SECTION 3
UNDERSTANDING NITRATE IN THE SEYMOUR AQUIFER

.1 NITRATE SOURCES

The primary regional source of nitrate is likely the agricultural application of fertilizers. Additionally important are several localized nitrate sources, predominantly septic tanks and barnyards near rural residences and sewers in urban areas. Groundwater nitrate concentrations in the Seymour aquifer increase with increased percentage of row crop and urban land uses within a 1000 m buffer surrounding each well based on the TWDB database (Fig. 3-1a) and decrease with increased percentages of rangeland, forest, pasture/hay, and small grains land uses (Fig. 3-1b). Total dissolved solids (TDS) levels are generally not related to land use (Figs. 3-1a, 3-1b). Soil sampling in agricultural areas with different types of crops showed that there is a reservoir of nitrate in the soil zone beneath dryland and irrigated wheat and cotton (Appendix _). Nitrate levels in soils in areas of irrigated and dryland alfalfa were low. Alfalfa is a legume and can fix nitrogen; however, the data suggest that rapid growth and frequent harvesting of alfalfa may use up all available nitrogen. An anthropogenic rather than geologic source of nitrate is indicated by a general lack of relationships between nitrate and other major inorganic anions (Fig. 3-2).

Leakage from centralized sewage systems, septic tanks, and/or barnyards may provide local sources of nitrate contamination to nearby public water supply and domestic wells as suggested by previous work conducted by Harden et al. (1978). Nitrate-N concentrations in groundwater wells associated with urban areas are statistically higher than in areas not associated with urban land uses (Fig. 3-3). The population of domestic wells in the TWDB database shows consistently higher nitrate-N concentrations than irrigation wells, though differences between the two in general water quality are relatively small as indicated by the distribution of TDS (Fig. 3-4).

Previous studies have suggested that the primary source of nitrate in groundwater in the Seymour Aquifer is from natural sources (Bartolino, 1994). High levels of groundwater nitrate prior to widespread application of fertilizers in the mid 1960s were attributed to oxidation of nitrogen that had built up in the soil zone over long times in nearby Runnels county (Kreitler, 1975) or to nitrogen fixation by legume plants such as mesquite in the Seymour Aquifer (Bartolino, 1994) and subsequent flushing of this nitrate into the underlying aquifer as a result of increased recharge rates from cultivation. Groundwater data from the TWDB database indicate high nitrate levels prior to 1950; however, the number of samples is low (130). Nitrate-N concentration profiles in soils in areas of native ecosystems that have never been cultivated were low (Appendix _). However, total nitrogen was not analyzed in these samples and may be high. Nitrate profiles in soils under native settings in semiarid/arid environments in other states (Nevada and Kansas) had very high nitrate concentrations in the soil profile and data showed that these high nitrate levels were mobilized under irrigated agriculture (Hartsough et al., 2001; Stonestrom et al., 2003; Walvoord et al., 2003). Current estimates of recharge (0.8 to 2.5 in/yr; mean 2 in/yr) for the Seymour Aquifer from the recently developed Groundwater Availability Model (Ewing et al., 2004) suggests that this original source of nitrate should be flushed through the system in areas of coarse textured soils but may remain in areas of fine textured soil which may explain the relationship between nitrate-N concentrations in groundwater and soil texture (Fig. 3-5).

.2 PRACTICES NECESSARY TO REDUCE GROUNWATER NITRATE CONCENTRATIONS

There are various approaches discussed in the literature for reducing nitrate derived from leaching of fertilizers. Currently fertilizers are generally applied one time prior to planting. Agricultural land uses account for 70.6% of the Seymour Aquifer area while irrigated areas constitute only 6.7% based on the National Land Cover Dataset (NLCD 1994).

To optimize fertilizer application so that crops use most of the applied fertilizers and leaching is minimized, studies suggest that fertilizer application should be split into multiple applications (2 – 4): preplanting and post planting. This may be a problem because the land is generally dry when fertilizers are applied prior to planting; however, precipitation after planting may make it difficult to apply fertilizers. If fertilizers are applied through irrigation water, the timing of application may not be difficult to control. The infrastructure does not seem to be available for aerial application of fertilizers in the Seymour regions. The type of fertilizer applied may also influence the leaching rate. Slow release fertilizers should result in less leaching than fast release fertilizers, however slow release fertilizers are generally more expensive. The timing of fertilizer application relative to water applications (precipitation or irrigation) may also be a critical factor in determining leaching. Although it may be difficult to control fertilizer applications relative to precipitation in dryland farming regions, irrigation applications may be controlled to minimize fertilizer leaching. The type of irrigation system plays a large role in controlling leaching: flood irrigation systems are more inefficient than center pivot systems and result in greater leaching. Subsurface drip irrigation systems are even more efficient than center pivot systems and a study is being conducted by the Texas State Soil and Water Conservation Board to evaluate such a system in the Seymour region. Irrigating at rates determined by monitoring potential evapotranspiration or soil moisture should result in much less drainage than uniform irrigation rates and should be considered. Soil profiles in land in the Conservation Reserve Program (CRP) have low nitrate levels (Appendix _), which indicates that if fertilizer is no longer applied the nitrate reservoir in the profile can be flushed out. The effects of these management practices on groundwater nitrate may take a long time to establish because of the time required for water to move through the unsaturated zone and through the groundwater system. With a recharge rate of 2 in/yr and average water content in the unsaturated zone of 10% by volume, the travel time through a 50 ft unsaturated zone would be 33 yr.

