ABSTRACT

Nitrate was discovered in ground water in the east Erda area of Tooele County, Utah, in 1994. The U.S. Geological Survey, in cooperation with Tooele County, investigated the ground-water flow system and water quality in the eastern part of Tooele Valley to determine (1) the vertical and horizontal distribution of nitrate, (2) the direction of movement of the nitrate contamination, and (3) the source of the nitrate. The potentiometric surface of the upper part of the basin-fill aquifer indicates that the general direction of ground-water flow is to the northwest, the flow system is complex, and there is a ground-water mound probably associated with springs. The spatial distribution of nitrate reflects the flow system with the nitrate contamination split into a north and south part by the ground-water mound. The distribution of dissolved solids and sulfate in ground water varies spatially. Vertical profiles of nitrate in water from selected wells indicate that nitrate contamination generally is in the upper part of the saturated zone and in some wells has moved downward. Septic systems, mining and smelting, agriculture, and natural sources were considered to be possible sources of nitrate contamination in the east Erda area. Septic systems are not the source of nitrate because water from wells drilled upgradient of all septic systems in the area had elevated nitrate concentrations. Mining and smelting activity are a possible source of nitrate contamination but few data are available to link nitrate contamination with mining sites. Natural and agricultural sources of nitrate are present east of the Erda area but few data are available about these sources. The source(s) of nitrate in the east Erda area could not be clearly delineated in spite of considerable effort and expenditure of resources.

INTRODUCTION

Tooele County in northwestern Utah (fig. 1) historically has been a rural county dominated by agriculture, mining, and defense industries. During the 1990s, a transition away from agriculture and mining to residential development began. The eastern part of the county is being absorbed into the greater Salt Lake City metropolitan area, and former agricultural lands now contain residential subdivisions.

From 1994 to 1997, the U.S. Geological Survey (USGS), in cooperation with the Utah Geological Survey; Tooele County; the Utah Department of Natural Resources, Division of Water Rights; and the Utah Department of Environmental Quality studied the water resources of Tooele Valley in eastern Tooele County, the most rapidly developing area of the county. The results of this study are published in a report by Steiger and Lowe (1997).

Water samples collected as part of this study delineated an area of high nitrate plus nitrite as nitrogen concentration in ground water to the east of Erda in Tooele Valley (Steiger and Lowe, 1997). The east Erda area is located on the eastern side of Tooele Valley between Tooele and Lake Point and is an area of disbursed, rapid growth.
Nitrate and nitrite generally are reported together as nitrate plus nitrite as nitrogen. In many cases, both were analyzed separately and nitrite concentration was rarely observed at greater than analytical detection limits. Nitrate plus nitrite as nitrogen will simply be referred to as nitrate for the remainder of this report.

Water from seven domestic wells exceeded the State ground-water quality standard of 10 mg/L for nitrate and had a maximum measured concentration of 30.3 mg/L. The east Erda area is a former agricultural area where grain crops and alfalfa were grown but is now becoming dominated by rural large-lot residential subdivisions. These ranchettes have individual wells and septic systems. Septic systems have been shown to be a source of nitrate contamination to ground water in other parts of the country and are a potential source of contamination in this area (Wilhem and others, 1994; Reneau and others, 1989).

After detection of high nitrate concentrations in water from wells in the east Erda area, several well owners deepened their wells in hopes of obtaining potable water. Water from the deeper wells did not have elevated nitrate concentrations, which indicates that they are completed below the zone of contaminated ground water. These data indicate that the nitrate contamination is limited to the upper part of the saturated zone and that perhaps it is contained in a distinct plume. However, the vertical and horizontal extent, the movement of the contamination, and the source of nitrate in the plume are unknown. Because ground water is the sole source of drinking water in this area, the distribution, source, and movement of nitrate contamination is important to the health of the residents and to Tooele County as it plans for new growth and manages existing and future water supplies.

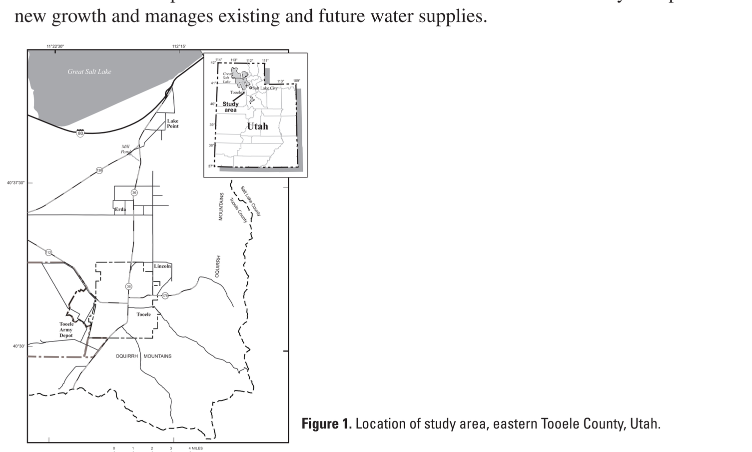


Figure 1. Location of study area, eastern Tooele County, Utah.

