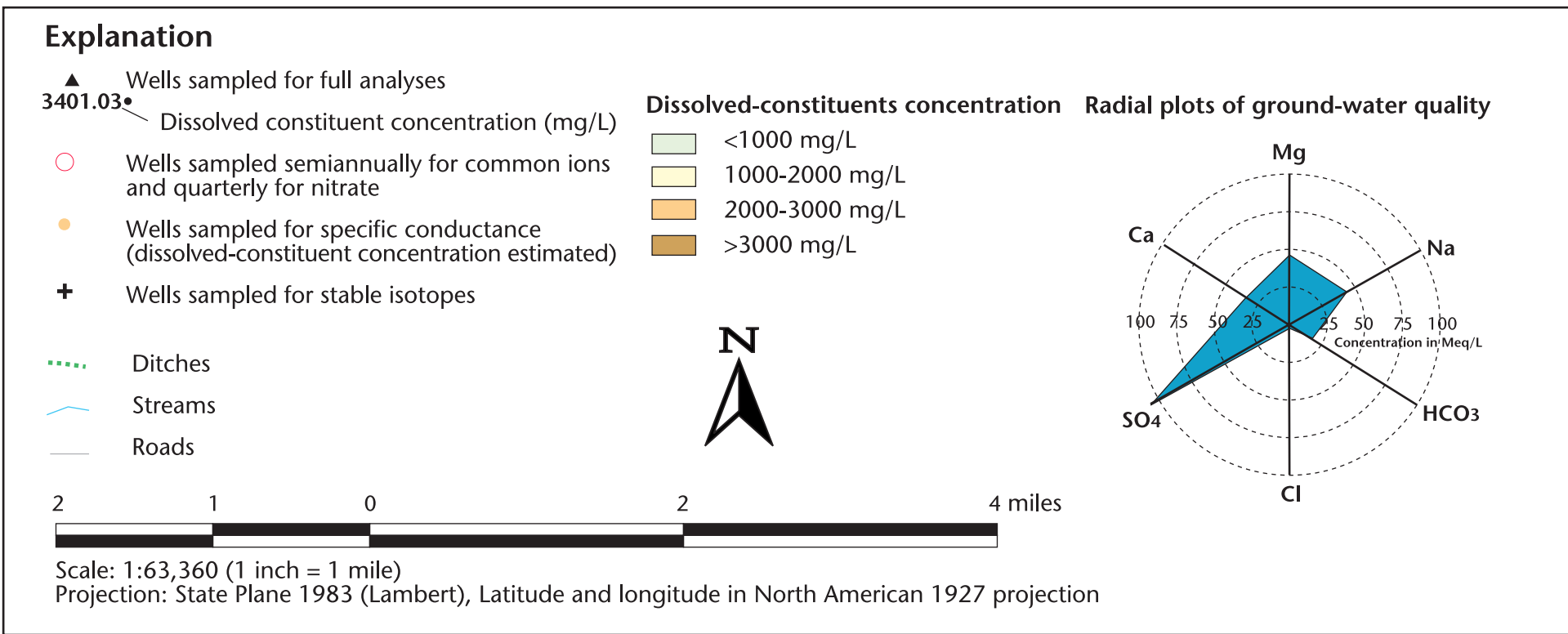


Plate 2: Ground Water Quality of the West Billings Area

Ground-water quality in the West Billings area ranges from relatively fresh water dominated by bicarbonate (HCO_3) anions to a highly mineralized water dominated by sulfate (SO_4) anions. Both water types have relatively even proportions of calcium (Ca), magnesium (Mg), and sodium (Na). Dissolved-constituents concentrations ($\text{Ca}+\text{Mg}+\text{Na}+\text{K}+\text{SO}_4+\text{Cl}+\text{HCO}_3$) range from <300 mg/L to >5,000 mg/L. Water containing <2,000 mg/L of dissolved constituents is generally satisfactory for domestic use. Water containing >3,000 mg/L of dissolved constituents is seldom used for domestic purposes.

Water-quality data presented on this plate are a summary of data collected as part of this project and existing data in MBMG's Ground-Water Information Center. These data are available at www.mbm.mtech.edu.

