PNNL-14099

Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Groundwater Conditions at Single-Shell Tank Waste Management Area TX-TY (January 1998 through December 2001)

D. G. Horton

October 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Summary

Waste Management Area (WMA) TX-TY at the Hanford Site contains the TX and TY single-shell tank farms and their auxiliary equipment. These tank farms, located in the northern portion of the 200 West Area, include 24 single-shell carbon steel tanks constructed in the 1940s and early 1950s. During operations, tanks received mixed waste from plants that processed spent reactor fuel to recover plutonium as part of Hanford's defense mission. The tank farms ceased active operations in 1980 but are currently storing waste and are currently regulated as *Resource Conservation and Recovery Act* (RCRA) Interim Status Facilities.

The water table is declining and groundwater flow directions are changing in the vicinity of WMA TX-TY. These changes are a result of the cessation of effluent discharge to ground in 1995 and the initiation of a major pump-and-treat operation in 1997. To meet the changing groundwater monitoring needs, twelve new RCRA monitoring wells have been constructed since 1997 and two others are in the planning stage.

Monitoring at WMA TX-TY indicates that chromium occurs above the drinking water maximum contaminant level at one well east of the WMA. Although the nearest potential source for the chromium is the WMA, the high concentrations of chromium appear to be deeper in the aquifer than the maximum concentrations of technetium-99. The most likely source for the technetium-99 and associated nitrate is WMA TX-TY. These constituents are located on the downgradient (east) side of the WMA and are currently migrating to the southeast.

A second plume is located south of the WMA. This technetium-99 plume is found in one well and is the result of altered groundwater flow directions in the area caused by the 200-ZP-1 pump-and-treat operations.

Data gathered during drilling indicate that carbon tetrachloride, tritium, and much of the nitrate result from past-practice activities and are distributed relatively deep in the upper part of the aquifer. Tank waste is found predominantly near the surface of the aquifer.

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1.0 Introduction

This report presents the findings of continued groundwater monitoring at Waste Management Area (WMA) TX-TY in the 200 West Area of the Hanford Site (Figure 1.1). The purpose is to address all constituents of concern in and adjacent to the WMA with respect to all applicable regulatory drivers. This report covers the period between January 1998 and December 2001.

In addition to the groundwater monitoring done by the Hanford Groundwater Monitoring Project to track the extent and rate of movement of groundwater contamination, the Office of River Protection has begun to implement corrective actions at single-shell tank waste management areas. Initial corrective actions have included construction of berms around waste management areas and turning off known, old water lines that cross the waste management areas. Studies are underway to determine the best future corrective actions that may include institutional controls, engineered barriers, waste removal technologies, and in-situ and ex-situ treatment technologies (DOE/RL 2000). These corrective actions will help prevent future groundwater contamination from single-shell tank waste management areas.

1.1 Scope

Only new water quality data and hydrologic testing results obtained subsequent to an initial assessment report (Hodges 1998) are included in this report. Hydrogeology of the site, stratigraphy, waste site descriptions, and contaminant hydrology were described in the first assessment report (Hodges 1998) and in an updated assessment plan (Hodges and Chou 2001). Therefore, the scope of this report is limited to evaluation and interpretation of new data acquired from

- twelve new wells installed since January 1998
- groundwater sampling data collected during well drilling
- additional routine, quarterly sampling data collected from the existing network from January 1998 through December 2001.

Supporting information (e.g., drilling information and hydrologic testing raw data) for this report are available in the project files of the Hanford Groundwater Monitoring Project at Pacific Northwest National Laboratory (PNNL) and in the borehole data packages for the new wells that were drilled during the report period (Horton and Hodges 1999, 2000, 2001; Horton 2002).

1.2 Basis for Groundwater Characterization and Monitoring at WMA TX-TY

Groundwater monitoring needs are principally defined by, and directly support, agreed-upon cleanup goals. Because such goals have not been developed and agreed to for the site in general and the WMA specifically, this section discusses only general guidelines for supporting the cleanup goals.