Purpose and Scope

This report describes the water quality and ground-water flow system along the eastern side of Tooele Valley in the Erda area from Lake Point to south of the city of Tooele (fig. 1). Ground-water levels and water-quality data were used to determine ground-water quality and flow directions. Specifically, (1) the vertical and horizontal distribution of nitrate, (2) the direction of movement of nitrate contamination, and (3) the source of the nitrate were investigated.

Previous Investigations

This study builds on the recent work of other investigations including Steiger and Lowe (1997), which described recharge and discharge areas and ground-water quality in Tooele Valley. Susong (1998) documented the water quality in the consolidated rocks on the west side of the Oquirrh Mountains. Stolp (1994) assessed the hydrology and potential for ground-water development in southeastern Tooele Valley, and Lambert and Stolp (1999) developed a ground-water flow model for Tooele Valley.

METHODS OF INVESTIGATION

Extensive ground-water-level and water-quality data have been collected in the east Erda area. Water levels in the east Erda area were measured by Steiger and Lowe (1997) in a network of wells with surveyed measuring points. From these data a potentiometric-surface map of part of the east Erda area was compiled (Steiger and Lowe, 1997). This network was expanded by surveying land-surface altitudes of additional wells with standard surveying methods. Water levels in the expanded network were measured during May and June 1997. These data were used to construct a potentiometric-surface map of the principal basin-fill aquifer in the east Erda area that was used to determine directions of ground-water flow and to estimate the direction of movement of the nitrate contamination in the upper part of the basin-fill aquifer.

Selected water-quality data from previous studies (Steiger and Lowe, 1997; Susong, 1998; Stolp, 1994) were compiled for the eastern side of Tooele Valley. The objective of this data compilation was to gather existing data into one data set for evaluation and to design sampling programs for collection of new data. Analyses done by the USGS, Utah Department of Health, and private laboratories are included. These data, along with data collected as part of this study, are listed in table 1.

Water-quality data were collected in a phased approach by sampling water from existing wells and from new wells as they were drilled, and by drilling permanent monitoring wells. A field reconnaissance of the distribution of nitrate in ground water in existing wells in the east Erda area was conducted by using field colorimetric kits. In this survey, water from wells in the east Erda area was sampled and nitrate concentrations were determined in the field.

Wells with water that had nitrate concentrations that exceeded 5 mg/L as nitrogen when measured with the field kits were resampled and analyzed for common ions, nutrients, methylene blue active substances (MBAS), boron, and caffeine. The objective of this resampling was to obtain more accurate measurements of nitrate in water and to collect data to help determine the source of nitrate concentration. MBAS, boron, and caffeine commonly are present in septic system effluent and have been used to identify water affected by septic systems (Thurman and others, 1984; Seiler, 1996). Nitrogen isotopes also have been used to distinguish among sources of nitrate contamination (Seiler, 1996). Two water samples from wells in the east Erda area were analyzed for nitrogen isotopes by Steiger and Lowe (1997). The results were inconclusive in determining the source of contamination. The two samples contained the highest and lowest nitrate concentrations (30.3 and 1.87 mg/L, Steiger and Lowe, 1997, sheet 3) measured in the east Erda area at that time. Additional nitrogen isotope samples were not collected as part of this study.

A program was initiated with local well drillers as part of this study to collect water samples from new wells as they were drilled in the east Erda area. The objective of this sampling was to develop vertical profiles of water quality to assess the vertical distribution of nitrate contamination in the east Erda area. Well drillers notified the USGS when work was begun on a new well and USGS personnel collected water samples as the wells were drilled. Most wells in this area were drilled with air rotary systems with casing advancers that allowed the collection of discrete samples during drilling. Sampling intervals generally were about every 20 ft below the saturated zone but varied with each well. Vertical water-quality depth profiles were collected from 10 new wells.

Ten new monitoring wells were drilled in the principal basin-fill aquifer as part of this study. Six wells in two well clusters were installed in the east Erda area and four monitoring wells were drilled in the Lake Point area to monitor water quality and water levels in the basin-fill aquifer. The Lake Point area, located to the north of the Erda area, is isolated from the hydrologic system to the south by a subsurface consolidated-rock high. The Lake Point area is influenced by its proximity to Great Salt Lake and by seepage from irrigation canals. Rapid development of large water-supply wells in the area has caused concern among residents about future water quality and supply. Drillers' logs for the monitoring wells are listed in table 2.

