand, Idaho (**Figure 1**). U.S. Highway 95 runs just east of town (the old route of U.S. Highway 95 is depicted on Figure 3) continuing on to Grangeville to the south and Lewiston to the north. Land use within the City of Ferdinand consists of residential homes and small businesses. The City of Ferdinand is a small, primarily agricultural community of approximately 200 people that provides municipal drinking water and sewer service to its residents. Homes outside the City of Ferdinand limits are not connected to the city water system or sewer system; they maintain domestic wells and individual septic systems. Dry-land farming of wheat is the predominant land use surrounding the City of Ferdinand. Secondary crops grown in the area include barley, peas, oats, canola, and alfalfa. Potential sources of nitrate contamination in the Ferdinand area include sewer and septic systems, commercial fertilizer, small feedlots (approximately 10-30 head of livestock), and a facility that distributes fertilizer and pesticides.

2.4 Previous Investigations

The IDEQ conducted a study during the summer of 1998 (*A Reconnaissance of Nitrite/Nitrate in Camas Prairie Ground Water* [Bentz, 1998]) evaluating the extent of nitrate contamination on the Camas Prairie. Ground water samples from 53 wells were collected during this regional investigation and analyzed for nitrate **(Figure 2).** The regional study suggested the groundwater in the Ferdinand area contained elevated nitrate levels. Of the 53 locations sampled during the regional study, 15 wells and two springs were located within a 2-mile radius of the City of Ferdinand. Six of the wells and the two springs were selected for additional evaluation during this study. These wells included four domestic wells, one industrial well, and one city well. The springs included one spring used for domestic water supply and one spring allowed to naturally discharge into a surface drainage and not used for drinking water. The wells and springs were selected because they are believed to be hydraulically upgradient of the City of Ferdinand wells.

3.0 CHARACTERIZATION OF THE WELLHEAD PROTECTION AREA

3.1 Climate

Mean annual precipitation on the Camas Prairie is approximately 22 inches based on precipitation records from the years 1961 through 1990 for the cities of Nez Perce and Grangeville (Idaho State Climate Services, 1999). Approximately one-half the precipitation is received during March through June. May is the wettest month, receiving approximately 3 inches of precipitation, and July is the driest month, receiving an average of 1 inch of precipitation.

The mean annual temperature is approximately 46^{o} Fahrenheit (Idaho State Climate Services, 1999). July is the warmest month with a mean temperature of 65^{o} Fahrenheit. January is the coldest month with a mean temperature of 28^{o} Fahrenheit. The annual frost-free days vary from 100 to 150 days (Barker et. al., 1983).

3.2 Soils

The *Nez Perce-Uhlorn-Shebang* is the primary soil unit in the Ferdinand area (Figure 3). Information regarding the soils in the area is important because they influence the rate of infiltration and affect contaminant transport. The general soil characteristics are as follows:

! very deep, gently sloping to moderately steep, moderately well drained and well drained soils that have a clayey and loamy subsoil; formed in loess (USDA, 1982).

The topography of this unit is characteristic of a large, undulating and rolling plateau (USDA, 1982). The Nez Perce soils face south, east, and west; Uhlorn soils face north; and Shebang soils have southern exposure (USDA, 1982).

Nez Perce soils have the following characteristics:

! they are moderately well drained
! the surface layer is dark gray and grayish brown silt loam about 17 inches thick
! the subsurface layer is light brownish gray silt loam about 3 inches thick
! the upper part of the subsoil is pale brown and brown silty clay about 22 inches thick
! and the lower part is light brownish gray silty clay about 60 inches deep.

Uhlorn soils have the following characteristics:

! they are well drained
! the surface layer is dark gray and dark grayish brown silt loam about 13 inches thick
! the upper part of the subsoil is brown silt loam about 5 inches thick
! the lower part is yellowish brown and brown silty clay loam to a depth of 60 inches.

Shebang soils have the following characteristics:

! they are moderately well drained

- the surface layer is dark gray silt loam about 9 inches thick
- the subsurface layer is gray silt loam about 1 inch thick
- the subsoil is very dark gray, dark grayish brown and brown, and dark brown clay to a depth of 60 inches.

3.3 Hydrogeology

The predominant geologic feature underlying the Ferdinand area is the Columbia River Basalt. Approximately 34-40 million years ago during the mid-Tertiary period, several basalt flows extruded from vents in what are now Oregon and Washington, resulting in a succession of faulted basalt layers (Castelin, 1976). These basalt flows did not extrude continuously, but were deposited such that weathering took place between flows. This weathering process produced interbeds of weathered material.

As the basalt flowed out across what is now the Camas Prairie, it inundated much of the granitic basement complex. Cottonwood Butte and other smaller granitic features on the prairie were not completely inundated by the flows. A contact between the basalt and the granite is located just to the south of the City of Ferdinand and runs in a roughly southeast-northwest direction. Figure 4 illustrates the general geology of the Camas Prairie, and shows the granite features protruding above the basalt flows (Bonf and Wood, 1978, and Johnson and Raines 1996). A report prepared by Dr. John Bond for the City of Ferdinand (Bond, 1997) indicates that a transition zone between the basalt and granite underlies the City of Ferdinand.

Wells surrounding of the City of Ferdinand are completed primarily in basalt. However, wells south of the city are completed in granite. Driller's logs are available for Well 02 (granite), Well 05 (basalt), and Well 06 (basalt). The locations of the wells are shown on Figure 4. Driller's logs from wells that were not sampled also were reviewed. Driller's logs for the City of Ferdinand Wells are included as Appendix A. The driller's logs indicate that in the basalt aquifer there are two primary water-bearing zones. These zones are basalt interbeds consisting of sandy clays, weathered basalt, and shale. The thickness and depth of occurrence vary spatially, but the uppermost interbed occurs primarily from 62 to 100 feet below land surface (bls), while the lower interbed occurs most frequently from approximately 125 to 175 feet. An example of a well completed in the basalt is shown on the driller's log from Well 05 (Figure 5).

Water occurs in the granite aquifer wells in primarily decomposed granite at depths greater than 200 feet bls. An example of a well completed in the granite is shown on the driller's log from Well 02 (Figure 6).

Ground water flow on the northern half of the Camas Prairie, in a very general sense, moves in a northeasterly direction (Bentz, 1998). Static water level measurements were collected from ten wells to better evaluate the direction of ground water flow in the aquifer below the City of Ferdinand. The direction of ground water flow could only be estimated from the water level measurements due to variations in well depth and subsurface geology. To accurately delineate the direction of ground water flow, all wells used in the water level survey should draw water from the same water-bearing zone. The water elevations shown on Figure 7 indicate that in November 1998 the ground water underlying Ferdinand was flowing to the east and northeast under a gradient of approximately 200 feet per mile (0.035 feet/foot). This depiction uses limited data and that ground water flow direction may vary considerably on a site-specific basis.

3.4 Wellhead Protection Area Delineation

The wellhead protection area for the City of Ferdinand was developed using two different methods: the Basic Method and the Refined Analytical Method. Comparison of the wellhead protection delineation methods was done to evaluate whether collection of site-specific hydrogeologic information is scientifically or economically justified. The wellhead protection areas created using the different methods are shown together on Figure 8 for comparison. The two methods are described in Chapter 4 the Idaho Wellhead Protection Plan.

In accordance with the Idaho Wellhead Protection Plan (IDEQ, 1997), the wellhead protection area for the City of Ferdinand is composed of four zones (IA, IB, II, and III). Zone IA, the sanitary setback zone, extends at least 50 feet from the well. The 3-year time of travel corresponds to Zone IB; the 6-year time of travel corresponds to Zone II; and the 10-year time of travel corresponds to Zone III. The outer boundaries of the zones represent the distance it takes water to travel to a specific well within a specific time period. For example, contaminated water at the outer 3-year time of travel boundary would take 3 years to travel to the well. The direction a water particle would take to the City wellfield is represented by pathlines in Figure 8.

The wellhead protection area zones are designed so that appropriate levels of management can be applied to contaminant sources within those zones. Typically more stringent management practices are applied to contaminant sources closer to the well and less stringent management practices are applied to contaminant sources further from the well. Ideally, all contaminant sources within a wellhead protection area should be managed in a manner to prevent contamination from reaching the water supply well.

3.4.1 Basic Method

Wellhead protection areas created with the Basic Method use generalized hydrogeologic information for the major aquifer types in Idaho and the well pumping rate. The delineation of a wellhead protection area involves drawing circles around the well for the 3-, 6-, and 10-year time of travel boundaries. The radius for each time of travel boundary is determined from pumping rate tables contained in the Idaho Wellhead Protection Plan that are specific for each generalized Idaho aquifer type. This method is used when site-specific data are not available. An advantage of this method is the low cost and ease with which a delineation can be performed. A disadvantage is the delineation does not use site-specific data and therefore may not accurately represent the source area of the drinking water.

The wellhead protection area was calculated using a Columbia River Basalt aquifer type and a peak pumping rate of 500 gallons per minute (gpm). Table 4.8b in the Idaho Wellhead Protection Plan (IDEQ, 1997) was used to determine the radii of the wellhead protection area zones. Because the pumping rate for the City of Ferdinand water system is between 100 gpm and 500 gpm, the greater of the two was used in the Basic Method calculation to be conservative. The wellhead protection area estimated using the Basic Method includes about 74 acres (Figure 8).

3.4.2 Refined Analytical Method

The Refined Analytical Method utilizes site-specific hydrogeologic information and a ground water flow computer model to delineate wellhead protection areas. The Refined wellhead protection area was delineated by the IDEQ using the WellHead Protection Area (WHPA) ground water flow computer model distributed by the U.S. Environmental Protection Agency (Blandford and Huyakorn, 1991). The wellhead protection area for the City of Ferdinand should be considered to be only an approximation because ground water flow conditions in the area are not well defined. The computer model used to calculate the wellhead protection area assumes the aquifer is uniform within the entire wellhead protection area and pumping rates do not change. In reality, the aquifer thickness, the ground water flow direction, the hydraulic conductivity, and porosity all vary within the wellhead protection area. To account for this variability, average values are used in the model to estimate the wellhead protection areas.