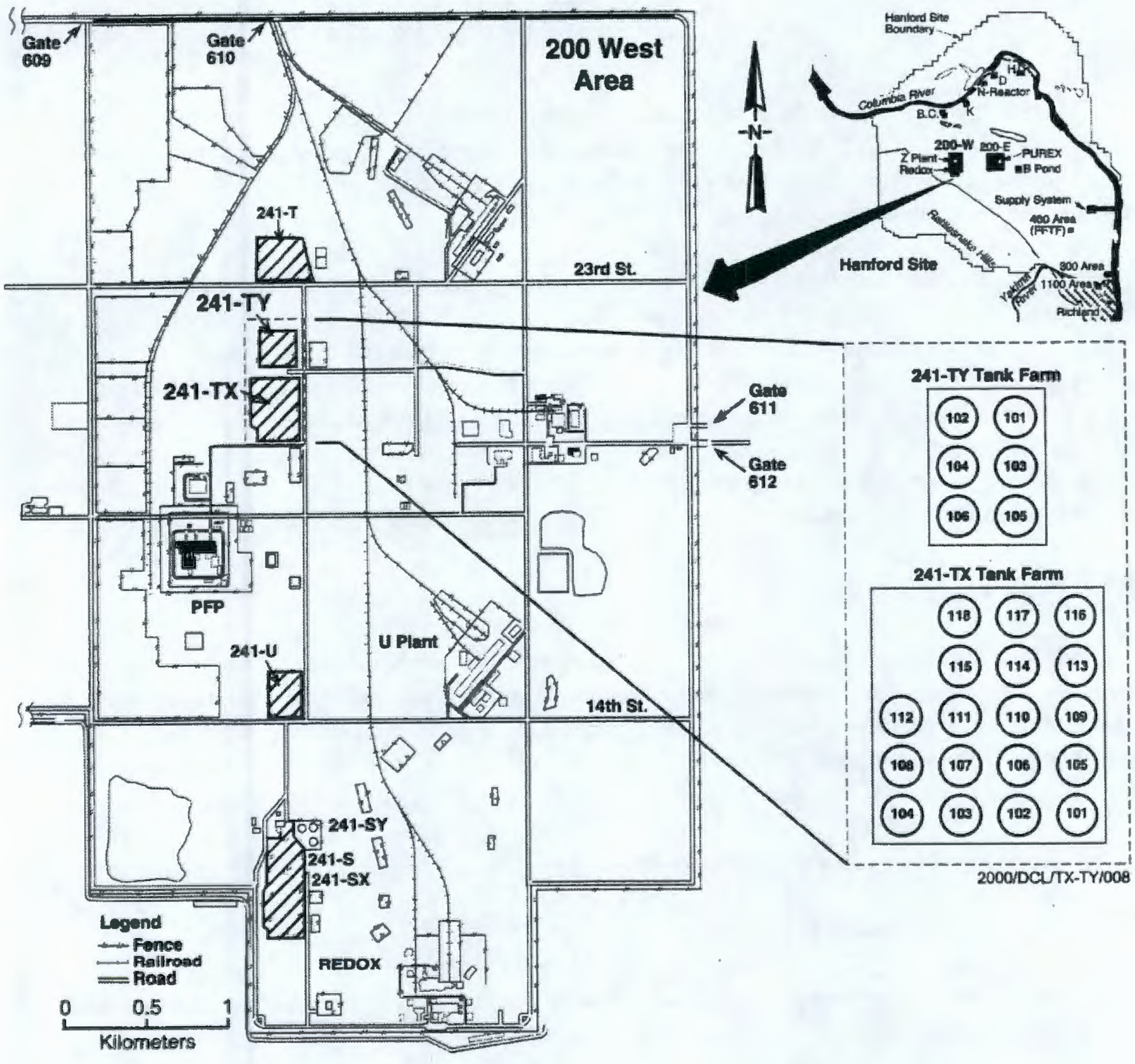

Figure 1.1. Location of Waste Management Area TX-TY on the Hanford Site

The following is based on the Hanford Cleanup, Constraints and Challenges Team strategy for groundwater protection, monitoring, and remediation. This strategy provides a common, sitewide perspective to guide the development of assessment activities for individual operable units and when appropriate, groups of waste sites. Guiding principles are summarized in the following list:

- When a new plume/contamination is discovered within an existing plume, assessment of the new plume/contamination should tie with the ongoing assessment of the existing plume as long as the cleanup goals/objectives of both are the same. For other plumes, assessment actions will be undertaken once contaminant concentrations are detected in groundwater above an agreed to threshold. Whenever possible, predictions of future conditions with reliable estimates or known inventory information will be utilized as a tool to locate future monitoring wells and determine future monitoring requirements.

- Assessment will focus on sites where there is adequate data to indicate sufficient mass of contaminant is present to leave the core zone at concentrations above the maximum concentration level, or significantly impact groundwater or the Columbia River.

- If contamination from an operating facility is observed, an evaluation will be performed to identify what needs to be done to correct problems at source.

- Predictions of future conditions will be used to establish the thresholds for triggering assessments and identifying the mass of contaminant that constitutes a threat to groundwater degradation.

Hodges and Chou (2001) described the objectives and general approach for assessment of groundwater quality at WMA TX-TY. Those objectives, as required by 40 CFR 265.93 (d) and WAC 173-303-400, are to determine

(i) *the rate and extent of migration of the hazardous waste or hazardous waste constituents in the groundwater*

(ii) *the concentration of hazardous waste or hazardous waste constituents in the groundwater.*

In addition to the requirements of the RCRA implementing regulations that govern dangerous or hazardous waste constituents, the U.S. Department of Energy (DOE) has issued DOE Order 5400.1 to ensure a groundwater protection program that demonstrates compliance with all federal, state, and local laws and regulations including the *Atomic Energy Act of 1954* (AEA). The objectives of groundwater monitoring under DOE Order 5400.1 are

(i) *Obtain data for the purpose of determining baseline conditions of groundwater quality*

(ii) *Demonstrate compliance with and implementation of all applicable regulations and DOE Orders* *(iii) Provide data to permit the early detection of groundwater pollution or contamination*

(iv) Identify existing and potential groundwater contamination sources and maintain surveillance of those sources.

The monitoring and testing done at WMA TX-TY during the reporting period to meet these objectives was described by Hodges and Chou (2001). The work included (1) installation of new wells to complete the monitoring well network in response to changing flow directions and declining water levels, (2) hydraulic testing of the new wells for determination of aquifer properties and groundwater flow rate and, (3) sampling the new wells to determine the vertical and lateral extent of contamination.