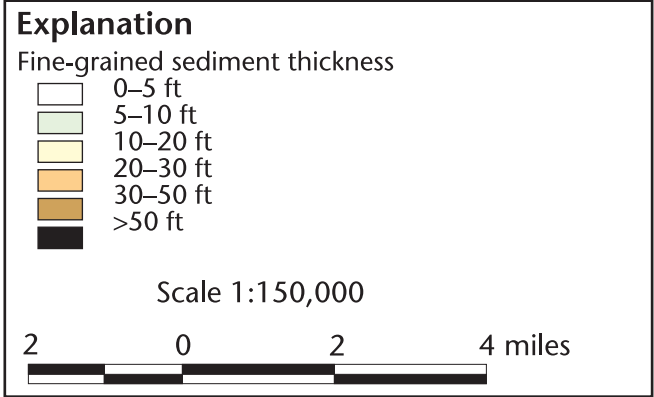


Summary of Sample Analyses (September 2000 and March 2001)

Common Ions (mg/L)	Min	Max	Avg	Sd	Trace Metals (ug/L)	Min	Max	Avg	Sd
Calcium	60	492	183	126	Aluminum	-	<30	-	-
Chloride	5	93	24	20	Antimony	<1	<2	-	-
Bicarbonate	278	594	441	89	Arsenic	<1	5.6	1.9	1.4
Potassium	3	12	6	3	Boron	83.8	1,370	495	306
Magnesium	20	440	121	107	Cadmium	-	<2	-	-
Sodium	32	1,100	264	274	Copper	<2	11.4	4.4	3
Sulfate	54	4,606	1,090	1,186	Chromium	<2	7.6	2.6	1.6
Fluoride	<0.5	1.5	0.6	0.4	Barium	8.3	134	41.1	35.4
Iron	<0.005	1.2	0.1	0.3	Beryllium	-	<2	-	-
Manganese	<0.01	2.7	0.6	0.7	Bromine	-	<2	-	-
Nitrate (as N)	<0.05	12.3	3.3	2.9	Cobalt	<2	7.4	4.4	2.3
Nitrite (as N)	-	<0.5	-	-	Lead	-	<2	-	-
Total Phosphate	<0.5	0.5	-	-	Lithium	<25	318	109.4	79
Ortho-Phosphate	<0.5	0.5	-	-	Molybdenum	<10	53.6	12.4	12.6
Silicate	8.9	30.2	19.1	5.2	Nickel	4	37.6	12.3	8.8
					Selenium	<1	87.4	9.4	19.3
					Silver	-	<2	-	-
					Strontium	520	7,780	2,412	1,893
					Titanium	-	<100	-	-
					Vanadium	-	<5	-	-
					Zinc	<2	41.6	6.8	8.9
					Zirconium	-	<100	-	-

Notes:
Min = minimum value
Max = maximum value
Avg = average value
Sd = one standard deviation
ug/L = microgram per liter
mg/L = milligram per liter