The geologic map and ground water flow data indicate the source of the drinking water supply for the City of Ferdinand moves through granite and basalt aquifers. These two rock types typically have very different hydrogeologic characteristics and would not generally be considered one aquifer. However, because the ground water appears to travel through both granite and basalt, the two aquifers are considered hydraulically connected. The aquifer hydraulic properties used in the computer model are generally more representative of basalt than granite because the City of Ferdinand wells are completed in basalt. The resulting wellhead protection area may be described as a composite delineation, where the length is based on ground water flow in a basalt aquifer, while the width is representative of the hydrogeologic conditions typical of granite. The aquifer parameters shown in Table 2 were used to delineate the wellhead protection area for the City of Ferdinand. The wellhead protection area estimated using the Refined Analytical Method encompasses approximately 840 acres and is shown on Figure 8.

Table 2. Aquifer Parameters used in Refined Wellhead Protection Area Delineation

Aquifer Parameter	Value	Comment
Hydraulic Conductivity (feet/day)	10	Estimate for Columbia River Basalt from Idaho Wellhead Protection Plan 1997
Aquifer Thickness (feet)	70	Estimate of thickness of water producing zones
Ground Water Flow Direction	SW to NE	Based on regional flow and water levels -Fall 1998
Ground Water Gradient (feet/foot)	0.03	Based on regional flow and water levels -Fall 1998
Well Pumping Rate (gallons/day)	75,000	250 users @ consumption rate = 300 gal per user
Effective Porosity (%)	15	Estimate for Columbia River Basalt from Idaho Wellhead Protection Plan 1997
Ground Water Velocity (ft/day)	2	Hydraulic conductivity x gradient/effective porosity

4.0 POTENTIAL CONTAMINANT SOURCES

A potential contaminant source is simply a location where there is or has been an activity having the potential to release contaminants into the ground water at a level of concern. The activity may be associated with a business, industry, or operation involving the use, transport, storage, or manufacture of the potential contaminants. Identification of a business, industry, or operation as a potential contaminant source does not mean that the business, industry, or operation is out of compliance with any local, state, or federal regulation, and it does not necessarily mean that the business, industry, or operation has or will cause contamination. What it does mean is that the potential for contamination (or pollution as it is sometimes called) exists due to the nature of the business, industry, or operation.

Potential sources of contamination are often separated into two categories: point sources and nonpoint sources. Point sources of contamination occur at discrete locations and are associated with facilities that handle large quantities of the contaminant. For example, ground water can be contaminated by a single point source at a specific location such as a leaking storage tank. Point sources include industrial facilities, animal feeding operations, waste disposal sites, and large accidental spills. Additionally, point sources can be associated with small businesses, abandoned wells, and other activities located in every community.

Nonpoint sources of contamination are more difficult to distinguish because they are associated with everyday activities and occur on an area-wide basis. Typically, contamination results when a large mass of contaminant is dispersed over a large area. No single release may be enough to affect ground water quality, but the cumulative effects of widespread releases may adversely impact ground water quality. Nonpoint sources of contamination include subdivisions with a high density of septic systems and fertilizer application on agricultural land and in urban areas.

A contaminant inventory of the study area was conducted during October of 1998 by IDEQ staff in the Lewiston Regional Office. The potential contaminant inventory involved identifying and documenting potential contaminant sources within the City of Ferdinand Refined Wellhead protection area. The potential contaminant inventory provides: 1) information on the locations of potential sources, especially those that present the greatest risks to the water supply, and 2) a reliable basis for developing a wellhead protection plan to reduce the risks to the water supply. The inventory covered an area of approximately 7 square miles (4480 acres).

4.1 Potential Contaminant Sources – Nonpoint

Dry-land agricultural operations that use fertilizer, pesticides, and herbicides appear to be the primary potential nonpoint sources of contamination surrounding the City of Ferdinand. The primary crop is wheat. Secondary crops include barley, peas, oats, canola, and alfalfa. The land is also used for the rearing of beef and dairy cows. Insecticides, herbicides, and commercial fertilizers containing nitrogen are the most common potential contaminants associated with agricultural crop production.

4.2 Potential Contaminant Sources – Point

Seven potential point sources of contamination were located within the wellhead protection area created with the Refined Analytical Method (Figure 9). The potential sources of contamination located within the wellhead protection area are listed in Table 3. The type of the facility, chemical information, quantity stored/generated, facility name/address and description were recorded (Table 4). Complete information was not available for every site.

A computerized review of databases containing businesses that could be potential sources of contamination identified only three potential sources in or near the wellhead protection area: a former gas station, an agriculture supply facility, and a dairy which is located just northeast of the wellhead protection area. Both these sites were identified during the October 1998 inventory.

Table 3. Potential Point Sources Within the City of Ferdinand Wellhead Protection Area

Map ID	Type of Facility	Potential Contaminants
P9	Feedlot	animal waste
P14	Concrete plant	petroleum, solvents, oils
P15	Concrete plant	petroleum, solvents, oils
P16	Veterinarian	medical wastes
P17	Closed service station	petroleum
P18	Agricultural supply	agricultural chemicals
P19	Fire Station	fire suppressants

The agricultural supply facility (P18) appears to be the most significant potential source of contamination located within the Refined wellhead protection area with regards to variety and quantity of contaminants stored on site. This site stores and distributes agricultural chemicals including insecticides, herbicides, and fertilizers.

A total of 22 potential point sources of contamination were identified within the study area (Figure 10). The potential contaminant sources located outside the City of Ferdinand wellhead protection area were identified to evaluate threats to ground water quality on a broader scale. Most of the potential contaminant threats are small in scale and include: small feedlots and homes with septic tanks, grain storage, fuel storage, and a cabinet manufacturer. The contaminants of concern associated with these types of potential contaminant sources include household chemicals, gasoline, diesel, and heating oil fuels, biological contaminants from animal and human wastes, and nutrients such as nitrate from fertilizers and human and animal wastes.

Table 4. Ferdinand Area Potential Contaminant Inventory

SITE #	TYPE OF FACILITY	Potential Contaminants	Wellhead Protection Zone location
P1	Gravel Pit/heavy equipment	Fuel, oils	Not in Wellhead Protection Area
P2	Grain Storage w/ 4 towers	Fuel,	Not in Wellhead Protection Area
P3	Small feedlot/ home	Nutrients	Not in Wellhead Protection Area
P4	Dispersed feedlot/home	Nutrients	Not in Wellhead Protection Area
P5	Small feedlot/home	Nutrients	Not in Wellhead Protection Area
P6	Nutrient rich stock pond	Nutrients	Not in Wellhead Protection Area
P7	Grain/Equipment Storage with tanks	VOC	Not in Wellhead Protection Area
P8	Small feedlot/home	Nutrients	Not in Wellhead Protection Area
P9	Small feedlot/home	Nutrients	**6-10 year time of travel**
P10	Dairy Feedlot/Fuel Storage	Nutrients/Petroleum	Not in Wellhead Protection Area
P11	Small feedlot/home	Nutrients	Not in Wellhead Protection Area
P12	Fuel Storage/home	Petroleum	Not in Wellhead Protection Area
P13	Cabinet Manufacturing	Solvents, paints, sealants	Not In Wellhead Protection Area
P14	Concrete/Crushing Business	Petroleum, solvents, oils	**0-3 year time of travel**
P15	Concrete/Crushing Business	Petroleum, solvents, oils	**0-3 year time of travel**
P16	Vet Clinic	Medical Wastes	**0-3 year time of travel**
P17	Historic Gas Station	Petroleum	**0-3 year time of travel**
P18	Ag-Chemical/Grain Storage	Pesticides, herbicides, fertilizers	**0-3 year time of travel**
P19	Fire Station	Fire suppressant, waste	**0-3 year time of travel**
P20	Small feedlot/home	Nutrients	Not in Wellhead Protection Area
P21	Wastewater Lagoons	Nutrients, chemicals	Not in Wellhead Protection Area
P22	Fuel/Equipment Storage	Petroleum products	Not in Wellhead Protection Area
P23	Concrete/Crushing Business	Petroleum, solvents, oils	Not in Wellhead Protection Area

5.0 GROUND WATER SAMPLING

The ground water sampling was conducted on November 9, 12, and 23 of 1998. All of the wells and two springs were sampled for seven major ions (bicarbonate alkalinity, calcium, chloride, magnesium, potassium, sodium and sulfate), nitrate ($NO_2 + NO_3$ as N), total Coliform bacteria, *E-coli* bacteria, and organic compounds. Two wells were sampled for ammonia (total ammonia as N). Duplicate nitrate and ammonia samples were collected at Well 05. Samples were also collected from all the wells and two springs for nitrogen stable isotope ratio analysis. All samples were collected in containers provided by the State of Idaho State Bureau of Laboratories (Idaho State Lab). The Idaho State Lab in Boise, Idaho completed all analyses except for the stable nitrogen isotope ratios. The nitrogen isotope analyses were performed by Coastal Science Laboratories, Inc. in Austin, Texas.

5.1 General Ground Water Quality

The major ion chemistry is evaluated because the chemical composition of ground water is a function of the mineral composition of the aquifer material as well as the residence time of the aquifer. Therefore, the major ion chemistry sometimes can be used as an indicator of the rock type of the aquifer. The other analyses - nitrate, nitrogen isotope, ammonia, pesticides, and bacteria - are used as indicators of different types of contamination from a variety of anthropogenic activities. The specific organic compounds contained in insecticides and herbicides that were analyzed for are contained in Table 5.

Table 5. Organic Compounds Analyzed in Water Samples

Alachlor	Butachlor
Atrazine	Metoloachlor
Simazine	Metribuzin
Chlordane	Aldrin
Endrin	Dieldrin
Heptachlor	Propachlor
Heptachlor epoxide	Benzo[a]pyrene
Hexachlorobenzene	Di(2-ethylhexyl)adipate
Hexachlorocyclopentadiene	Di(2-ethylhexyl)phthalate
Lindane	Methoxychlor
Toxaphene	Polychlorinated biphenyls (PCBs)

5.2 Nitrogen Isotopes

The nitrogen stable isotope ratio analysis (SIRA) was conducted on the samples to identify the source of nitrate in the ground water. The nitrogen SIRA test provides a measurement of the ratio of the two most abundant isotopes of nitrogen, ^{14}N and ^{15}N. The ratio of these two isotopes is a useful indicator of sources of nitrogen contamination because unique $^{15}N/^{14}N$ ratios are associated with each of the predominant sources of nitrogen contamination.