.3 HISTORICAL TRENDS IN NITRATE CONCENTRATIONS

Time series information from the TWDB database is limited. There are 2283 wells in the TWDB data base that are within the outcrop areas of the Seymour Aquifer. Of those, 1906 (83.5%) have only one water quality analysis record while only 135 (5.9%) have three or more nitrate-N concentrations reported through time. Most samples were collected and analyzed in the late 1960's (Wilbarger Co., Jones Co.) or mid 1970's (Haskell Co., Knox Co.). Individual wells showed increasing, decreasing, and variable trends through time.

Haskell and Knox Counties account for approximately 45% of the Seymour Aquifer nitrate-N data. Sampling was also generally more widely spread both spatially and temporally relative to the other pods and provides the best overall data set for a temporal analysis of nitrate-N concentrations. Analysis for the entire well population in these counties shows a significant general increase over time in nitrate-N concentrations and median concentrations that have generally been in excess of 10 mg/L (Fig. 3-6a).

However, approximately 30% of the data used in this analysis are domestic wells, which may be subject to local contamination. Though much of the repeat sampling of individual wells occurred for domestic wells, an analysis that excludes domestic wells and which might reflect more ambient regional conditions, also suggests increasing concentrations with time and median concentrations also generally remained greater than 10 mg/L (Fig. 3-6b). However, the significance of this regression is much lower and suggests that regional temporal trends in nitrate-N concentrations may not be significant.

.4 NITRATE STRATIFICATION

Permian age formations underlay the Seymour Aquifer and generally do not contain water that, without treatment, is of suitable quality for a public water supply system, primarily as a result of elevated sulfate and/or TDS concentrations. Groundwater nitrate-N concentrations from the TWDB database were evaluated to determine if there is any distinct stratification of water chemistry with depth in the Seymour Aquifer that would allow shallower or deeper wells to be drilled to minimize nitrate levels.

The Seymour Aquifer is relatively thin. Saturated thickness generally ranges from less than 10 ft near pod boundaries to approximately 100 ft in a few locations near pod centers, and generally ranges from 20 to 60 ft. There is no obvious relationship between nitrate-N concentration and well depth (Fig. 3-7). Median nitrate-N concentrations were grouped by well depth intervals to evaluate depth trends. The analysis indicates fairly uniform median nitrate-N levels with depth with most median values near or exceeding 10 mg/L. Additionally, the middle 50% of the nitrate-N concentration distributions overlapped for all intervals indicating that drilling shallower or deeper wells within the Seymour Aquifer would not likely result in acceptable nitrate-N concentrations. The uniform nitrate-N concentrations with depth may be attributed in part to the high permeability of the Seymour aquifer throughout its thickness and particularly in the gravel layer found at the base of the aquifer in many areas.

.5 EXPERIENCE OF OTHER STATES

Groundwater nitrate contamination in neighboring states is generally not as widespread as in Texas. The following summarizes the state of knowledge with respect to nitrate in Oklahoma, Louisiana, New Mexico and Arkansas.

Oklahoma: ambient groundwater monitoring program

- Range NO_3-N: 0.0 to 19.8 mg/L; Median NO_3-N: 0.76 mg/L (339 samples, 2002 – 2004).
- Highest nitrate located in western and northwestern areas of the state.
- Potential sources: fertilizers, septic tanks, and confined animal feeding operations (primarily swine).

Louisiana: ambient groundwater monitoring program

- Range NO_3-N: <0.05 to 0.63 mg/L (2001 – 2003).

New Mexico: no ambient groundwater monitoring program

- Range NO_3-N: 0.0 to >500 mg/L
- 200 nitrate plumes affecting 710 private and 82 public water supply wells (McQuillan et al., 2004).

- Potential sources: natural, confined animal feeding operations, septic tanks, and sewer systems.
- EPA study of 94 dairies: 36% have NO_3-N ≥ 10 mg/L; waste lagoons responsible for NO_3-N ≥ 100 mg/L.
- Large capacity septic tank study: 50% ≥ 10 mg/L NO_3-N in groundwater.

Arkansas: no ambient groundwater monitoring program

- Range NO_3-N: < 0.05 to 60 mg/L (2001 – 2003) (high in NW part of state).
- SE part of state mostly confined aquifers; nitrate does not reach aquifers or is denitrified in aquifers.
- Potential sources: septic systems, sewers, fertilizers, confined animal feeding operations.