1.3 Report Organization

Organization of this report is based on the objectives to determine the rate and extent of migration and the concentration of contaminants in groundwater. Accordingly, Chapter 2 describes the groundwater monitoring network, particularly salient information gathered from installation of new wells that may reflect conditions in the aquifer. Chapter 3 discusses the rate of groundwater movement and direction of flow based on hydrologic data acquired during the reporting period. Chapter 4 discusses the spatial and vertical extents of contamination, contaminant concentrations, and contaminant types based on new observations made during drilling of new monitoring wells for this assessment. Chapter 4 also provides some information obtained from routine quarterly sampling between January 1998 and December 2001. Chapter 5 provides information on the highest contaminant concentrations found at the WMA. Chapter 6 updates the conceptual model for WMA TX-TY with interpretations of data collected during the reporting period. Chapter 7 presents conclusions regarding the rate and extent of contaminant migration, possible source areas, and the likelihood of detecting groundwater contamination that could arise from this WMA in the future.

2.0 Monitoring Well Network Evaluation

The groundwater monitoring network at WMA TX-TY has required continued modification, both because of a declining water table and because of changing groundwater flow directions. The locations of monitoring wells are shown in Figure 2.1.

2.1 Existing Network

Three of the original WAC 173-160 compliant wells at WMA TX-TY (299-W10-18, 299-W14-12, and 299-W15-22) are dry as a result of the declining water table. The last of the WAC-compliant wells, 299-W10-17, is near the end of its useful life with less than 1 meter of water remaining in the well.

The current groundwater monitoring network at WMA TX-TY consists of 15 wells. Two of these wells, wells 299-W14-5 and 299-W14-6, are older wells constructed before WAC 173-160 was implemented and are used as downgradient wells on the southern part of the east side of the 241-TX tank farm. These older wells have 9 to 11 meters of perforated casing. Well 299-W10-17, constructed in 1990, is the only original WAC 173-160 compliant well still in use at WMA TX-TY. That well was originally located downgradient on the north side of 241-TY tank farm. Because of changes in groundwater flow direction since 1990, well 299-W10-17 is now lateral to the WMA with respect to groundwater flow.

Twelve new WAC-compliant wells have been installed at WMA TX-TY since 1998. Wells 299-W15-765 and 299-W15-40 are the new upgradient wells located west of 241-TY and 241-TX tank farms respectively. Wells 299-W15-763 and 299-W15-41 are new wells located south of the 241-TX tank farm. Under natural groundwater flow conditions, these wells would probably be lateral to the WMA; however, the 200-ZP-1 pump-and-treat operations, located south of the WMA, have altered groundwater flow beneath the 241-TX tank farm to a southerly direction so that these wells are downgradient monitoring wells.

The remaining eight wells in the monitoring network are located downgradient along the eastern boundary of the WMA. Two of these, wells 299-W14-16 and 299-W14-17, are located ~130 meters east of the tank farm fence. The other six wells are near-field monitoring wells located within ~30 meters of the tank farm fence.

The groundwater monitoring network at WMA TX-TY is based on the current understanding of subsurface conditions. The initial network was designed based on professional judgment. Since the beginning of declining water levels in the area, the locations of wells were evaluated using a model (MEMO, Wilson et al. 1992). This provided an initial basis for the spacing and locations of wells. These wells have been effective in detecting contamination and defining plume contours.

The current well spacing on the downgradient side (east side) of WMA TX-TY ranges from 41 to 113 meters with all but one distance at less than 77 meters. The largest separation is between wells 299-W14-14 and 299-W14-6 east of 241-TX tank farm. The groundwater in this area is affected by the