Isotopes of an element have the same number of protons but a different number of neutrons. Elements have a predominant isotope and less abundant isotopes. The standard notation for identifying different isotopes is to write the sum of the number of protons and neutrons in the upper left corner of the symbol of the element (e.g., ^{1}H=common hydrogen with one proton and zero neutrons; ^{3}H=[tritium] hydrogen with one proton and two neutrons).

The nitrogen isotopes ^{15}N and ^{14}N constitute an isotope pair. The lighter isotope ^{14}N is significantly more abundant in the environment than ^{15}N. In the atmosphere there is one atom of ^{15}N per 273 atoms of ^{14}N (Drever, 1988). The ratio of the heavier isotope to that of the lighter isotope in a substance can provide useful information because the slight differences in the mass of the isotopes cause slight differences in their behavior. Stable isotopes are measured as the ratio of the two most abundant isotopes of a given element. Isotope values for nitrogen and other elements are presented in the delta notation:

$$\delta^{15}N = \{[(^{15}N/^{14}N)_{sample} \,)\, (^{15}N/^{14}N)_{air}\,] - 1\} \times 1000$$

The δ-value is expressed as parts per thousand or per mil ($^{0}/_{00}$) difference from the reference. For example, a $\delta^{15}N$ value of +10 per mil has 10 parts per thousand (one percent) more ^{15}N than the reference. A positive δ-value is said to be "enriched" or "heavy", while a negative δ-value is said to be "depleted" or "light". The reference standard for the stable isotopes of nitrogen ($^{15}N/^{14}N$) is atmospheric nitrogen (Clark and Fritz, 1997).

Several steps in the nitrogen cycle can modify the stable-isotope composition of a nitrogen-containing chemical. These changes, called fractionation, occur as a result of physical and chemical reactions. Isotopic effects, caused by slight differences in the mass of two isotopes, tend to cause the heavier isotope to remain in the starting material of a chemical reaction. Denitrification, for example, causes the nitrate of the starting material to become isotopically heavier. Volatilization of ammonia results in the lighter isotope preferentially being lost to the atmosphere, and the ammonia that remains behind becomes isotopically heavier.

These isotopic effects mean that, depending on its origin, the same compound may have different isotopic compositions. For stable isotopes to provide a useful tool in identifying sources of nitrogen contamination, the isotopic composition of the potential source materials must be distinguishable. The major potential sources of nitrogen contamination in the environment commonly have characteristic $^{15}N/^{14}N$ ratios. Typical $\delta^{15}N$ values for important sources of nitrogen contamination are presented in Table 6 (Seiler, 1996).

Table 6. Nitrogen Sources Associated with d ^{15}N Values

Nitrogen Source	**d ^{15}N ($^{0}/_{00}$)**
Precipitation	-3
Commercial Fertilizer	-4 to +4
Organic Nitrogen in Soil	+4 to +9
Animal or Human Waste	> +10

6.0 RESULTS AND DISCUSSION

A variety of analytical tests were performed on the ground water samples collected during this investigation to allow examination of multiple lines of evidence to determine whether specific sources are responsible for the nitrate levels in the City of Ferdinand drinking water. The analytical results for Ferdinand are summarized in Table 7 and discussed in later sections. The general chemistry of the ground water is presented first, followed by a discussion of nitrates and nitrogen isotope results. The bacteria and pesticides data are then summarized and finally, the quality assurance results are reviewed.

Table 7. Analytical Results

Well/Spring #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sample Date	11/9/99	11/9/99	11/9/99	11/9/99	11/12/99	11/12/99	11/12/99	11/12/99
Nitrate (NO_2+NO_3 -N) (mg/l)	3.57	0.298	6.81	6.61*	6.49	9.77	14.1	3.45
Ammonia (mg/l)	NA	NA	NA	0.014	<0.005	NA	NA	NA
Bicarbonate Alkalinity (mg/l)	180	79	197	256	220	202	182	185
Calcium (mg/l)	37.6	6.2	44.9	77.7	49	48.5	49.7	41.3
Chloride (mg/l)	2.0	5.18	6.3	13.3	8.32	5.48	2.3	2.69
Magnesium (mg/l)	14.4	0.3	12.8	21.5	16.2	15.1	15	13.6
Potassium (mg/l)	2.4	0.7	1.5	3.4	2.7	2.4	2.0	1.5
Sodium (mg/l)	29	47	38	31	35	32	25	16
Sulfate(mg/l)	12.9	26.9	13.8	62.5	16.5	13.3	14.6	6.73
Nitrate Isotope (per mil)	2.9	INS	1.8	INS	4.6	1.7	1.6	2.3
Total Coliform (cfu/100 ml)	ND	ND	ND	130	1	ND	14	291
E. Coli (cfu/100 ml)	ND	ND	ND	ND	ND	ND	ND	5
Pesticides	ND	ND	ND	ND	ND	ND	ND	ND

* = Questionable Value - water sample collected in August 1998 did not contain nitrate. Nitrate was not measured in sample submitted for nitrogen isotope ratio analysis.
NA = Not Analyzed
INS = insufficient nitrogen present in sample for analysis to be completed.
ND = not detected

6.1 General Ground Water Chemistry

The major ion chemistry data were evaluated using two different graphical techniques: Stiff Diagrams and Piper Diagrams. These graphical methods are useful for illustrating variations in major ions between different aquifers. The Piper Diagram is a convenient method for comparing a large number of chemical analyses because numerous water samples can be plotted on a single diagram. Water samples with different major ion chemistry will plot on different portions of the Piper Diagram. The Stiff Diagram is useful for providing quick simple comparisons of chemical analyses for individual water samples. Using this technique, a separate diagram is created for each water sample. Water samples containing similar levels of major ions yield diagrams of roughly the same shape.

Stiff Diagrams for the water samples collected from the six wells and the two springs are shown on Figure 11. Cations [calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K)] are plotted on the left side of the diagram while anions [chloride (Cl), bicarbonate (HCO_3), and sulfate (SO_4)] are plotted on the right side of the diagram. The concentrations of both cations and anions are expressed in milliequivalents per liter (meq/l). According to *AquaChem* (Waterloo Hydrogeologic, 1998-1999) all the water samples, except the water sample from Well 02, are identified as a Ca-Na-Mg-HCO_3 or Ca-Mg-HCO_3 water type. These water samples appear to be characteristic of a basalt aquifer source.

The Stiff Diagrams indicate that the water sample collected from Well 02 is distinctly different in major ion composition from the other seven water samples. Well 02 is classified as a Na-HCO_3-SO_4 water type. This appears to be the only sampled well that draws water exclusively from the granite aquifer. The Stiff Diagram for Well 04 displays a compositional signature slightly different from the other wells. This well contains higher levels of calcium, magnesium, potassium, chloride, bicarbonate, and sulfate than found in the other wells. The elevated major ion concentrations may be related to operations at the adjacent concrete plant.

The Piper Diagram (Figure 12) depicts the major ion composition of each water sample on a single plot. Water samples with similar chemistry plot in the same area on the diagram. The major cations are plotted on the left triangle. The major anions are plotted on the right triangle. The plotted points for each water sample are then projected to the upper diamond-shaped area which shows cation and anion groups as a percentage of the sample. All but two of the water samples plot in the same area of the diagram. The Piper Diagram indicates that the chemistry of the water sample Well 02 deviates significantly from the other samples due to differences in cation and anion chemistry. The water sample from Well 04 also deviates somewhat from the other samples, primarily due to the higher concentration of sulfate.

Spring 07, Spring 08, and Well 01 are located in granite according to the geologic map. However, the major ion chemistry of water samples from these three locations is similar to water samples collected from wells drawing from the shallow basalt aquifer.

6.2 Nitrate Results

Only one of the water samples exceeded the drinking water standard for nitrate of 10 mg/l. The water sample collected from Spring 07 contained a nitrate concentration greater than 10 mg/l (14.1 mg/l). The second highest nitrate concentration occurred at Well 06 with a concentration of 9.77 mg/l. This particular well is completed to a depth of 82 feet and is considered a “shallow” well. The nitrate results from this study and the summer 1998 Camas Prairie Study (Bentz, 1998) are summarized on Figure 13.

Of the six wells sampled, two wells (Well 01 and Well 02) are completed in granite and four wells (Well 03, Well 04, Well 05, and Well 06) are completed in basalt. Water samples collected from wells completed in granite contained nitrate levels of 3.57 mg/l and 0.298 mg/l. The wells completed in basalt contained nitrate levels of 6.81 mg/l, 6.61 mg/l, 6.49 mg/l, and 9.77 mg/l. These data indicate ground water quality in the basalt aquifer is degraded by nitrate.

Well 02 is completed to a depth of 600 feet in granite. The log indicates that the well penetrates layers of solid and decomposed granite. A bentonite seal extends to a depth of 50 feet. Water was encountered at a depth of 560 feet bls and subsequently rose to 390 feet bls, indicating a confined aquifer. The water sample collected from Well 02 contained the lowest nitrate concentration (0.298 mg/l) of the six wells sampled.

City of Ferdinand Well #1(Well 05), is completed to a depth of 242 feet. The log indicates the well penetrates basalt (both broken and solid) and interbedded material of shale/claystone. The well is perforated from a depth of 142 to 202 feet, drawing water from a semi-confined aquifer. A clay seal is present to a depth of 32 feet. Historically, this well has had nitrate concentrations above 5 mg/l. The water sample contained a nitrate concentration of 6.49 mg/l. The well log (Figure 5) indicates the static water level was 54 feet bls at the time the well was installed in 1973.

Well 06 is completed to a depth of 82 feet in basalt and claystone material. The well is perforated from a depth of 60 to 80 feet and draws water from the upper-most basalt aquifer. A bentonite seal is in place to a depth of 18 feet. Nitrate concentration from Well 06 was the highest (9.77 mg/l) of the six wells.