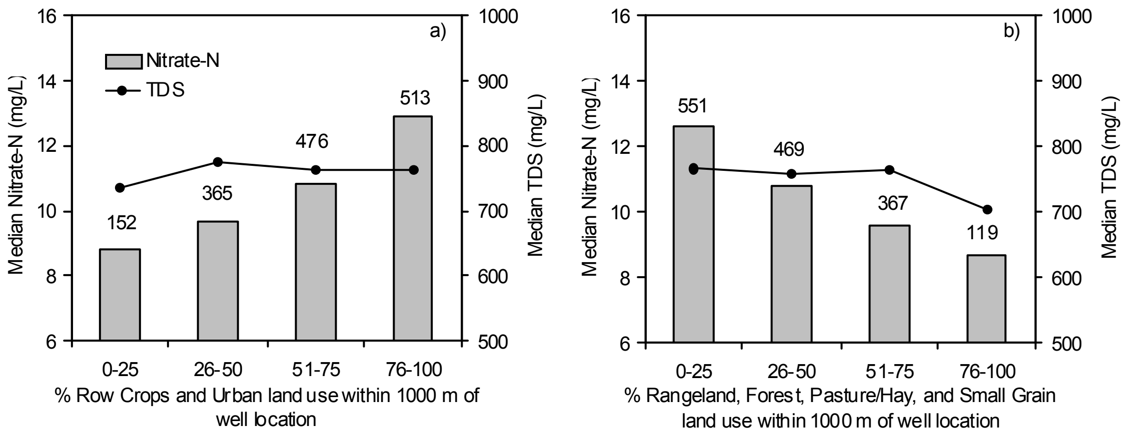

Figure 3-1

Median nitrate-N and TDS concentrations in groundwater in relation to land use within a 1000 m radius of well locations for a) the combined percentages of row crops (NLCD code 82) and urban (NLCD codes 21, 22, 23, 85) land use categories and (b) the combined percentages of rangeland (NLCD codes 51, 71), forest (NLCD codes 41, 42, 43) and the remaining agricultural (NLCD codes 81, 83) land use categories. The complimentary analyses account for an average of 99% of the area within 1000 m of all wells. Numbers indicate the quantity of wells within each group.

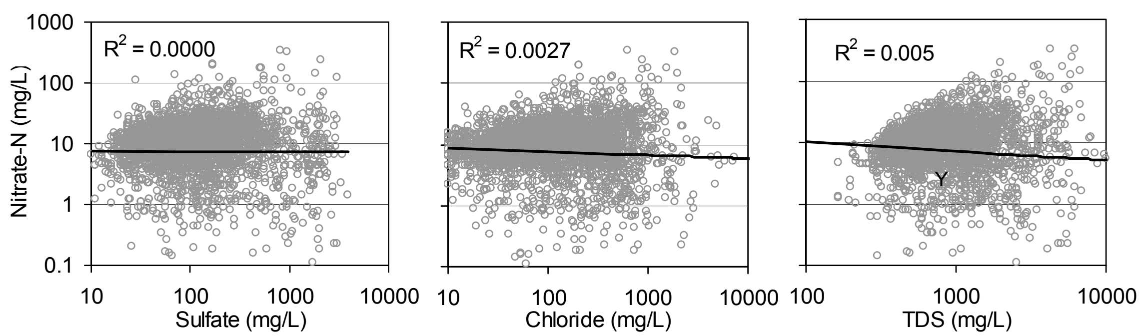

Figure 3-2

Relationship between nitrate-N and sulfate, chloride, and TDS for 3417 groundwater samples in the Seymour Aquifer. (Source: TWDB database).

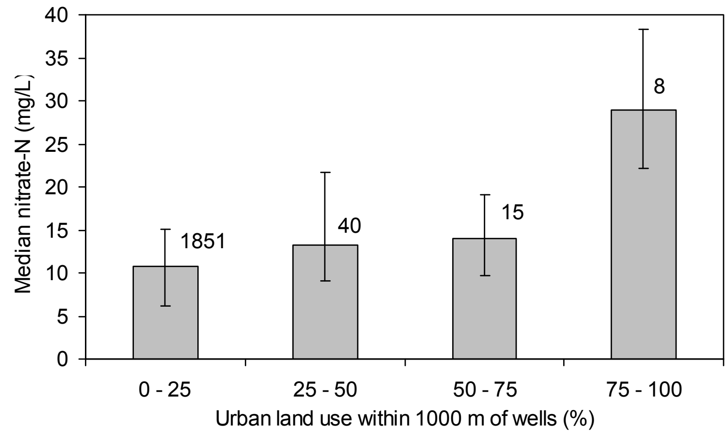

Figure 3-3

Median nitrate-N concentrations in groundwater in relation to the percentage of Urban (NLCD codes 21, 22, 23, 85) land use categories within a 1000 m radius of the well locations. Values represent the number of wells within each group. Error bars represent the middle 50% (i.e., median ±25%) within each group. The population means are statistically different to $p<0.01$.

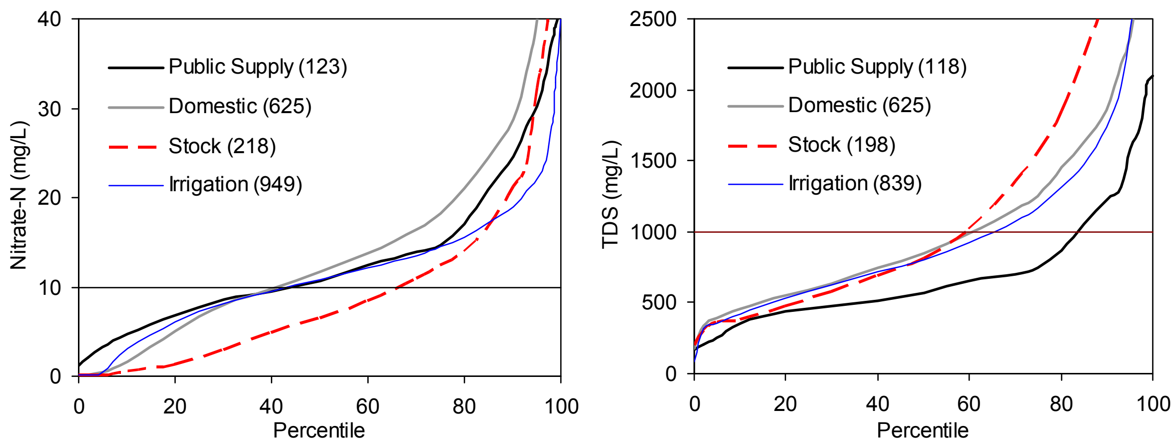

Figure 3-4

Distribution of nitrate-N and TDS concentrations in the Seymour Aquifer as a function of primary well use. Numbers in parenthesis indicate number of wells in each category. The most recent water sample for each well was used in the analysis.