Well clusters were drilled to monitor nitrate concentrations with depth in the east Erda area. The first site, (C-2-4)35dcc (fig. 2), was located upgradient of the elevated nitrate concentrations in the east Erda area. The second site, (C-2-4)22ddd, was located near what is believed to be the leading edge of the plume. Three wells were completed in the borehole at each site. A well was completed in the upper 10 ft of the saturated zone, which generally contains the highest nitrate concentration in the vertical nitrate profiles. The second well was completed lower in the zone of nitrate contamination, and the third well was completed below the zone of nitrate contamination. Each well had a 10-ft screened interval that was sand packed. The remaining borehole was filled with bentonite grout except for the upper part of the well. The upper 100 ft at site (C-2-4)35dcc and the upper 50 ft at site (C-2-4)22ddd were cased with 8-in. steel casing that was cemented in. The well-screen intervals at each site are listed below and drillers' logs for these wells are listed in table 2.

Site (C-2-4)22ddd		Site (C-2-4)35ddc	
Well number	Well-screen interval (Depth, in feet below land surface)	Well Number	Well-screen interval (Depth, in feet below land surface)
1	57.5-67.5	1	200-210
2	139-149	2	252-262
3	187-197	3	342-352

GROUND-WATER MOVEMENT

The potentiometric surface of the principal basin-fill aquifer in the east Erda area was determined from water levels measured from May 28 to June 16, 1997 (fig. 3). Most of the wells measured in the area were domestic wells that were perforated in the upper 200 ft of saturated thickness. Thus, the potentiometric surface represents the upper part of the basin-fill aquifer.

The regional direction of ground-water flow is generally to the north or northwest on the eastern side of Tooele Valley (fig. 3). On a smaller scale, several interesting features can be seen on this potentiometric surface. There is a ground-water mound in the southeastern part of the Erda area (fig. 3). This mound is believed to be the result of recharge from springs emanating from the consolidated rock of the Oquirrh Mountains and (or) from subsurface recharge to the basin-fill aquifer from consolidated rock. Spring (C-2-4)26ddd-S1, locally known as Rose Spring or Bryan Spring, is located on the eastern side of the ground-water mound and has had measured discharges of as much as 1,770 gal/min (October 1, 1984) (Stolp, 1994). Water years 1982-84 were some of the highest-precipitation years on record for Tooele Valley, and discharge from springs may have contributed substantially to the mound during this period. There may be additional subsurface discharge from consolidated rock directly to the basin-fill material in this area. Two water-quality samples from Rose Spring had dissolved-solids concentrations of 314 and 352 mg/L (table 1), which are less than dissolved-solids concentrations in ground water from the basin-fill material in much of the east Erda area. Dissolved-solids concentrations in ground water measured at wells in the mound were similar to concentrations in the Rose Spring samples.

The steep ground-water gradient in the upper part of figure 3 is likely associated with large municipal water-supply wells in the northeastern quarter of section 27 that supply Stansbury Park and with a subsurface consolidated-rock high to the north. These public-supply wells are located downgradient from the areas of nitrate contamination. The wells are perforated for most of their depth and are drawing water from throughout the basin-fill aquifer. North of this area, beyond the area with the potentiometric-surface contours, the subsurface consolidated-rock high separates the ground-water flow system in the Erda area from the flow system in the Lake Point area (Lambert and Stolp, 1999). Data from the few wells drilled into the consolidated rock indicate that water levels there are about 100 ft lower in altitude and much higher in dissolved-solids concentrations (table 1, well (C-2-4)14cdb-1, 960 ft deep) than they are in the basin-fill aquifer in this area. The relation between the ground-water flow systems in the consolidated rock and the basin-fill material is poorly understood in this area. A significant discharge area for ground water in this area is the large spring (C-2-4)15cac-S1, locally known as Mill Pond Spring, (fig. 2) located near the western extension of the subsurface consolidated rock high. Water discharging at this spring is probably a mixture of water from consolidated rock and basin-fill material. Dissolved-solids concentrations from the spring are greater than those in the upper part of the basin-fill aquifer and considerably less than those in water from well (C-2-4)14cdb completed in the subsurface consolidated-rock high.