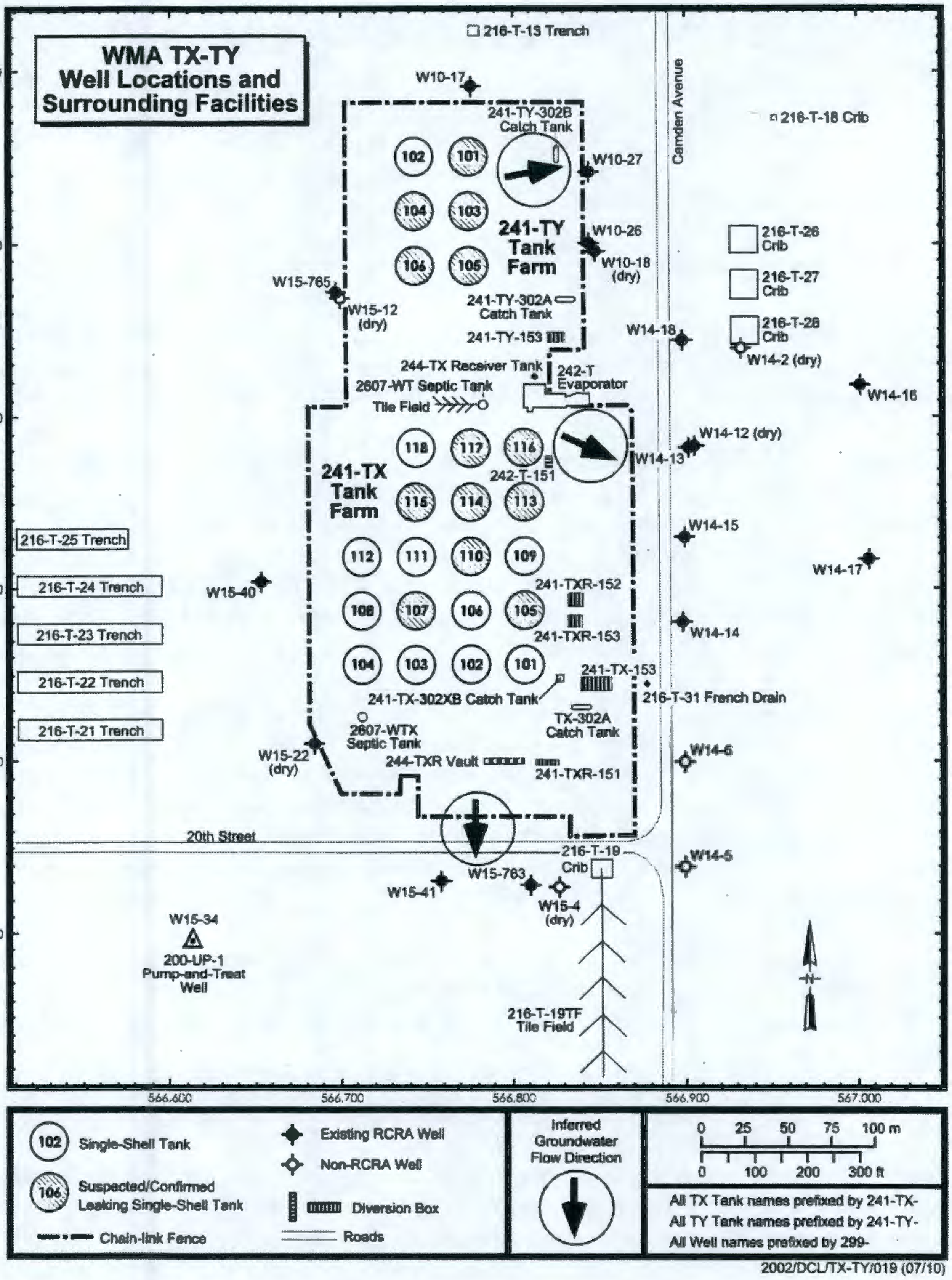

Figure 2.1. Waste Management Area TX-TY, Surrounding Facilities, and Monitoring Well Locations

200-ZP-1 pump-and-treat operation such that these two wells currently are located upgradient or lateral to the WMA with respect to groundwater flow direction. Thus, the spacing between these two wells is of minimal concern to monitoring contaminants originating from the WMA until the pump-and-treat operations are stopped. The well spacing at WMA TX-TY is considered adequate if contaminant plumes can be mapped sufficiently for decision making purposes.

2.2 Description of New Wells

Details on the drilling and construction of new wells and on the geologic conditions encountered during drilling can be found in the borehole completion reports (Horton and Hodges 1999, 2000, 2001; Horton 2002).

Twelve new wells have been installed at WMA TX-TY since 1998. Three of these wells (299-W10-26, 299-W14-13, and 299-W14-18) were drilled as replacements for existing, downgradient wells. Two of the new wells (299-W15-40 and 299-W15-765) were drilled as replacements for the original upgradient wells that have gone dry. Three of the new wells (299-W10-27, 299-W14-14, and 299-W14-15) were installed as new downgradient wells in response to changing groundwater flow directions. Two new wells (299-W14-16 and 299-W14-17) were installed as downgradient wells to address the extent of contamination (Hodges and Chou 2001). The remaining two new wells (299-W15-41 and 299-W15-763) were installed south of the 241-TX tank farm as downgradient wells in response to changes in flow directions due to the 200-ZP-1 pump-and-treat operations. Table 2.1 lists the new wells and information about each well pertinent to hydrogeologic characteristics of the screened intervals.

Some indications of aquifer properties are found from information in the geologist's logs made during drilling. Of particular interest are textural descriptions that may indicate variations in permeability. In general, better sorted sediments and sediments with less fine-grained material are expected to be more permeable than poorly-sorted or fine-grained sediments. For example, the description of the sediments through the screened interval of well 299-W15-765 notes changes from silty sandy gravel to relatively clean gravel in specific zones in the screened interval. Thus, the silt-poor zones are expected to be more permeable than the silt-rich zones in this well. Similar lithologic changes are suggested by wireline geophysical surveys for the screened interval in wells 299-W15-40 and 299-W15-763 and by the geologist's log and/or sieve analyses for wells 299-W10-27, 299-W14-14, 299-W14-15, 299-W14-16, and 299-W14-18. The geologists' logs, borehole geophysical logs, and sieve data are in the borehole completion reports for the wells (Horton and Hodges 1999, 2000, 2001; Horton 2002).