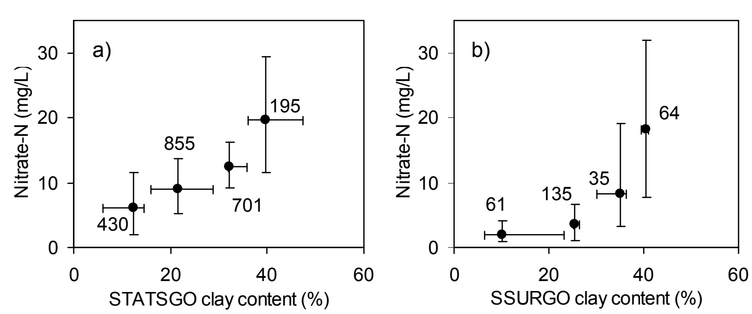

Figure 3-5

Relationship between nitrate-N concentrations in groundwater and average soil clay content at well locations in a) the entire Seymour Aquifer based on generalized soils data from the State Soil Geographic (STATSGO) soil database and b) outcrop areas of the Seymour Aquifer in Jones County based on detailed soils data from the Soil Survey Geographic (SSURGO) soil database. Numbers indicate quantity of wells in each group. Points are plotted at the average clay content versus median groundwater nitrate-N concentration for each group. X error bars indicate the range of clay content values for each group and Y error bars indicate the middle 50% range (i.e., median ± 25%) of nitrate-N concentrations for each group.

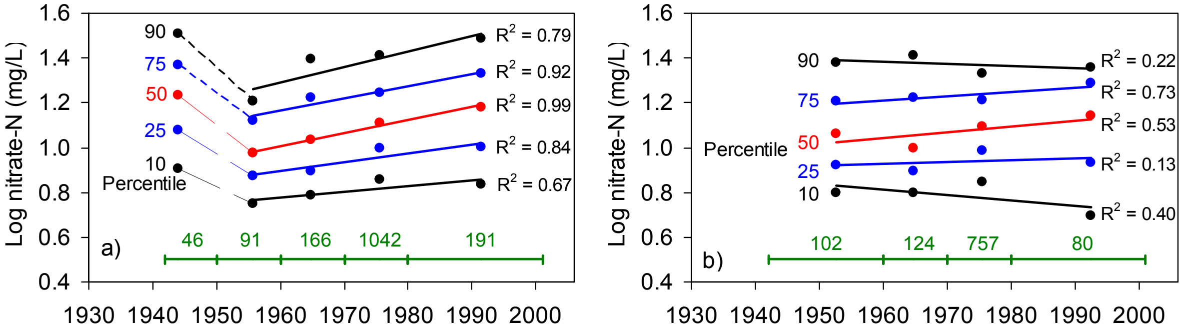

Figure 3-6

Temporal trends of log nitrate-N by percentile distribution for a) all wells and b) excluding domestic wells in the Haskell and Knox Counties pod of the Seymour Aquifer. Range bars and values at the bottoms of the figures respectively indicate the sample periods and number of samples within each period. Points are plotted at the average sample date within each range. Solid lines represent linear regression fits to the data and R^2 values are also shown. The slopes of the median (50th percentile) regression lines are significant to a) p<0.01 and b) p<0.27.

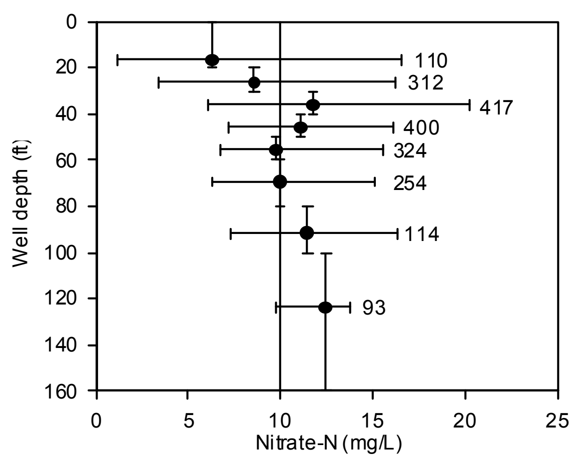

Figure 3-7

Relationship between nitrate-N concentrations and well depth in the Seymour Aquifer. Points are plotted at the median nitrate-N concentration and average well depth for each group. Numbers indicate the quantity of well in each group. X error bars indicate the middle 50% range (i.e., median ± 25%) of nitrate-N concentrations in each group and Y error bars indicate the range of well depths in each group. The latest sample for each well was used in the analysis.