The nitrate concentrations in the water samples collected from Well 03 and Well 04 were 6.81 mg/l and 6.61 mg/l, respectively. The nitrate results from Well 04 are questionable (this is discussed in more detail in *Section 6.6 Quality Assurance Results)*. Well logs are not available for these wells, but they are believed by the well owners to be less than 200 feet deep. Water samples from Spring 07 and Spring 08 contained nitrate concentrations of 14.1 mg/l and 3.45 mg/l, respectively.

These results indicate that higher nitrate concentrations are occurring in the basalt aquifers. The variation in nitrate levels appears to be the result of a combination of factors including land use and hydrogeologic conditions under which ground water occurs. Land use over the granite is less agriculturally intense and more undeveloped which would tend to result in lower application of nitrogen fertilizer. Additionally, the wells completed in granite draw water from confined water bearing zones encountered at depths of 300 feet or greater.

6.3 Nitrogen Isotope Results

The nitrogen isotope analyses were conducted to evaluate the causes of the elevated nitrate levels in the ground water. The nitrogen isotope $\delta^{15}N$ values varied from +1.6 $^{0}/_{00}$ to +4.6 $^{0}/_{00}$. Two of the samples (Well 02 and Well 04) were determined by the laboratory to contain insufficient nitrate to conduct the nitrogen isotope analysis. Five of the six samples yielded a $\delta^{15}N$ value less than +3 $^{0}/_{00}$. The $\delta^{15}N$ results, coupled with the land use, strongly suggest the elevated nitrate levels in these wells is likely a result of leaching of inorganic commercial nitrogen fertilizer (see Table 6). Nitrogen isotope $\delta^{15}N$ values ranging from –4 to +4 $^{0}/_{00}$ are indicative of commercial fertilizer sources. The nitrogen isotope results are summarized in Table 7 and on Figure 14.

The lowest $\delta^{15}N$ value (1.6 $^{0}/_{00}$) was detected in the ground water sample collected from the location containing the highest nitrate concentration - Spring 07. This low value suggests the nitrate level is strongly influenced by commercial fertilizer.

The water sample containing the highest $\delta^{15}N$ value (4.6 $^{0}/_{00}$) was collected from City of Ferdinand Well #1 (Well 05). This value could represent a combination of commercial inorganic fertilizer and organic sources such as animal manure or human wastes from septic tanks and/or leaking sewers. The value also could represent a naturally occurring organic nitrogen source resulting from decomposition of plant material. However, the crops observed within the study area do not support this conclusion. Legume crops (alfalfa, beans, peas) are considered the primary sources of organic nitrogen. Although some legumes are grown in the area, the majority of land is devoted to wheat.

6.4 Bacteria Results

The water samples were analyzed for total coliform bacteria as an indicator of potential bacterial contamination. Coliform bacteria are common in the environment and are not generally harmful. However, the presence of coliform may indicate the water is contaminated with organisms which cause diarrhea, cramps, nausea, headaches, and fatigue. Samples for total coliform bacteria were collected from all eight sampling sites. Four of those eight samples had bacteria present (04, 05, 07, and 08). Both of the springs returned positive bacteria samples. The highest total coliform level was 291 colony forming units per 100 milliliters (cfu/100 ml) from Spring 08. This high total coliform level is not surprising based on two factors: (1) the site is a spring and is very susceptible to surface water influence, and (2) livestock are present near the spring at least part of the year. Spring 07 is a drinking water spring with a total coliform level of 14 cfu/100ml. This site is protected from livestock influence, but it is not immune from surface water runoff. Wells 04 and 05 had total coliform counts of 130 cfu/100 ml and 1 cfu/100 ml, respectively. However, the high total coliform count at Well 04 may be due to sampling difficulties. This sample was collected at a location not ideal for sample collection, and bacterial contamination may have occurred during collection. Therefore, the result may not be an accurate representation of ground water quality.

E-Coli bacteria were present in only one of the sites sampled (Spring 08). The water sample from this spring contained the highest total coliform concentration. An *E-Coli* concentration of 5 cfu/100ml was detected in this water sample. *E-Coli* are typically associated with animal or human wastes and can be an indicator that pathogens are present in the ground water. The *E-Coli* detection may be attributed to the presence of livestock around the spring. This spring is not a drinking water source; therefore, human health impact is not an issue at this time.

6.5 Pesticide Results

All eight sites were analyzed for the presence of organic compounds contained in herbicides and insecticides commonly applied in the area (Table 3). There were no organic compounds detected in any of the samples. It should be noted that the laboratory test used in this study does not encompass the entire suite of compounds present in herbicides and insecticides. Rather, the test is used as an indicator of potential for ground water contamination due to pesticides.

6.6 Quality Assurance Results

To evaluate the reproducibility of the analytical results a duplicate sample was collected from Well 05 and analyzed for nitrate and ammonia. The nitrate value differed by only 0.01 mg/l and both samples did not contain detectable levels of ammonia. The samples were submitted to two different laboratories for nitrogen isotope ratio analysis. Unfortunately, only one laboratory was able to complete the analysis.

The nitrate analytical results from the water samples collected during this study in November 1998 were compared with the results from the water samples collected during the regional study in the summer of 1998. Well 04 was the only location that showed significant variation between the two sampling events. The water samples collected from Well 04 in August and November of 1998 contained nitrate concentrations of <0.005 mg/l and 6.61 mg/l, respectively. The laboratory conducting the nitrogen isotope analyses determined that the water sample collected from Well 04 in November 1998 contained insufficient levels of nitrogen to run the analysis. This confirms the August 1998 analytical result for nitrate and indicates the November result is not accurate.

To evaluate the accuracy of the major ion analyses, a cation-anion balance was conducted. Cations are positively-charged ions, such as calcium, sodium, or potassium; anions are negatively-charged ions such as chloride, sulfate, and bicarbonate. The cation-anion balance is calculated by subtracting anions from cations and dividing by total ions. A cation-anion balance error indicates either a lack of accuracy or that ions are present in the water that were not analyzed. The balance errors (Table 8) ranged from –0.76% to 6.80% . These errors are relatively low, indicating the analyses were accurate and no significant ions were missed.

Table 8. Cation-Anion Balance

Sample	Total Anions (meq/l)	Total Cations (meq/l)	Balance Error (%)	Calculated TDS (mg/l)
Well 01	3.9887	4.5035	6.06	191.6
Well 02	2.2846	2.3963	2.39	86.6
Well 03	4.5088	4.9848	5.01	214.3
Well 04	6.7906	7.0814	2.10	339.7
Well 05	5.0758	5.3693	2.81	237.2
Well 06	4.6213	5.1157	5.08	228.1
Spring 07	4.2351	4.8527	6.80	225.0
Spring 08	3.9761	3.9141	-0.79	176.5

(meq/l) = milliequivalents per liter

7.0 CONCLUSIONS

- The City of Ferdinand drinking water system is impacted by levels of nitrate greater than 50 percent of the drinking water maximum contaminant level (MCL) for nitrate of 10 mg/l. The nitrate levels have remained relatively constant over the last 15 years with 10 of the last 14 measurements ranging between 5 mg/l and 7 mg/l.
- The highest nitrate concentrations were detected in ground water samples collected from wells drawing from the shallow basalt aquifer that provides drinking water to the City of Ferdinand. Ground water from wells that draw from the granite aquifer typically contain much lower nitrate levels, indicating that the deeper granite aquifer has not been similarly impacted.
- The use of specific types of ground water monitoring, particularly the use of nitrogen isotopes, provided valuable information for the development of future wellhead protection activities.
- The nitrogen isotope analyses indicate that, at the time of sampling, commercial fertilizer was the predominant source of the nitrate contained in the ground water. The widespread occurrence of elevated nitrate levels suggests nonpoint sources of nitrate, such as application of commercial fertilizer on cropland, are impacting ground water quality
- Wellhead protection areas were developed for the City of Ferdinand using Basic and Refined Analytical Methods. The wellhead protection area created using the Refined Analytical Method was significantly different in shape and size than the wellhead protection area created with the Basic Method. The refined delineation increased the size of the wellhead protection area from approximately 74 acres to approximately 840 acres. However, the number of potential point sources identified within each wellhead protection area did not change. Seven point sources were located within both wellhead protection areas, with six of the seven the same. A small feedlot was located within the Refined wellhead protection area that was outside the Basic wellhead protection area. A concrete batch plant was located within the Basic wellhead protection area that was outside the Refined wellhead protection area.

8.0 RECOMMENDATIONS

- Regional ground water protection, as well as local wellhead protection efforts, should focus on management practices to reduce leaching of commercial fertilizer from agricultural land. The agricultural lands are outside the direct jurisdiction of the City of Ferdinand so partnerships with tribal, state, and county governments are needed. Additionally, partnerships with agricultural agencies and industry groups should be pursued.

- Ground water quality monitoring should be conducted concurrent with implementation of best management practices (BMPs) to evaluate effectiveness of activities.

- Additional nitrogen isotope analyses may be useful for evaluating seasonal variations in sources of nitrate contamination and to monitor changes associated with BMP implementation.

- Wells used for drinking water should be extended into deeper water bearing zones in the basalt and sealed to prevent hydraulic connection with the shallow nitrate impacted aquifer.

- Future land uses within the City of Ferdinand wellhead protection area should be protective of ground water quality. A wellhead protection plan should be developed by the City of Ferdinand to provide written documentation to guide future protection efforts.

- City of Ferdinand wellhead protection activities should be based on the wellhead protection area developed using the Refined Analytical Method instead of the Basic Method wellhead protection area. The Refined Analytical Method is more accurate because site-specific hydrogeologic information is used to calculate the wellhead protection area.

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Geochemical Analysis, Plotting and Modeling Software.