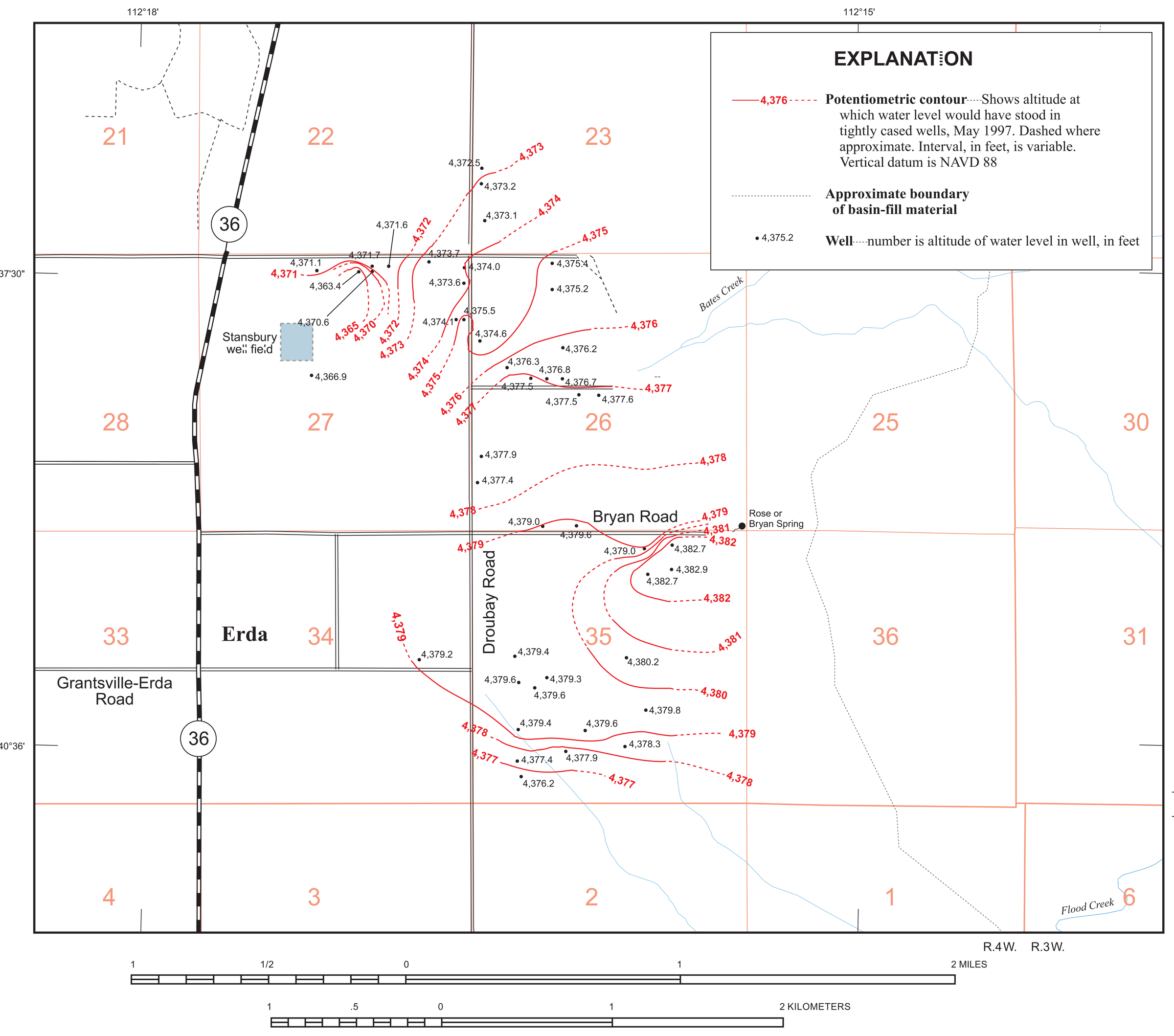
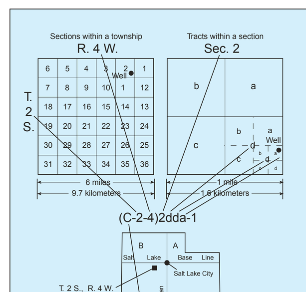


Figure 3. Potentiometric surface of the east Erda area, Tooele County, Utah, May-June 1997.



Numbering system used for hydrologic-data sites in Utah.

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. The land-survey system divides the State into four quadrants separated by the Salt Lake Base Line and the Salt Lake Meridian. These quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range, in that order, follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section—generally 10 acres for a regular section[1]. The lowercase letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract. When the serial number is not preceded by a letter, the number designates a well. When the serial number is preceded by an "S," the number designates a spring. A number having all three quarter designations but no serial number indicates a miscellaneous data site other than a well or spring, such as a location for a surface-water measurement site or tunnel portal. Thus, (C-2-4)2dda-1 designates the first well constructed or visited in the southwest 1/4 of the northeast 1/4 of the northwest 1/4 of section 26, T. 2 S., R. 4 E.