Other potentially useful information can be gained by the geologists' comments. For example, the geologist noted that well 299-W14-16 took a long time for the water level to recover during drilling at a depth of 68.3 meters, suggesting that this part of the screened interval is relatively less permeable than other parts of the screened interval. This interpretation is supported by the available data from sieve analyses which show that the sediment at a depth of 68 meters is silty sandy gravel whereas the sediment at 73 and 77 meters is sandy gravel. Also, the geologist noted differences in the water level during drilling of well 299-W15-41 depending on the depth of the temporary casing. These differences suggest

Table 2.1. Construction and Lithologic Characteristics of the Screen Intervals of New Wells at Waste Management Area TX-TY[(a)]

Well[(b)]	Date Drilled	Drilling Method	Screen Interval Depth (m)[(c)]	Pump Intake Depth (m)[(c)]	Total Drill Depth (m)[(c)]	Depth to Water[(d)] (m)[(c)]	Comments
W10-26	08/90	Air Rotary	66.15 to 76.85	70.56	79.86	66.26	Silty sandy gravel throughout the screened zone[(e)].
W10-27	01/01	Cable tool	67.36 to 77.11	76.50	81.90	67.25	67.1 to 68.6 m is slightly silty gravelly sand with good penetration rate; 68.6 to bottom of screened interval is silty sandy gravel and very hard drilling;[(e)] sieve analyses from sediment at 69 and 73 m yields silty sandy gravel, sieve analysis from 77.4 m (below the screen) is sandy gravel; geophysical log indicates no significant change in lithology in screened zone.
W14-13	08/98	Air Rotary	66.02 to 76.73	70.53	79.86	65.78	Moderately sorted silty sandy gravel throughout screened interval.[(e)]
W14-14	11/98	Air Rotary	66.14 to 76.90	70.56	135.03	66.27	The upper 0.3 m of screened interval is gravelly sand and the rest of the screened interval is silty sandy gravel.[(e)]
W14-15	08/00	Air Rotary	66.98 to 77.61	67.27	79.25	67.27	Sandy gravel from above the screen to 67.4 m and silty sandy gravel from 67.4 m to below the bottom of the screened interval;[(e)] sieve analyses of samples from 68 and 72 m show silty sandy gravel, sieve analysis from a 77 m sample shows sandy gravel.
W14-16	10/00	Air Rotary	67.95 to 78.60	70.98	80.77	67.83	Sandy gravel throughout the screened interval;[(e)] sieve analysis of sample from 68 m is silty sandy gravel, sieve analyses of samples from 73 and 77 m are sandy gravel; geophysical log indicates less silt between ~70 and 76 m depth. Water was added to the borehole below the water table to aid in removal of cuttings indicating a fairly tight formation with slow recovery. Geologist also noted that the water level took a long time to recover.[(f)]
W14-17	10/00	Air Rotary	67.6 to 78.3	71	80.9	67.6	Sandy gravel throughout the screened interval;[(e)] poor recovery of split spoon samples at 69.4 and 74.7 m depths due to dense gravels, good recovery at 77.7 m depth;[(f)] no distinct anomalies in geophysical log.

Table 2.1. (contd)

Well[b]	Date Drilled	Drilling Method	Screen Interval Depth (m)[c]	Pump Intake Depth (m)[c]	Total Drill Depth (m)[c]	Depth to Water[d] (m)[c]	Comments
W14-18	08/01	Cable Tool	66.5 to 77.1	73.2	79.7	67.2	Borehole was drilled with hard tool throughout screened interval;[f] lithology is gravelly sandy silt between 67 and 71.6 m and between 73.2 and 79.5 m depths and gravelly silt between 71.6 and 73.2 m depth;[e] no distinct changes noted on geophysical log.
W15-40	08/98	Cable Tool from 0 to 38.1 m and Air Rotary from 38.1 to 80 m	66.4 to 77.1	70.5	80	66.5	Sandy gravel throughout the screened interval;[e] geophysical log suggests minor variations in gravel content through screened interval.
W15-41	11/99	Air Rotary	65.81 to 70.4	66.7	72.8	65.0	Sandy gravel from 65.5 to 69.2 m depth and silty sandy gravel from 69.2 to 72.8 m depth;[d] geophysical log shows an increase in silt content with depth throughout the screened interval; water level was at 65.1 m with casing set at 66.8 m depth and at 66.1 m with casing set at 71.9 m depth.[f]
W15-763	11/00	Cable Tool from 0 to 40.9 m and Air Rotary from 40.9 to 78.5 m	65.54 to 75.2	69.4	78.5	66.1	Silty sandy gravel with iron oxide and silica cement from 64.3 to 66.8 and from 73.2 to 78.3 m depth, silty sandy gravel from 66.8 to 70.1 and 71.6 to 73.2 m depth, and sandy gravel from 70.1 to 71.6 m depth;[e] slow driving casing from 71.6 to 73.4 m depth, a lot of water added to the borehole below the water table to aid in bailing cuttings and to control heaving sand;[f] sieve analysis at 66.1 m is sandy gravel, sieve analysis at 70.7 m is silty sandy gravel.
W15-765	10/01	Air Rotary	67.1 to 77.7	69.9	81.4	67	67 to 70.1 m depth is silty sandy gravel; 70.1 to 71.6 m depth is gravel; 71.6 to 73.2 m depth is silty gravel; 73.2 to 76.2 m depth is silty sandy gravel; 76.2 to 77.7 m depth is gravel; 77.7 to 80.6 m depth is sandy gravel; 80.6 to 80.7 m depth is gravel.[e]

(a) Information on well construction is from Horton and Hodges 1999, 2000, 2001; Horton 2002.
(b) All well names prefixed with 299-.
(c) All depths are relative to ground surface.
(d) Depth to water at the time of well construction.
(e) Information from geologists' logs.
(f) Information from daily drilling report.

differences in recovery rates, which may reflect differences in lithology. Both the geophysical logs and the geologist's description of lithology for this well show differences in silt content corresponding to the zones with different groundwater recovery rates. Although these types of observations are subjective, they are valuable clues in deciphering aquifer properties.