FIGURES

FIGURE 1. Vicinity Map

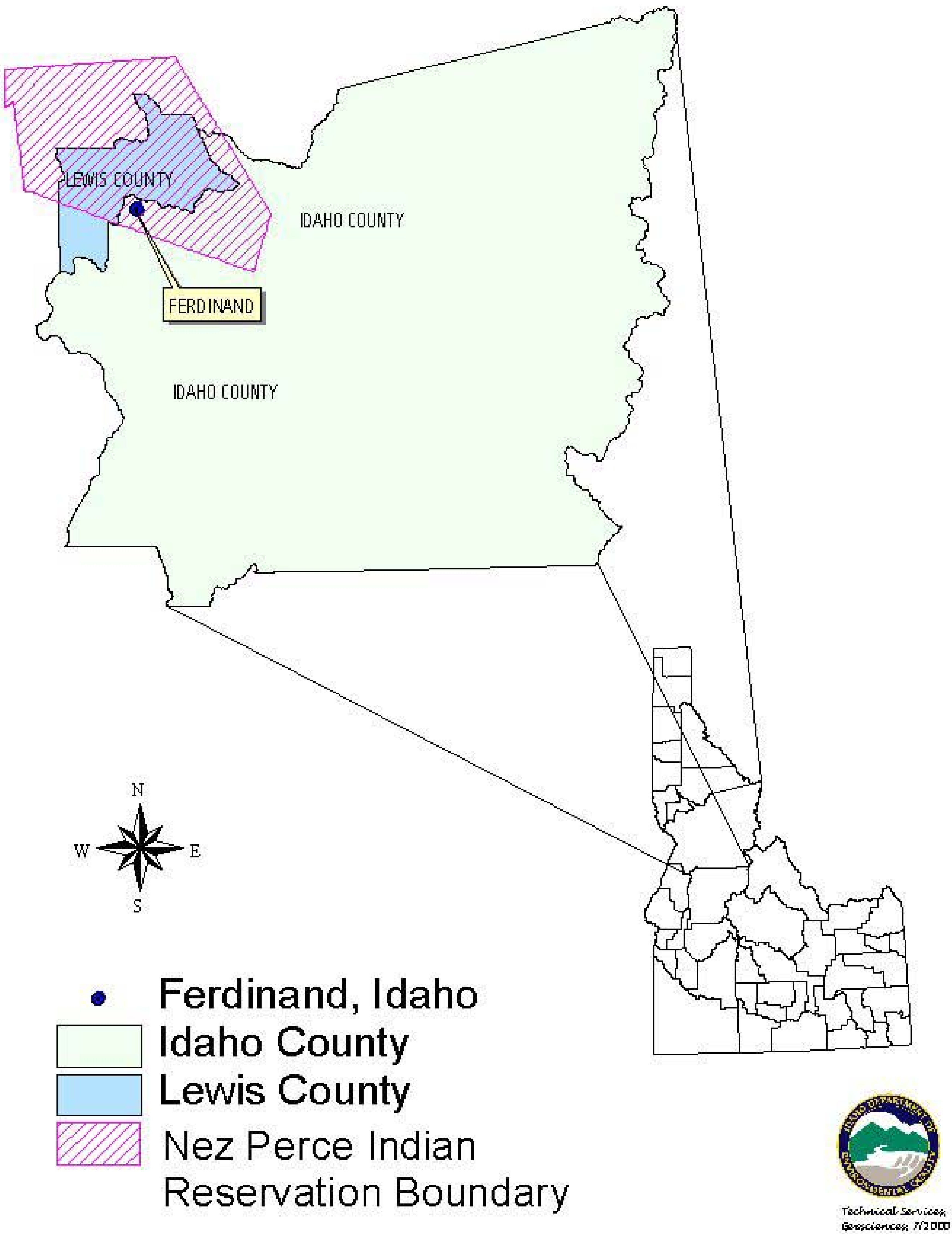

Figure 2
Camas Prairie Investigation

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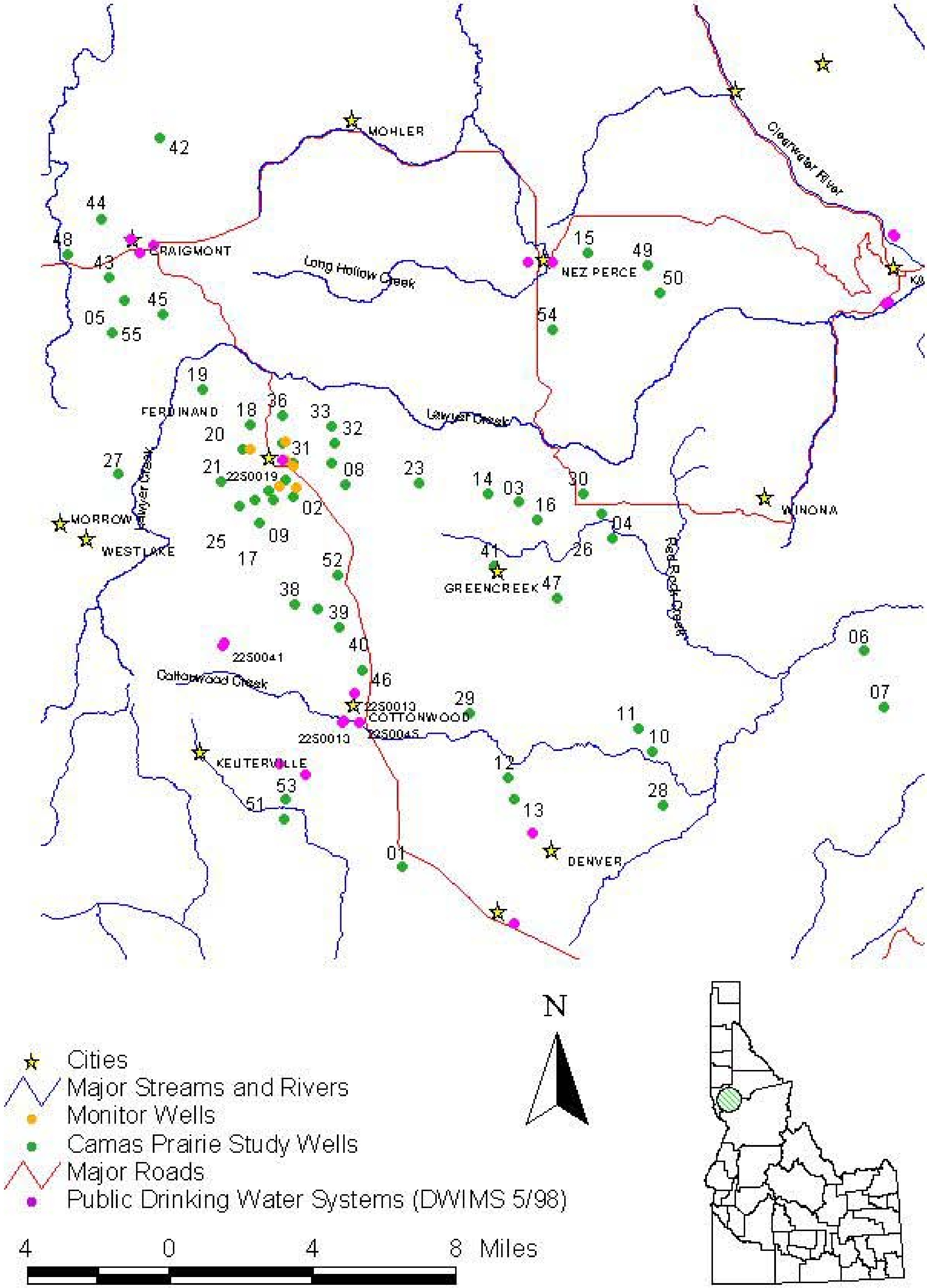