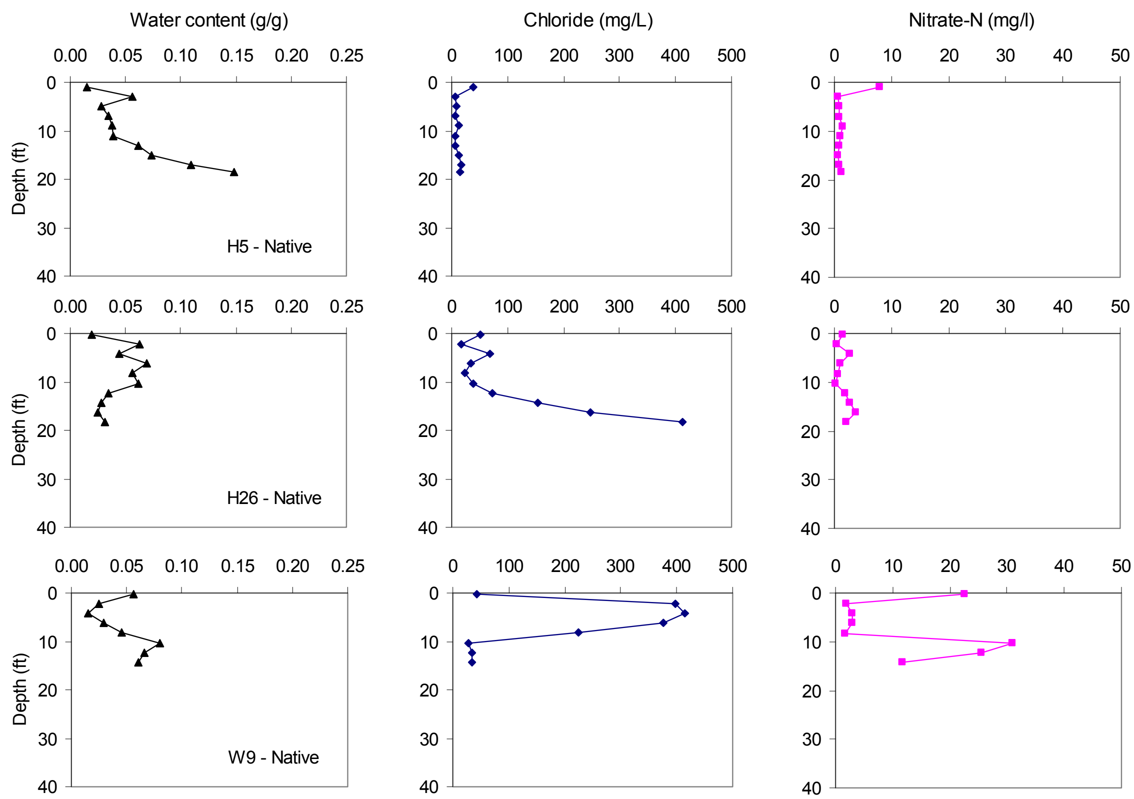

Figure X-1. Soil water content, chloride, and nitrate-N concentration profiles for boreholes in native vegetation areas.