Although not a controlled hydrologic test, the amount of drawdown during well development gives an indication of the relative permeability of the screened interval, or at least of some zone within the screened interval. These data are useful because well development is done routinely for all wells and, thus, is available for each well as opposed to other types of hydrologic test data. The pumping rate and amount of drawdown for all wells at WMA TX-TY drilled since 1998 are presented in Table 2.2. The

Table 2.2. Development Pumping Data for Wells Drilled at Waste Management Area TX-TY since 1998

Well	Year Completed	Pump Intake Depth (m)	Pumping Rate (L/min)	Drawdown (m)	Specific Capacity (L/min/m)
299-W10-26	1990	Bottom of Screened Interval	34.1	1.6	21
		Middle of Screened Interval	37.8	1.3	29
299-W10-27	2001	76.7	26.5	8.2	3
		76.7	3.8	7.8	0.5
299-W14-13	1998	Bottom of Screened Interval	30.3	1.6	19
		Middle of Screened Interval	30.3	1.3	23
299-W14-14	1998	NA	NA	NA	-
299-W14-15	2000	76.5	90.8	2.7	34
		71.0	94.6	2.6	36
299-W14-16	2000	78.3	90.8	4.5	20
		72.2	90.8	NA	-
299-W14-17	2000	Bottom of Screened Interval	87.1	2.7	32
		Middle of Screened Interval	64.3 – 75.7	2.5	26 – 30
299-W14-18	2001	75.6	37.9	6.2	6
		75.6	18.9	5.8	3
299-W15-40	1998	76.5	22.7	1.8	13
		71.6	NA	1.5	-
299-W15-41	1999	69.5	98.4	1.0	98
299-W15-763	2000	73.1	18.9 – 22.7	6.8	3
		69.4	18.2	1.0	18
299-W15-765	2001	77.0	113.6	1.4	81
		72.5	113.6	1.6	71

specific capacity for each well is also shown on the table. The specific capacities were calculated from the pumping rate and drawdown measured during well development. The specific capacity is a measure of the yield of a well per unit of drawdown. All wells in Table 2.2 are screened in the Ringold Formation hydrogeologic unit 5 (Williams et al. 2002).

The data in Table 2.2 suggest that the screened interval in most wells is relatively permeable with little difference between the lower and middle portions of the screened intervals. Wells 299-W10-27 and 299-W14-18, however, appear to be screened in a much less permeable formation than the other wells. This is particularly so for well 299-W10-27, which had extreme drawdown with low pump rates and to which water had to be added during development to maintain a water level above the pump.

Also of note is the very transmissive nature of the screened interval in wells 299-W15-41 and 299-W15-765. Finally, the sediment around the screened interval in well 299-W15-763 appears to vary in permeability from relatively tight near the bottom of the screen to relatively transmissive near the middle of the screen.

The drawdown data from development pumping at well 299-W15-763 are also of note. Based on the drawdown information, there appear to be vertical differences in permeability of the sediments through the screened interval with the upper part being more permeable than the lower part. The geologist noted cemented zones interlayered with non-cemented zones in the upper part of the aquifer during drilling of this well.

Well-to-well variability in the permeability of the screened intervals noted at WMA TX-TY is similar to variability noted among the new wells installed at WMA T, slightly to the north of WMA TX-TY. Changes in the formation permeability seem to occur over short distances and are probably localized. This is illustrated by the variation in apparent permeability among wells 299-W10-26, 299-W10-27, and 299-W14-18 all of which are located in the northeast part of the WMA.

Changes in the permeability of the aquifer formation influence the results of groundwater sampling in that samples will contain a larger proportion of water from the more permeable zones. Also, heterogeneities in permeability can influence the distribution of contaminants in the aquifer. Contaminants entering the aquifer may not migrate vertically through a "tight" zone in the formation.

2.3 Planned Network Upgrade

The 200-ZP-1 pump-and-treat operations have changed flow directions at the south part of the WMA. The pump-and-treat operations are expected to continue until a record of decision is reached. Therefore, the drilling of an additional downgradient well on the south end of WMA TX-TY is planned in fiscal year 2003. Also, one additional well is planned for the east side of WMA TX-TY, south of well 299-W14-14 near the non-WAC compliant well 299-W14-6.

3.0 Rate and Direction of Groundwater Flow

The rate of groundwater movement beneath WMA TX-TY is estimated from classical methods (Darcy equation) and from borehole tracer dilution tests. Groundwater flow rate indicates the maximum (conservative) flow rate for contaminants, whose movement through the aquifer is not retarded by mechanisms such as sorption or reaction.

3.1 Flow Direction

The direction of groundwater flow was estimated based on the gradient in the water-table elevations in the WMA TX-TY network monitoring wells. This approach assumes the aquifer is homogeneous. Because there is evidence that the aquifer is non-homogeneous, this limitation must be kept in mind when applying the gradient analysis approach to estimate flow direction. A general flow direction may be estimated over the WMA, but at any specific location, perturbations may occur in the local flow direction due to localized low or high permeability zones. Details of the changes in groundwater flow direction that occurred at WMA TX-TY in about 1998 are presented in Hodges and Chou (2001). Prior to 1997, groundwater flow was toward the northeast. In about 1998, the 200-ZP-1 pump-and-treat operation began to affect the groundwater flow direction beneath the southern part of WMA TX-TY.