FIGURE 3
Ferdinand, Idaho Generalized Soil Units

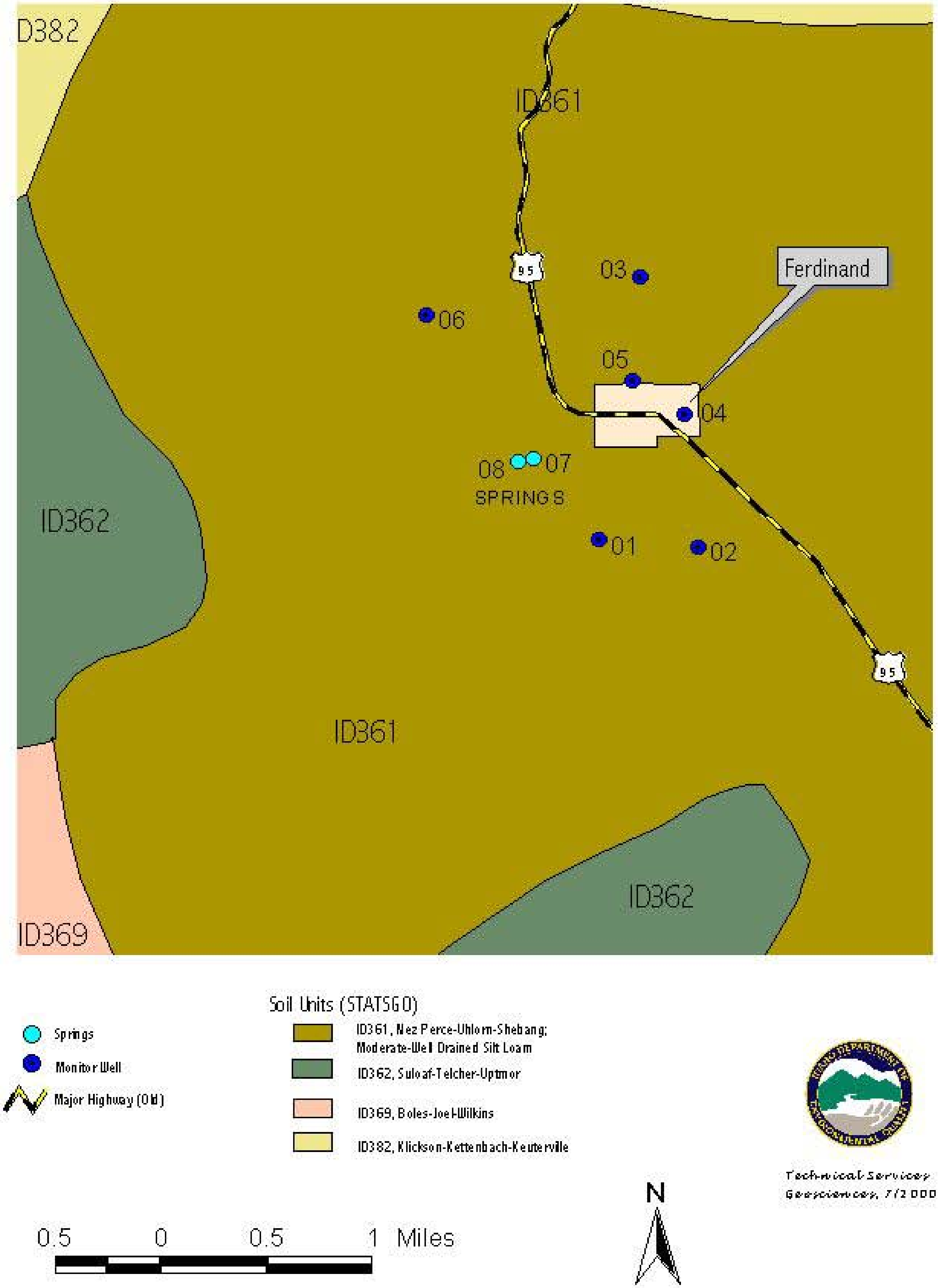

FIGURE 4

Generalized Geologic Formations
Ferdinand, Idaho T33N, R1W AND T32N, R1W

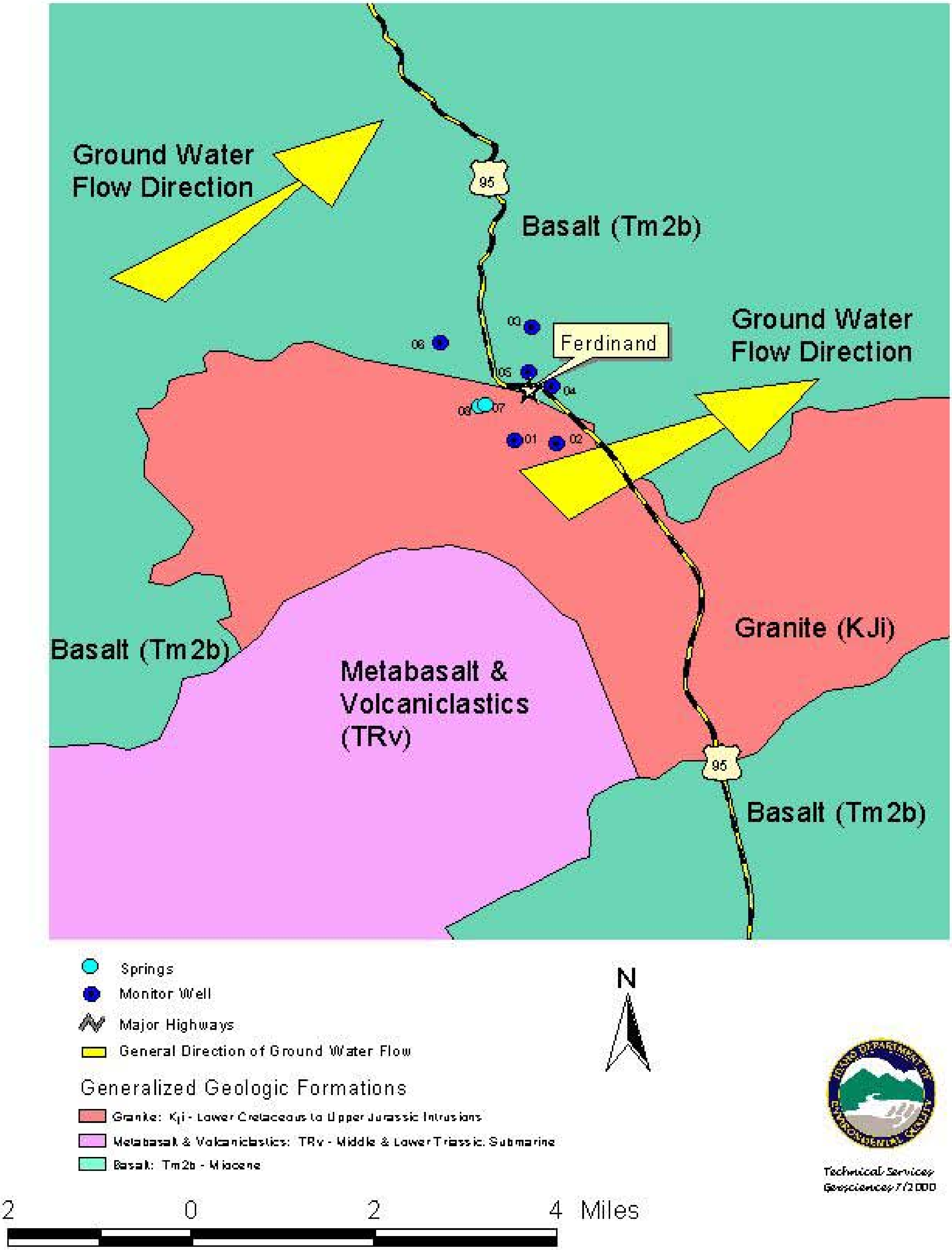

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FIGURE 7
GROUND WATER ELEVATIONS

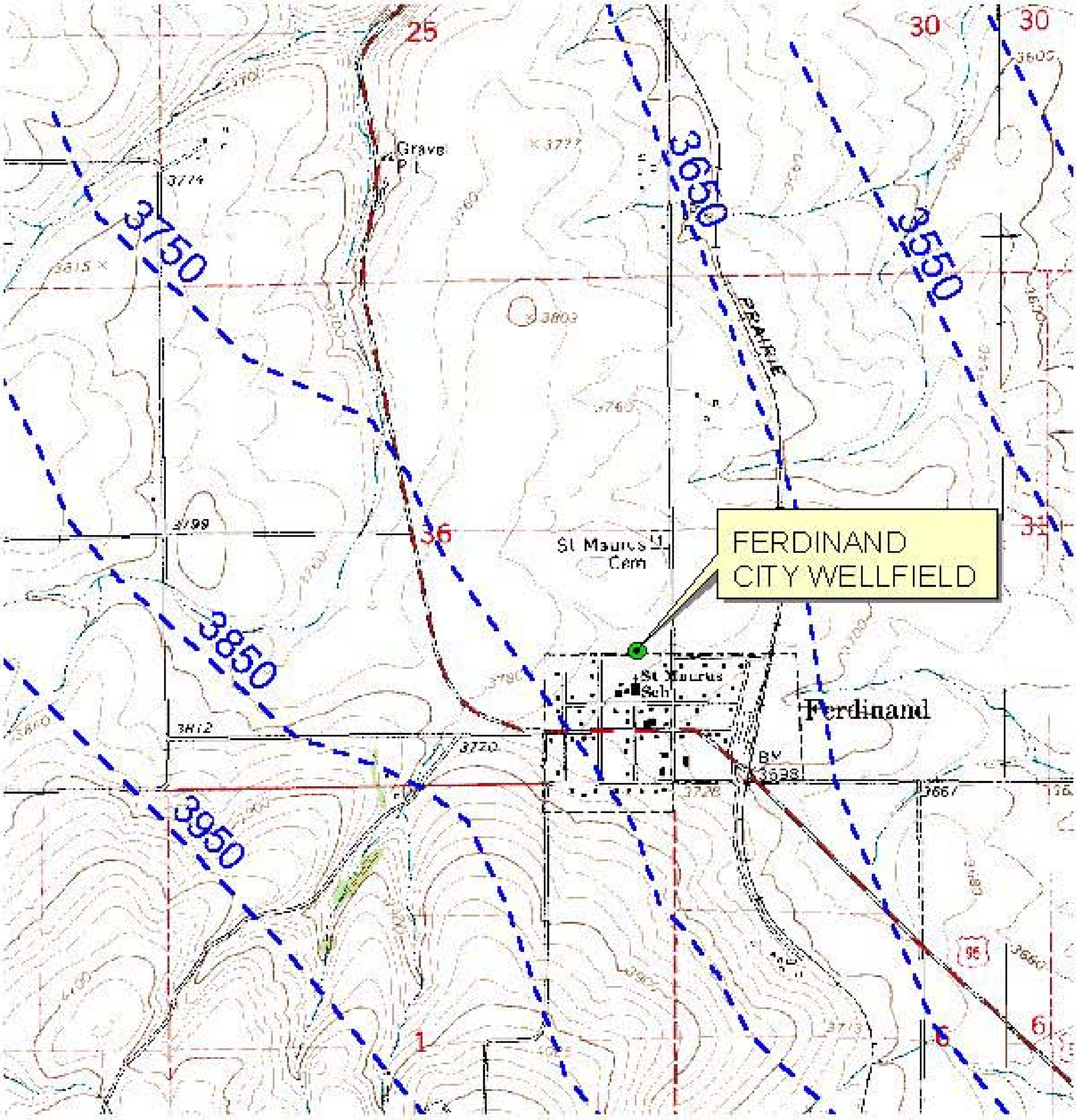
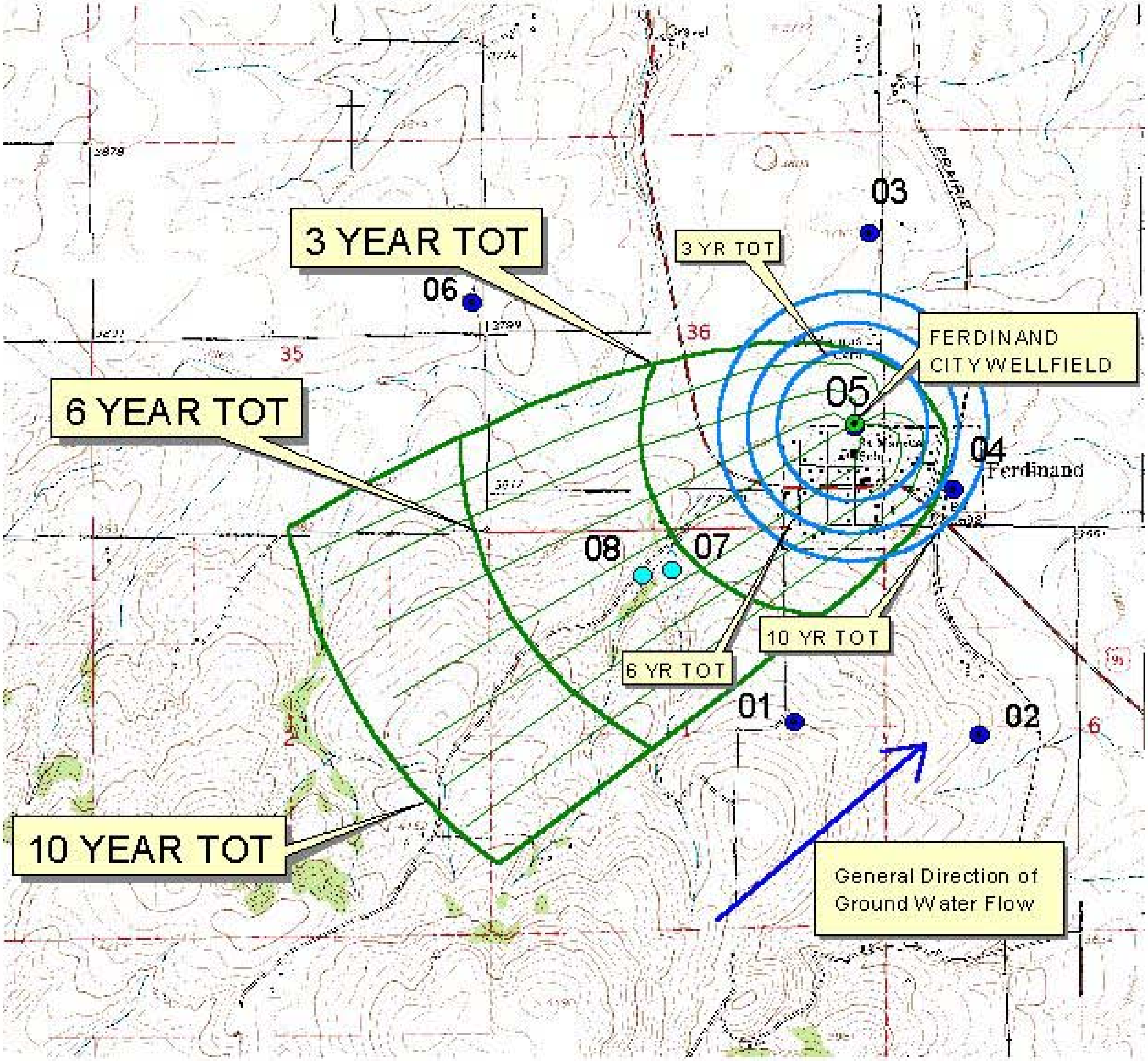