Fine-grained Sediment Thickness Map

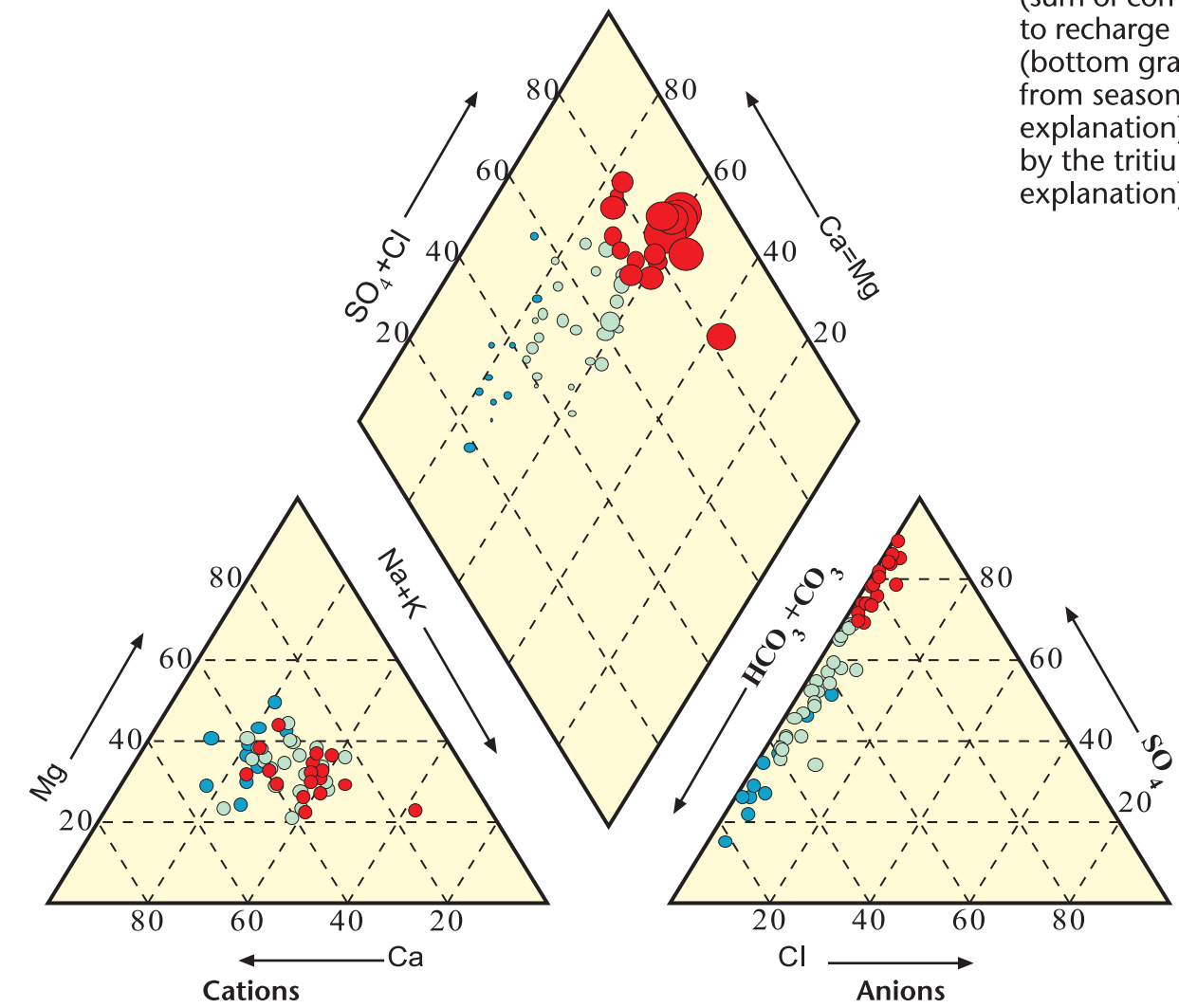
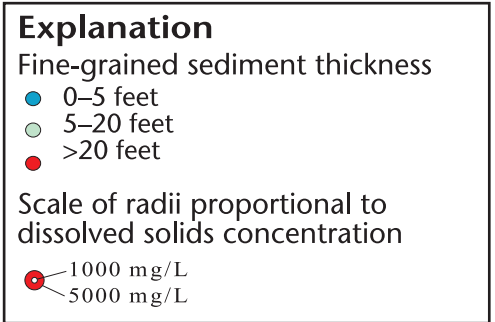


The Influence of Fine-Grained Sediment Thickness on Ground-Water Quality

The distribution of dissolved constituents concentrations are strongly influenced by the thickness of fine-grained sediments overlying the sand and gravel aquifers. Where the fine-grained sediment cover is thin, irrigation water can infiltrate rapidly and water quality remains relatively unchanged. Where the fine-grained cover is thick water infiltrates slowly and dissolved solids accumulate through evapotranspiration and soil-mineral dissolution.