[1]Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular in size and shape. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

Conversion Factors, Datums, and Abbreviated Water-Quality Units

Multiply	By	To obtain
acre-feet (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06308	liter per second
inch (in.)	25.4	millimeter
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Chemical concentration and water temperature are reported only in metric units. Chemical concentration is reported in milligrams per liter (mg/L) or micrograms per liter (mg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (µS/cm).

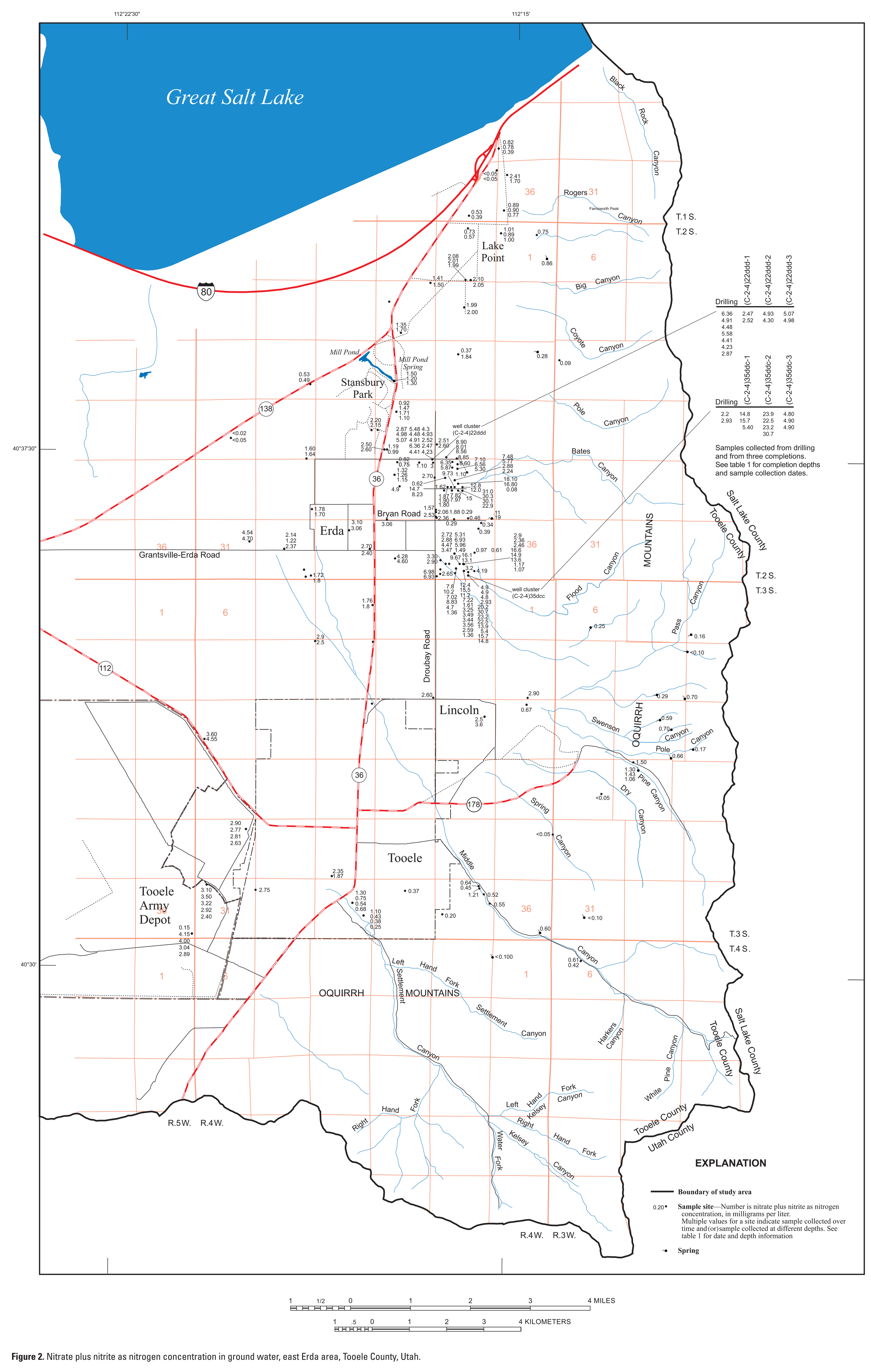


Figure 2. Nitrate plus nitrite as nitrogen concentration in ground water, east Erda area, Tooele County, Utah.