FIGURE 8
WELL HEAD PROTECTION AREAS



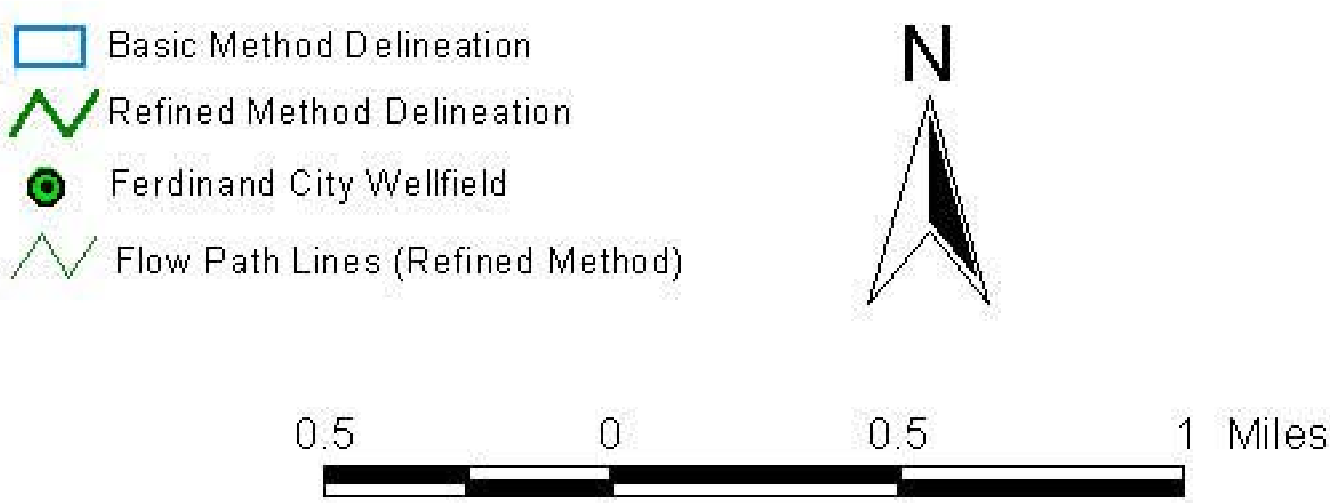


Figure 9
Potential Contaminant Sources - Wellhead Protection Area

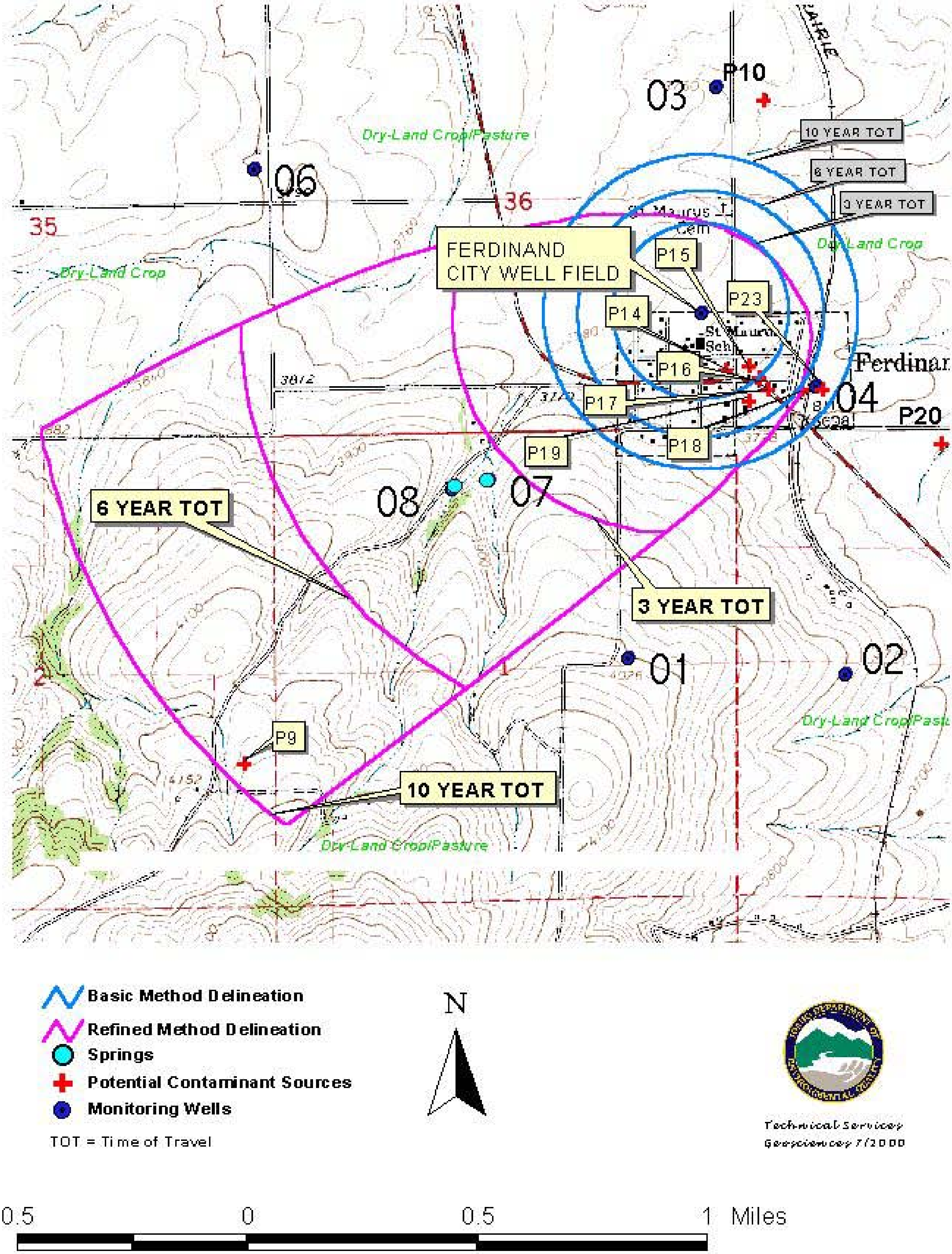


Figure 10
Potential Contaminant Sources - Ferdinand Area

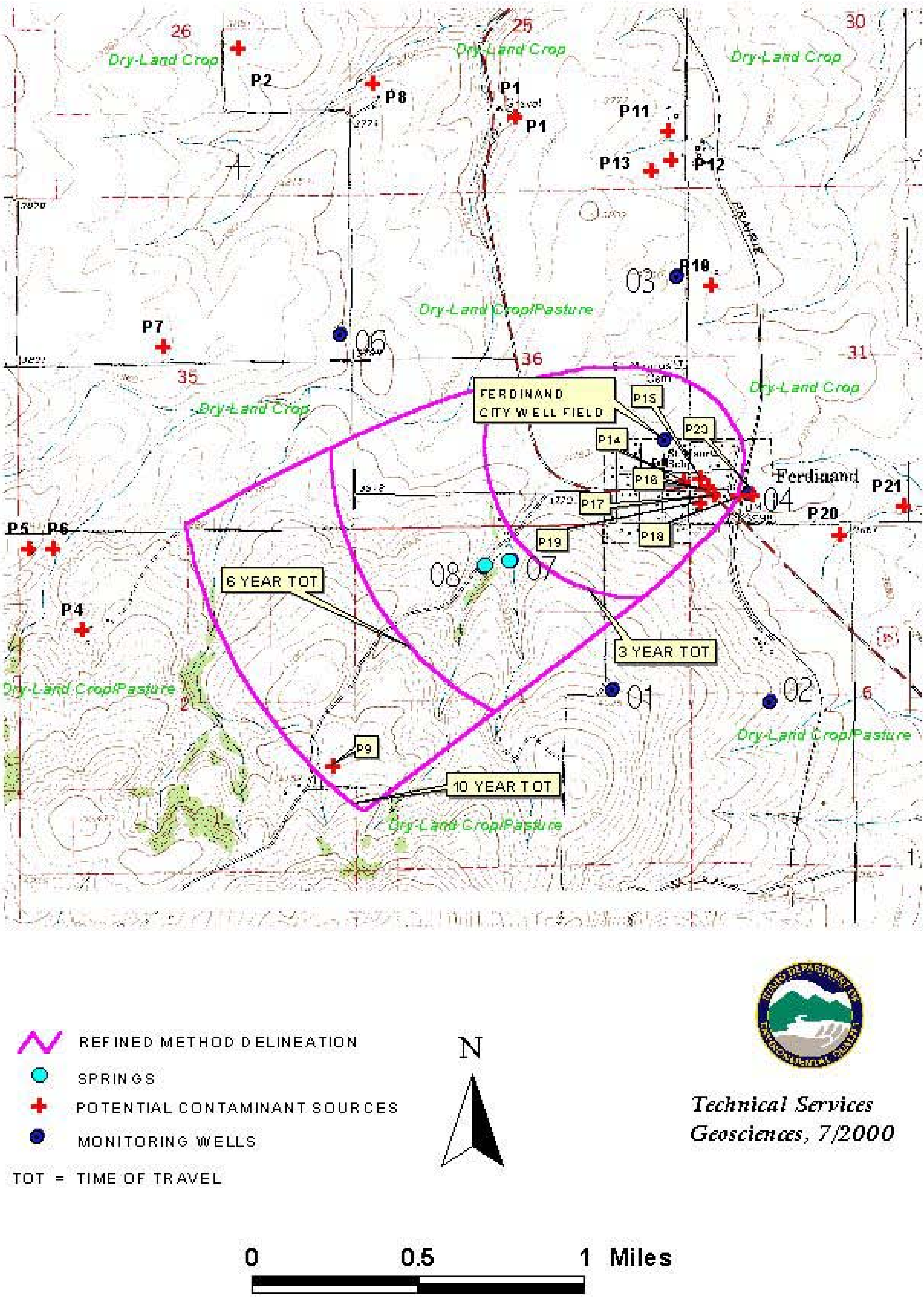


FIGURE 13
Nitrate Concentrations for Wells and Springs