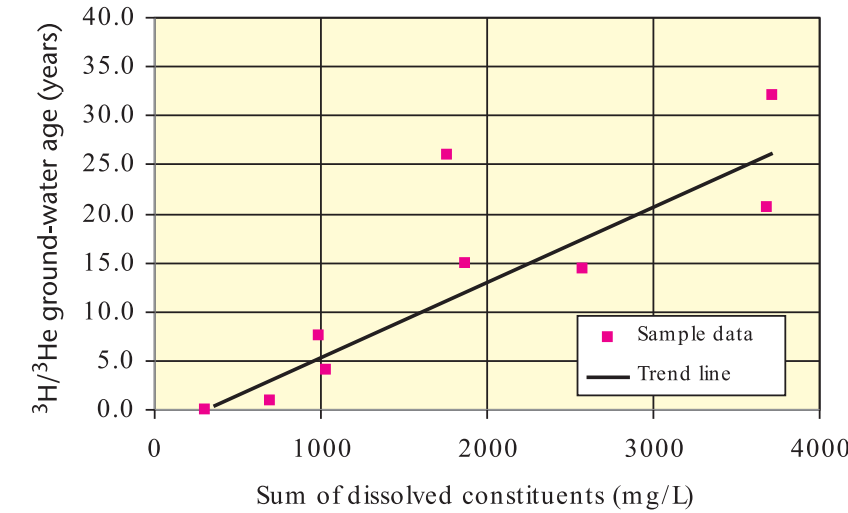
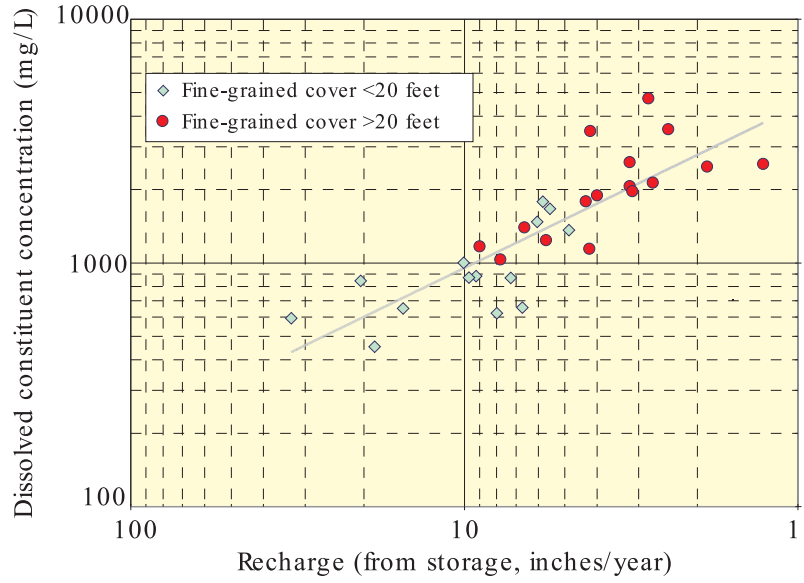
Piper Plot

The piper plot shows the relative proportion of common ions expressed in percent of milliequivalents per liter. The size of the dot is proportional to the sum of dissolved-constituents concentration. The color of the dots indicates the thickness of fine-grained sediment overlying the aquifer at the well location.