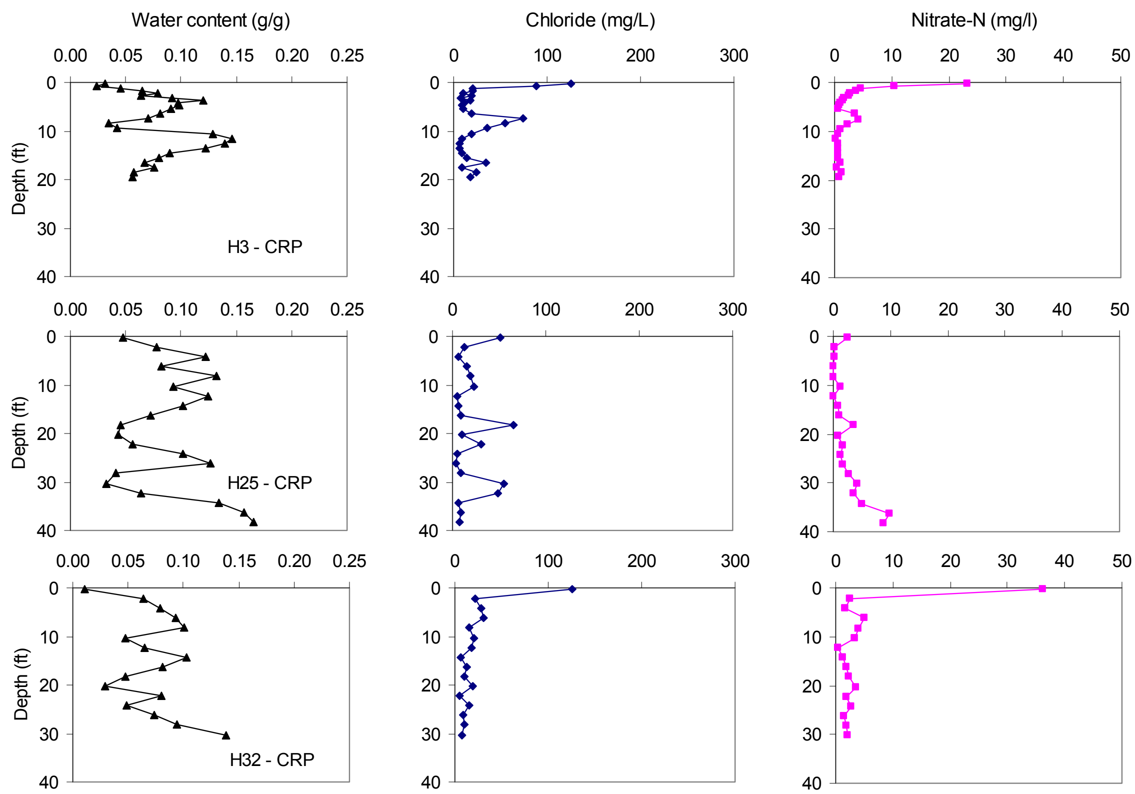

Figure X-2. Soil water content, chloride, and nitrate-N concentration profiles for boreholes in Conservation Reserve Program (CRP) areas.

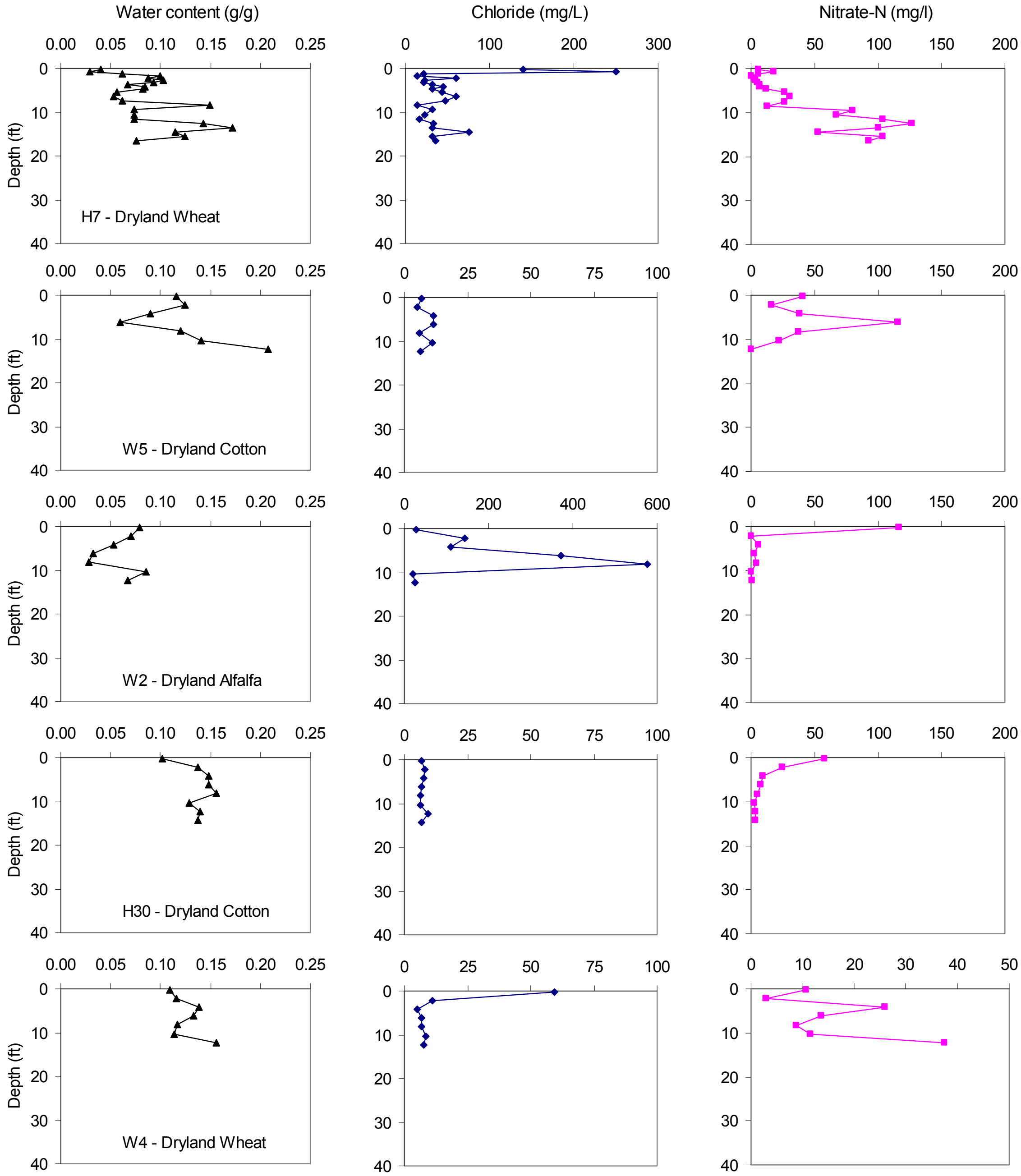

Figure X-3. Soil water content, chloride, and nitrate-N concentration profiles for boreholes in dryland agricultural areas.