NITRATE IN GROUND WATER

The spatial distribution of nitrate in ground water on the eastern side of Tooele County is variable both spatially and vertically and is shown in figure 2. Data sites may have multiple values listed because samples were collected from different depths during drilling and (or) at different times. Nitrate concentrations for each data site are shown in figure 2 and complete water-quality analyses are listed in table 1, along with well depth and sample date.

Nitrate concentrations were greater than background concentrations in ground water from the basin-fill aquifer in Township 2 South, Range 4 West, Sections 23, 26, 27, 31, and 35. Nitrate concentrations from 0 to 3 mg/L generally are considered to be the range of natural background conditions in ground water (Madison and Brunett, 1984). In the east Erda area, nitrate concentrations ranged from 0.288 to 30.7 mg/L (table 1) depending upon location and depth of completion of the well.

Two distinct areas contain elevated nitrate concentrations (fig. 2). The areas are generally divided geographically into north and south parts by Bryan Road. The ground-water mound shown in the potentiometric surface (fig. 3) separates the two parts.

Separation of the nitrate plume into two distinct parts reflects the hydrology of the area. The area of low nitrate concentration is coincidentally aligned with the ground-water mound in figure 3. One explanation for the split plume morphology is that there was a substantial influx of water from Rose Spring, (C-2-4)26ddd-S1, and discharge from consolidated rock to the basin-fill aquifer created the ground-water mound and diluted the nitrate plume. This is supported by very large discharges measured at Rose Spring in the early 1980s, some of the wettest years on record in Utah (Stolp, 1994). It is assumed that prior to the early 1980s the plume was continuous through the east Erda area and that the recharge from spring discharges caused the ground-water mound to grow there by diluting and splitting the plume. Prior to the 1980s there were a limited number of wells in the area and few nitrate data to document any changes in size of the mound and (or) changes in nitrate concentration. Another explanation is that the two parts are two distinct plumes with separate sources. However, large separate sources of nitrate have not been identified in the area.

The upgradient extent of the plume to the south toward Pine Canyon and Lincoln is unknown. Water samples from USGS monitoring wells at site (C-2-4)35dcc contained elevated nitrate concentrations in the shallow well ((C-2-4)35ddc-1) and a nitrate concentration of 30.7 mg/L in the middle well (table 1, (C-2-4)35dcc-2). This is strong evidence that the plume extends to the south beyond its current known boundaries. The western boundary of the plume is also not well demarcated. There is evidence that elevated nitrate concentrations decrease to background levels in a westerly direction. The boundaries of the plume are difficult to determine because few wells are completed in the plume and because most well owners choose to drill deeper to obtain water with a lower nitrate concentration. Consequently, there are large areas without any wells in which to sample the plume. Future development and coordination with drilling efforts could provide data for some of these areas.

Vertical Profiles of Nitrate Concentration

Nitrate contamination is distributed vertically in the basin-fill aquifer in the east Erda area. Vertical profiles of nitrate concentration in ground water in the basin-fill aquifer were compiled from water samples collected during the drilling of new wells (fig. 4). Ten profiles were obtained during 1997-99. Elevated nitrate concentrations generally are confined to the upper 50 to 150 ft of the saturated zone. Vertical profiles of nitrate concentration in the basin-fill aquifer follow several patterns. The first pattern occurs when the nitrate contamination is in the upper part of the saturated zone and decreases with depth, as in well (C-2-4)35cda-1. This indicates that the nitrate contamination is limited to the upper saturated zone and there has been little movement of the contamination downward in the basin-fill aquifer. A second pattern occurs when nitrate contamination is present in the middle of the profile with low nitrate concentrations in water both above and below. This profile indicates that nitrate contamination has moved deeper into the basin-fill aquifer and that more recent recharge overlies the contaminated zone. A third pattern occurs when elevated nitrate concentrations are not present. Specific conductance, which is a proxy measure of the dissolved-solids concentration in water (Hem, 1985), displays similar vertical profiles (fig. 4) to nitrate concentration, with the exception of water from well (C-2-4)14cdb-1, which contains background concentrations of nitrate. Overall, this pattern indicates that other conservative dissolved constituents are moving with the nitrate. Specific-conductance data are plotted in figure 4 rather than dissolved-solids concentration data because not all samples have both nitrate and dissolved-solids analyses. The differences among the nitrate and specific-conductance profiles may be attributed to the location of the well in the plume and the stratigraphy and hydrology of the basin-fill aquifer.