Relationships between Ground-Water Quality, Recharge and Ground-Water Age

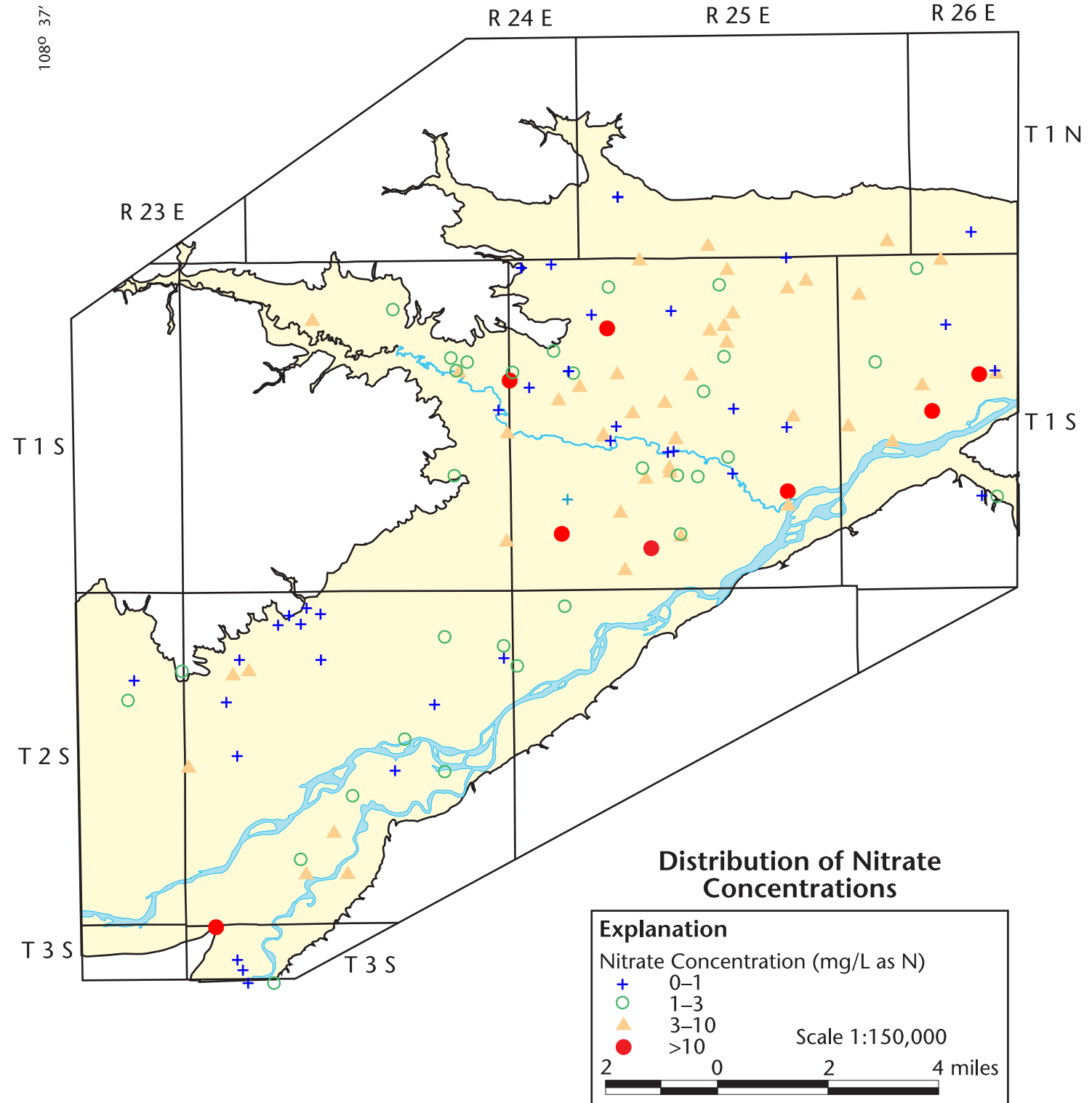
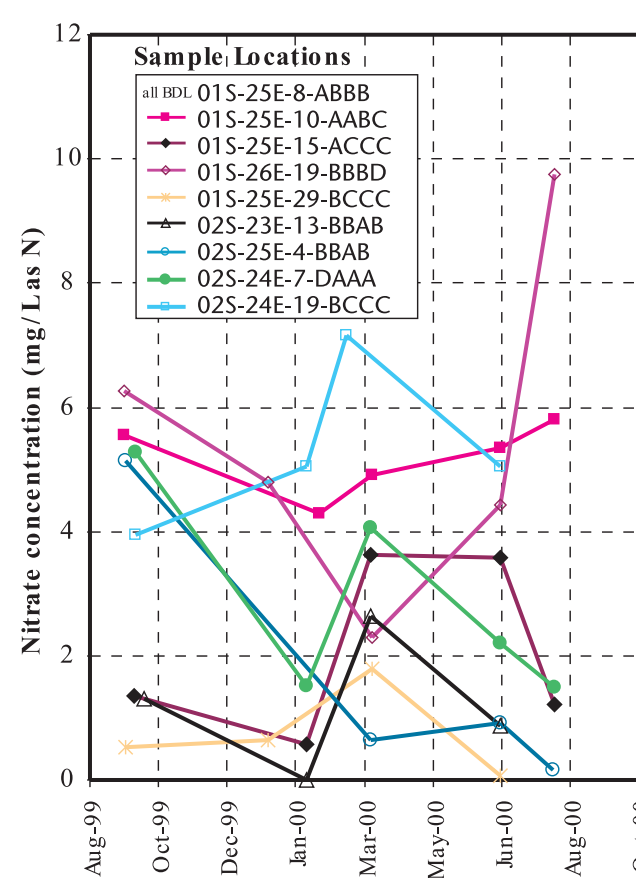
The sum of dissolved-constituents concentration (sum of common ion concentrations) is proportional to recharge rates (top graph) and ground-water age (bottom graph). The recharge rates were calculated from seasonal storage changes (see text for explanation). Ground-water ages were calculated by the tritium-helium-3 method (see text for explanation).



Nitrate in Ground Water

Ground-water nitrate concentrations in the project area ranged from below detection (<0.1 mg/L) to 20 mg/L with an average concentration of 3.4 mg/L. The concentrations appear to be sporadically distributed across the project area. Evaluation of nitrate concentrations by land use and fine-grained soil cover indicates average nitrate concentrations on irrigated lands were slightly higher than residential areas, and average nitrate concentrations for both land-use categories were higher where the fine-grained cover is thin.

Nitrate Concentration Fluctuations



Nitrate Concentrations by Land Use and Fine-Grained Cover

Group	Number of samples	Average nitrate concentration (mg/L-N)	Fine-grained sediment thickness <20 feet	Fine-grained sediment thickness >20 feet
All wells	84	3.4	3.8	2.8
Irrigated land	34	3.6	3.9	3.1
Residential	50	3.0	3.6	1.3