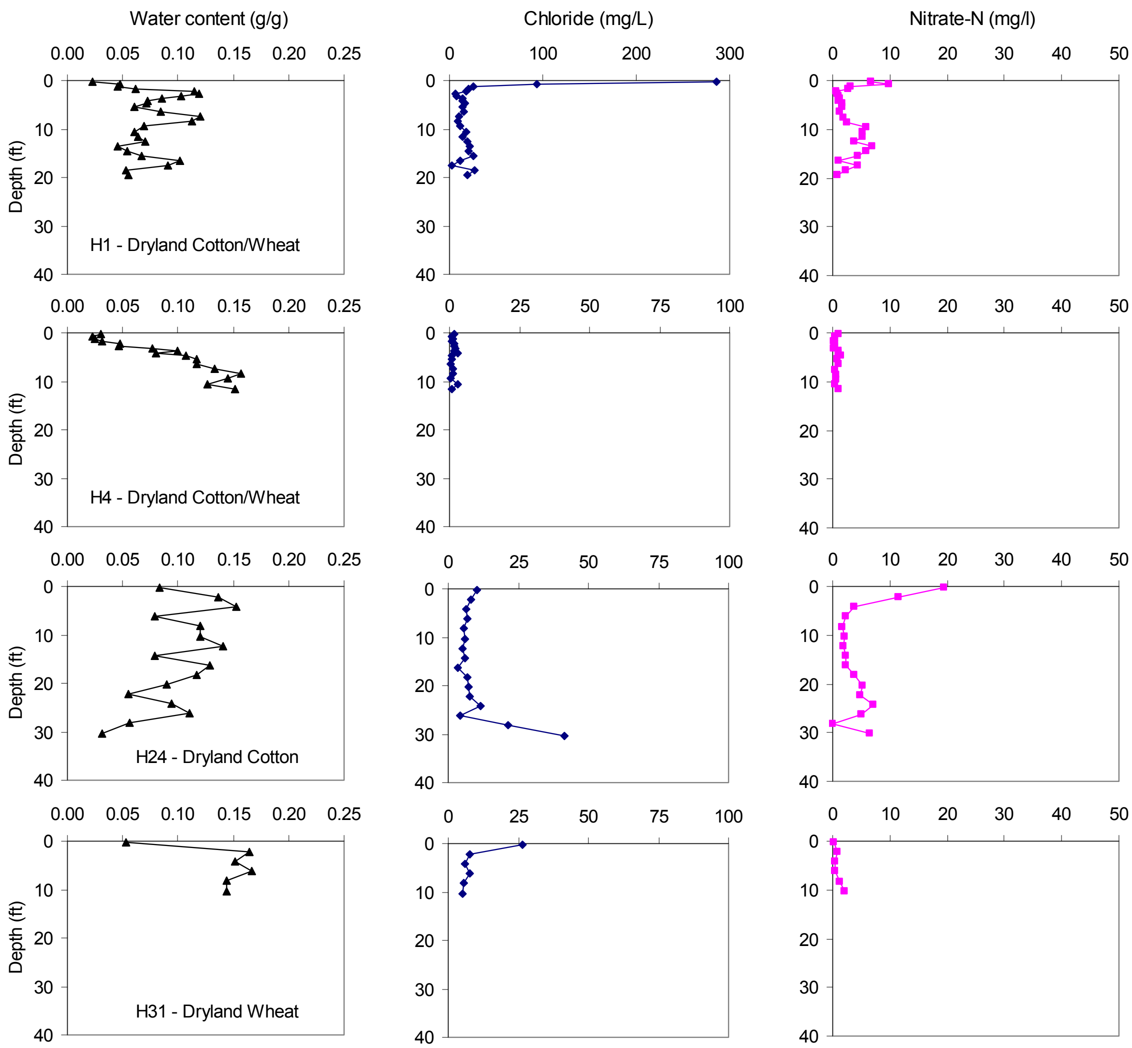

Figure X-3 (cont.). Soil water content, chloride, and nitrate-N concentration profiles for boreholes in dryland agricultural areas.