Water-Quality Change Over Time

Changes in dissolved-solids and nitrate concentration in the basin-fill aquifer over time were examined for water from selected wells in the east Erda area (fig. 5). USGS monitoring wells at sites (C-2-4)35dcc and (C-2-4)22ddd are completed at different depths. Nitrate concentration in water from well (C-2-4)35dcc-2, (the middle well, 252 ft), increased from 13.9 mg/L to 30.7 mg/L in an 8-month period (fig. 5). The change in nitrate concentration indicates that nitrate is moving downward in the basin-fill aquifer in this area. Dissolved-solids concentration in the middle well has increased along with nitrate, indicating the general downward movement of water in the aquifer. An alternative explanation for the increasing nitrate and dissolved-solids concentrations is that water levels in the area are generally dropping because of pumpage and drought. This could change the vertical distribution of dissolved constituents as well. In the upper well there has been no overall change in dissolved-solids concentration. Nitrate concentration in water from the three monitoring wells collected as part of the time-series sampling is generally higher than that measured in the water samples collected during drilling of the well (table 1). This may be partly explained because the samples were not collected from the same depth intervals. Nitrate concentration has remained static in the deepest completed well (352 ft) at about 4.9 mg/L.

Dissolved-solids and nitrate concentrations have not changed substantially in water from wells at site (C-2-4)22ddd (fig. 6). This site is located at the downgradient end of nitrate contamination and concentrations generally are lower and have not changed substantially since the wells were drilled. Concentrations of dissolved solids and nitrate measured in the time-series samples are similar to concentrations measured in samples collected during drilling (table 1).

A time-series distribution of dissolved-solids and nitrate concentrations was compiled for water from three wells near the mouth of Pine Canyon (fig. 5). Dissolved-solids concentrations in wells (C-3-4)13abb-1 and (C-3-4)14adb-1 display a slight decreasing trend. Nitrate concentrations in water from these wells are within the background range of 0 to 3 mg/L. Nitrate concentrations in water from well (C-3-4)12dcc-1 decreased from 8.9 to 2.9 mg/L during 1977-95. Water-quality analyses of one sample from this well are the only evidence that nitrate contamination was located upgradient, near Pine Canyon, from the current known nitrate plume. The sample collected in 1978 may have been reported as nitrate rather than nitrogen. Converting it to nitrogen yields a concentration of 2.0 mg/L.