Water-table elevations for the area around WMA TX-TY are illustrated in Figure 3.1, based on March and August 2001 water-level measurements. Contours on the water-table map indicate that general groundwater flow direction below WMA TX-TY changes with location. The general flow direction is toward the southeast below the northern part of the WMA and toward the south, or possibly the south-southwest, below the southern part of the WMA. Groundwater beneath the southern part of the WMA is strongly influenced by the 200-ZP-1 pump-and-treat system.

Trend-surface analyses also have been applied to monitoring well water-level elevations at WMA TX-TY (Spane et al. 2001a, b). Trend surface analysis was done with commercially available software (WATER-VEL™ from In-Situ, Inc.). Water-level elevations from neighboring representative wells were used as input to calculate groundwater flow directions. The program uses a linear, two-dimensional trend surface (least squares) with randomly located water level elevation input data (Spane 2001a).

Analysis of May 1999 water-level data from wells 299-W10-17, 299-W10-18, 299-W14-12, 299-W15-12, and 299-W15-22 indicate a flow direction of 18 degrees east of south at wells 299-W10-26 and 299-W14-13. Analysis of May 2000 water-level data from wells 299-W14-5, 299-W14-6, 299-W14-14, 299-W15-40, and 299-W15-41 indicate a flow direction 16 degrees east of south at well 299-W15-41. The trend-surface derived flow direction for the former two wells at the northern part of the WMA is in good agreement with the flow direction inferred from the water-table map. The trend-surface derived flow direction for the southern well, 299-W15-41, is more easterly than the direction indicated on the water table map. This is because the trend-surface analysis did not include wells south or southwest of well 299-W15-41, which are influenced by the 200-ZP-1 pump-and-treat operations.

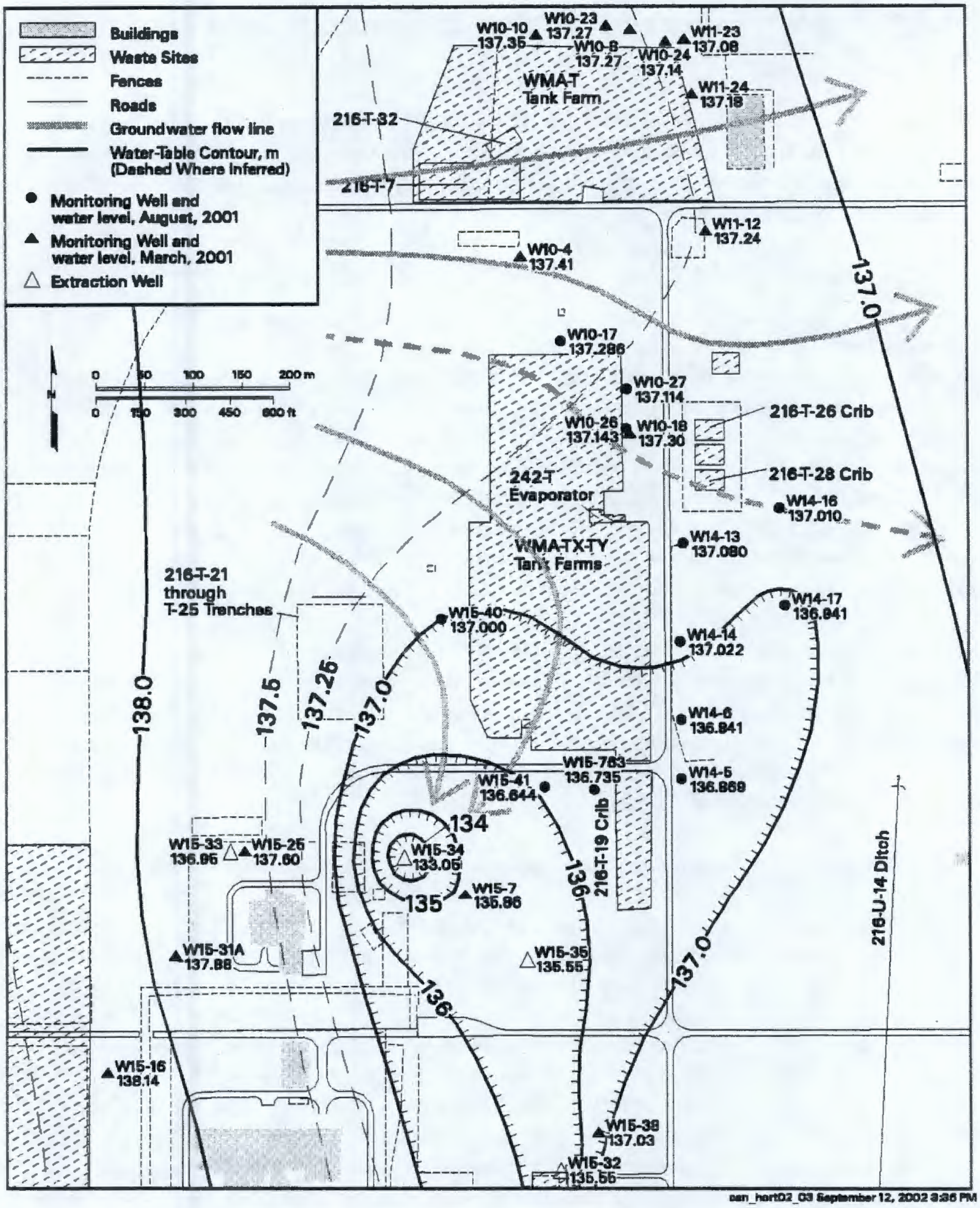

Figure 3.1. Water-Table Elevation Map for Waste Management Area TX-TY (March and August 2001 data)