Ferdinand, Idaho

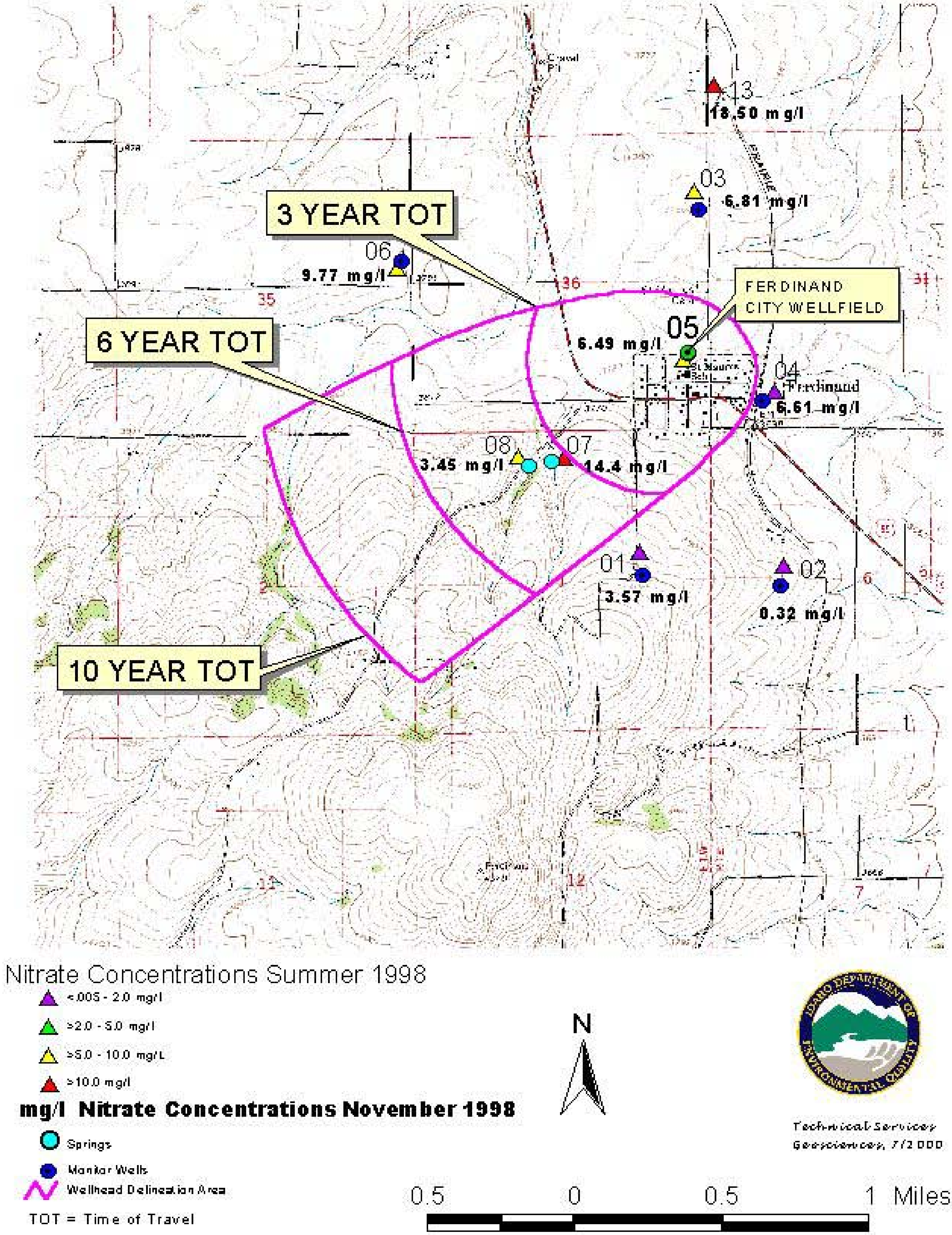
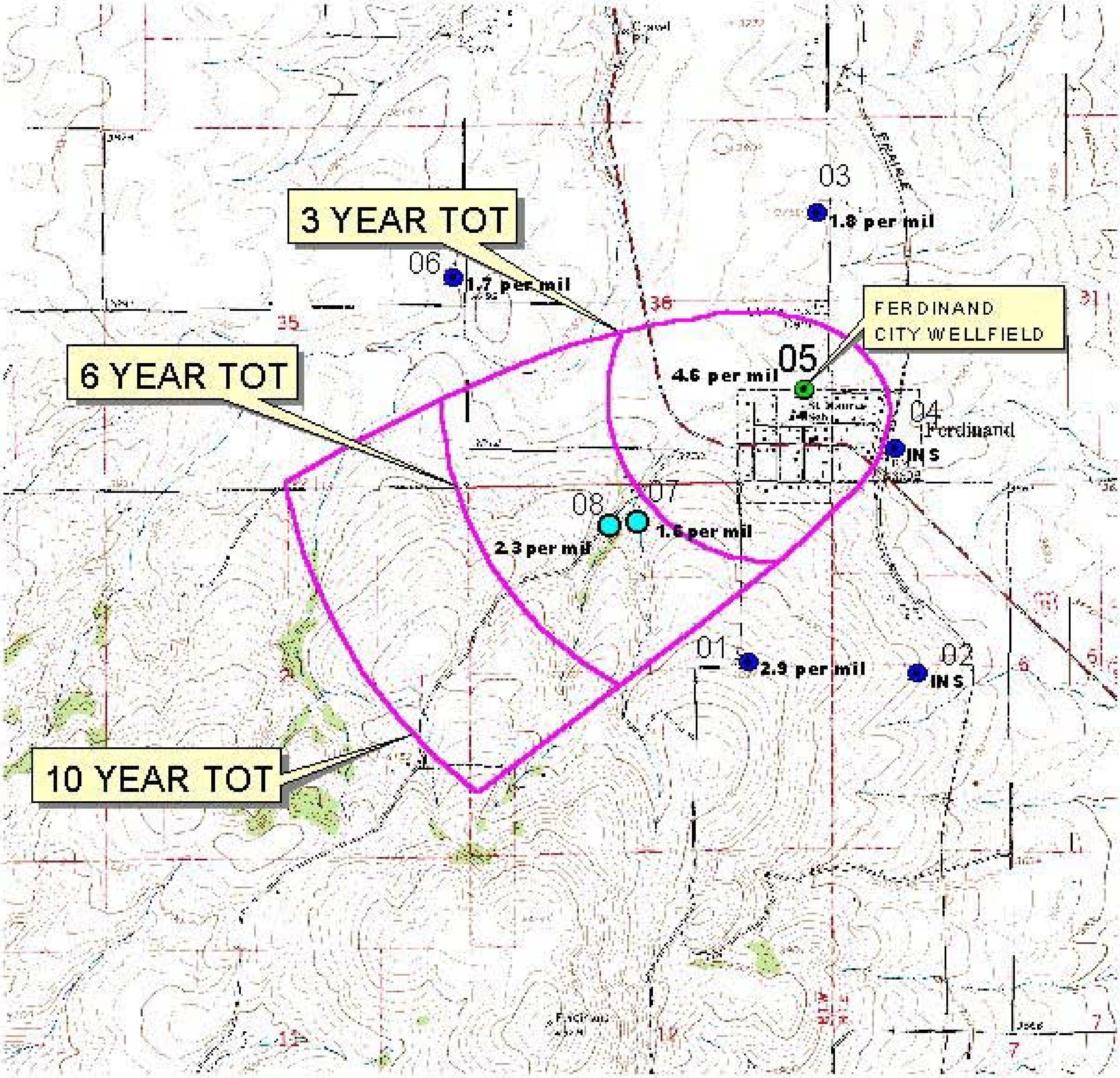


FIGURE 14
NITROGEN ISOTOPE VALUES



Ferdinand City Well Field

Monitor Wells

Springs

Wellhead Delineation Area

INS = Insufficient nitrogen to conduct test

N

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0.5 0 0.5 1 Miles