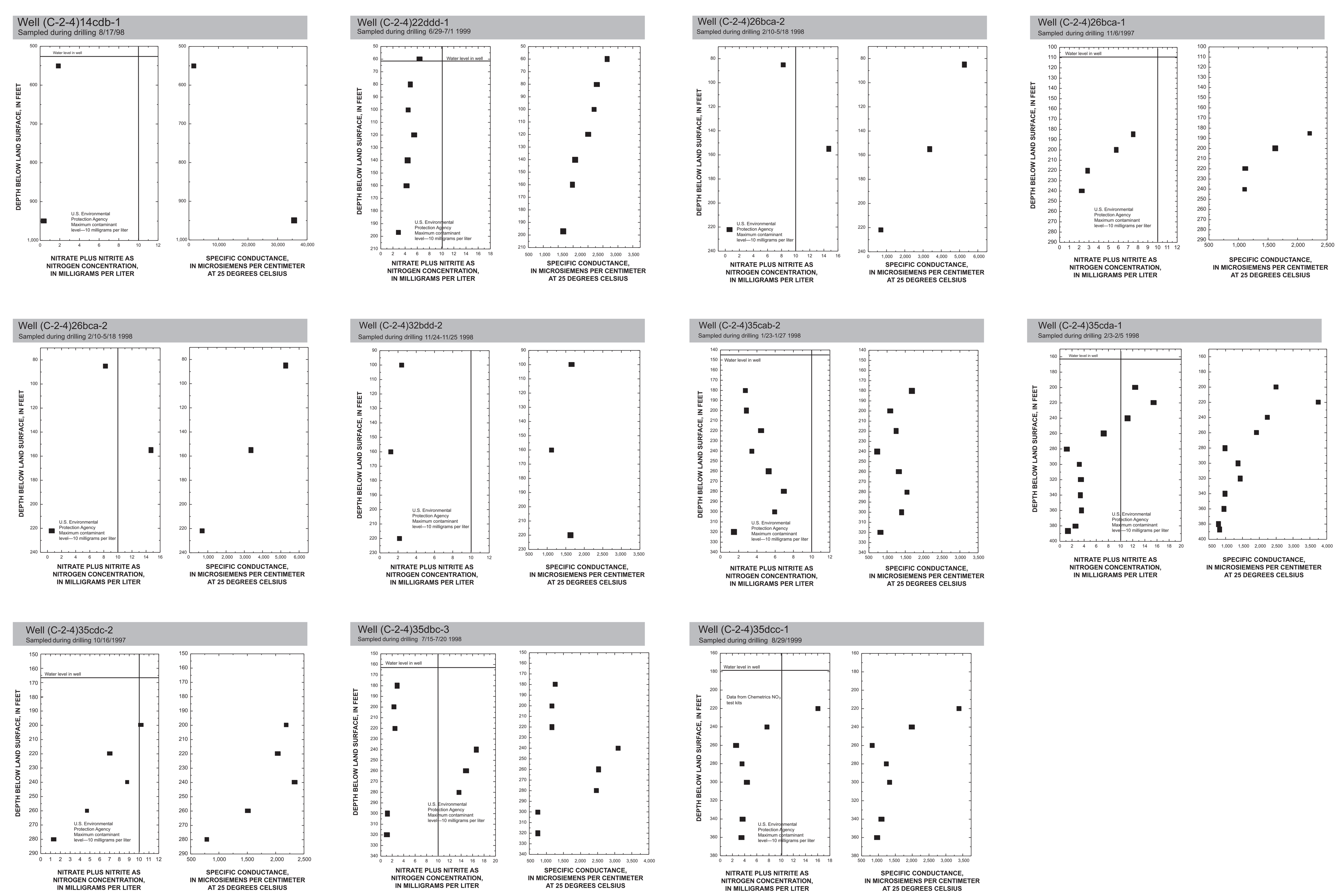


Figure 4. Vertical profiles of nitrate plus nitrite as nitrogen concentration and specific conductance in ground water from selected wells, east Erda area, Tooele County, Utah.

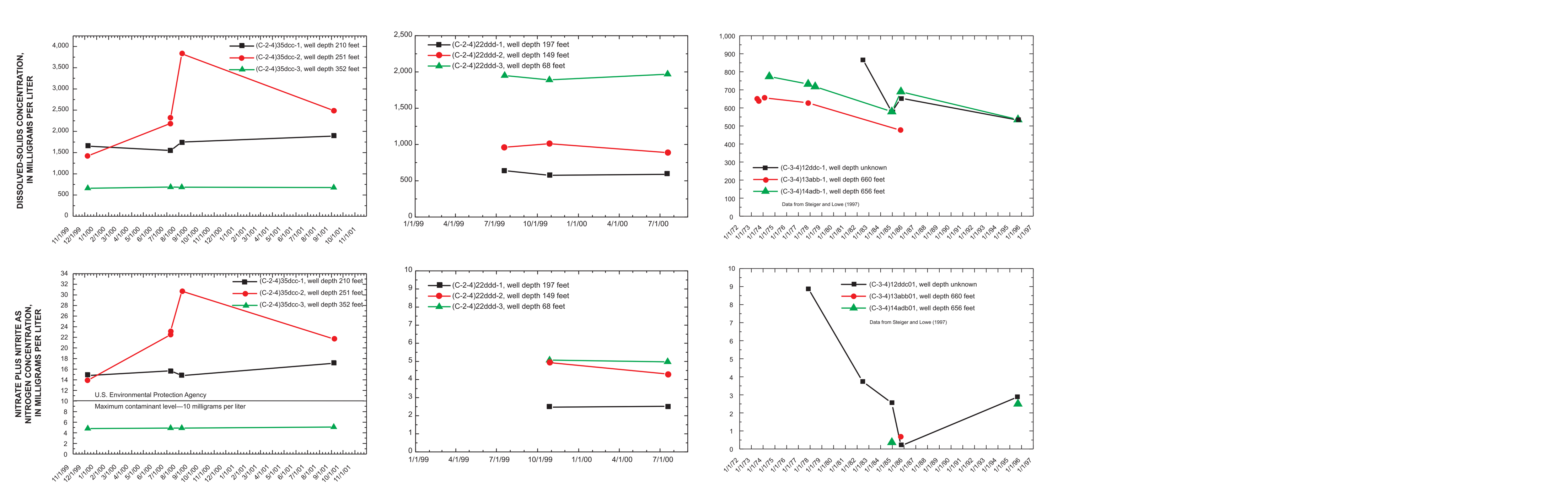


Figure 5. Time-series distribution of nitrate plus nitrite as nitrogen concentrations in ground water from selected wells, east Erda area, Tooele County, Utah.

Ground-Water Movement and Nitrate in Ground Water, East Erda Area, Tooele County, Utah, 1997-2000

By D.D. Susong

2005