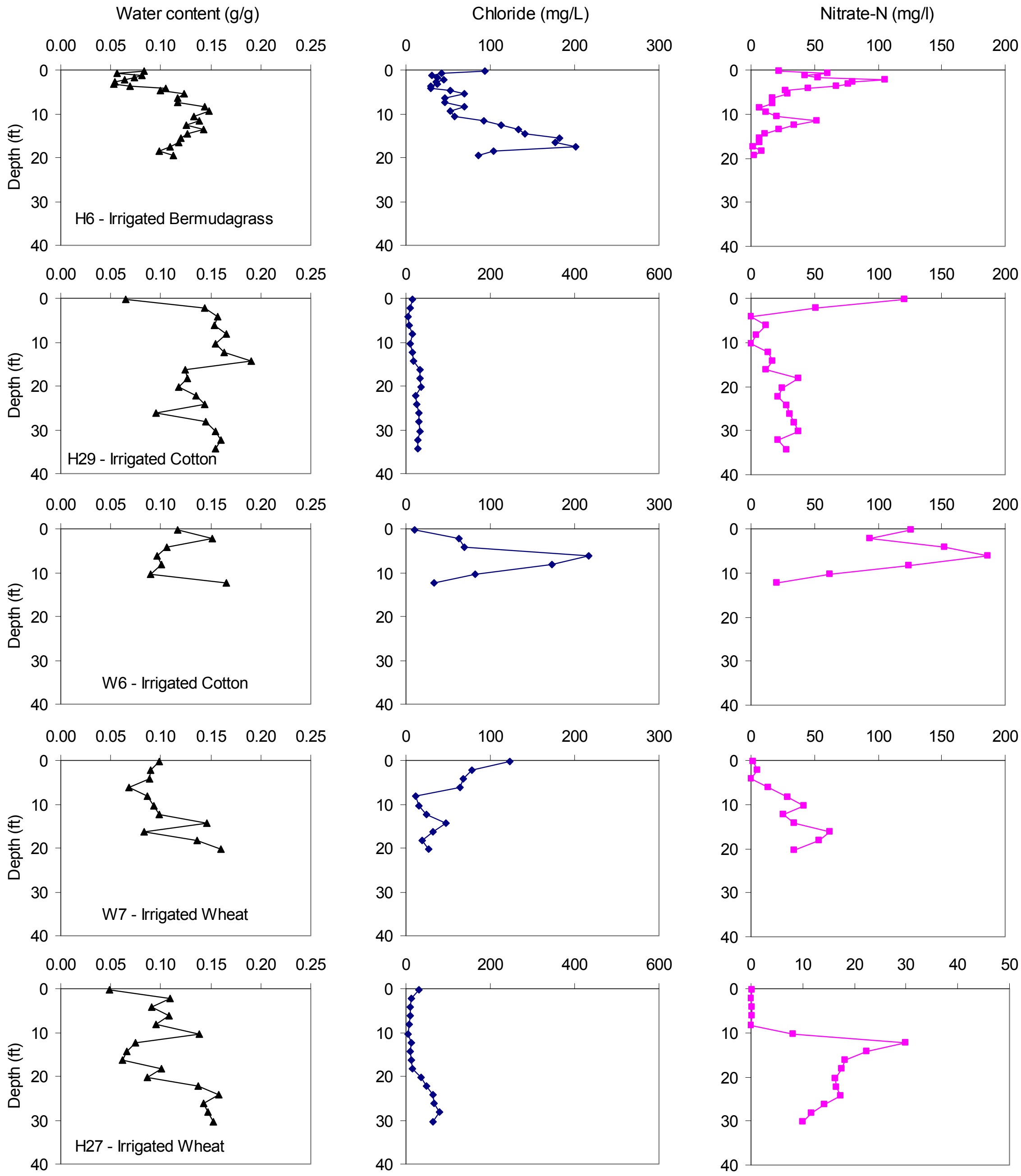

Figure X-4. Soil water content, chloride, and nitrate-N concentration profiles for boreholes in irrigated agricultural areas.

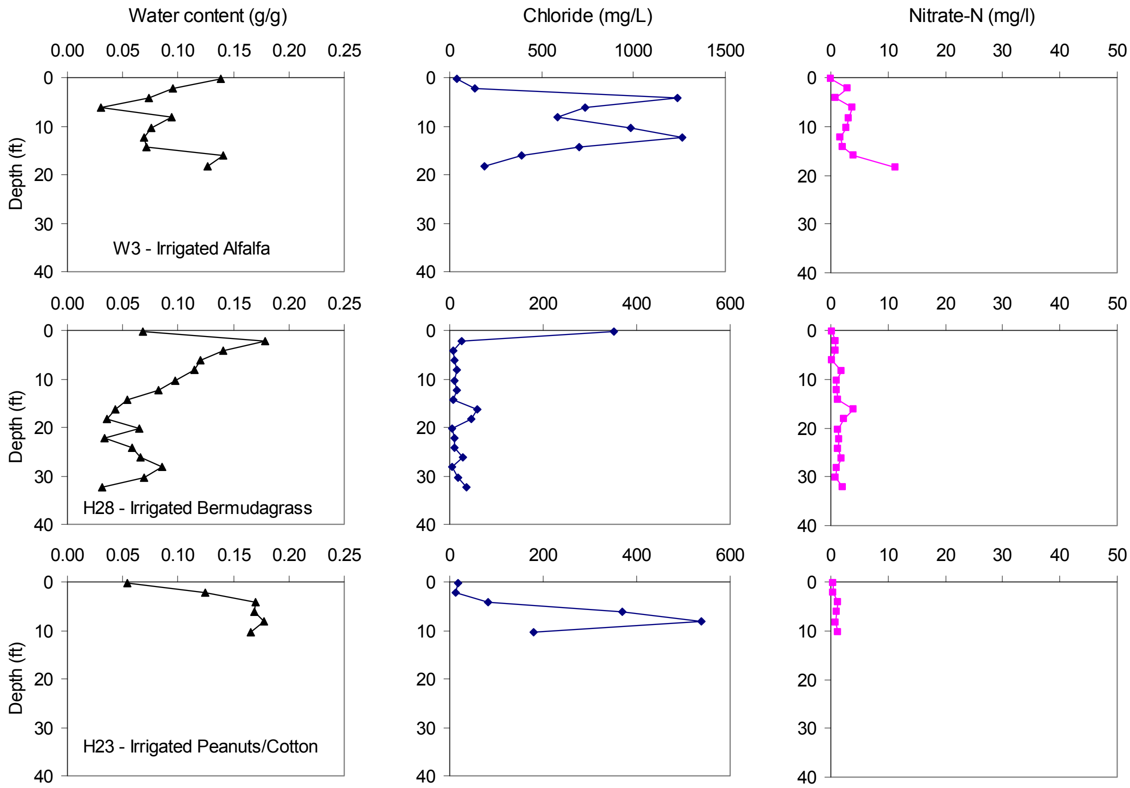

Figure X-4 (cont.). Soil water content, chloride, and nitrate-N concentration profiles for boreholes in irrigated agricultural areas.