3.2 Borehole Tracer Dilution and Tracer Pumpback Testing

Borehole tracer dilution and tracer pumpback tests were conducted in three of the new RCRA monitoring wells at WMA TX-TY. These tests permitted some inferences about flow rate as well as aquifer homogeneity. After introduction of a bromide tracer into the boreholes, continuous measurements of the bromide concentrations were made using downhole bromide sensors and a data logger system. Five probes positioned ~1 meter apart were used to characterize the 4.8-meter screened interval of well 299-W15-41. Six equally spaced probes were used to characterize the 10.7-meter screened intervals in wells 299-W10-26 and 299-W14-13. These tests allowed direct observation of the effect of lateral groundwater flow through the screened interval of the wells, and, thus, provided an indication of the variability of flow through the screened intervals. Details of the test methods, computations, and the results are included in Spane et al. (2001a, b).

A significant feature of the tracer dilution test results is evidence for downward, vertical hydraulic gradients within the upper portion of the aquifer in wells 299-W10-26 and 299-W14-13. Vertical flow within these wells was first indicated by tracer-dilution studies and later confirmed by vertical tracer tests specifically designed to detect vertical flow within a borehole (Spane et al. 2001a). Downward vertical flow in these two wells was subsequently confirmed by electromagnetic flowmeter surveys (Waldrop and Pearson 2000). Data from all three tests are shown in Table 3.1.

Table 3.1. In-Well, Downward Vertical, Flow-Velocity Summary for Wells 299-W10-26 and 299-W-14-13 at Waste Management Area TX-TY (from Spane et al. 2001a)

	Tracer-Dilution Profile		Vertical Tracer Test[(a)]		Electromagnetic Flow-Meter Survey	
Test Well	Range (m/min)	Average (m/min)	Range (m/min)	Average (m/min)	Range (m/min)	Average (m/min)
299-W10-26	0.002 – 0.004	0.003	0.004 – 0.008	0.005	0.003 – 0.006	0.004
299-W14-13	0.008 – 0.015	0.011	0.013 – 0.014	0.012	0.012 – 0.013	0.012

(a) In-well, vertical, flow-velocity range calculated using tracer peak arrival method for selected sensor depth, while the average was determined using the center-of-mass technique.

The electromagnetic flow-meter surveys found that the depth of maximum downward flow was at 4.9 meters below the water table in well 299-W10-26 and at 5.6 meters below the water table in well 299-W14-13. Both wells have fairly homogeneous lithology throughout the screened interval (see Table 2.1) and the well development drawdown data do not indicate substantial variations in hydraulic conductivity.

Table 3.2 shows horizontal groundwater flow velocities determined from tracer pump back tests. These velocities are about an order of magnitude greater than the calculated velocities in Table 3.3 for wells 299-W10-26 and 299-W14-13. Both the measured and calculated velocities are about the same for well 299-W15-41. The vertical flow in wells 299-W10-26 and 299-W14-13 probably resulted in an overestimation of measured flow velocities. Also, the relatively rapid groundwater flow velocity for well 299-W15-41, located at the south end of WMA TX-TY, is likely a result of higher hydraulic gradients in the vicinity of the 200-ZP-1 pump-and-treat.

Table 3.2. Results from Tracer-Dilution and Tracer-Pumpback Tests in Wells at Waste Management Area TX-TY (from Spane et al. 2001a,b)

Well	Effective Porosity[a]	Groundwater[a] Flow Velocity (m/d)	Average In-Well Flow Velocities Average[b]
299-W10-26[c]	0.010	0.124	0.086
299-W14-13[d]	0.009	0.191	ND
299-W15-41	0.068	0.374	0.311

(a) Data from tracer pump back tests.
(b) Data from tracer dilution tests.
(c) Slight downward vertical flow, data uncertain.
(d) Strong downward vertical flow, data highly uncertain.
ND = Not determined.

Table 3.3. Hydraulic Properties from Slug and Constant Rate Pumping Tests and Calculated Darcy Velocities at New Wells at Waste Management Area TX-TY

Well	Hydraulic[a,b] Conductivity (m/d)	Hydraulic[a,c] Conductivity (m/d)	Transmissivity[a,c] (m^2/d)	Specific[a,c] Yield	Calculated Flow Velocity (m/d)
299-W10-26	1.39 – 1.95	1.49	82	0.14	0.014[d]
299-W14-13	1.66 – 2.43	2.45	135	0.12	0.020[d]
299-W14-14	1.97 – 2.64	ND	ND	ND	0.026[e]
299-W15-40	0.88 – 1.22	ND	ND	ND	0.012[e]
299-W15-41	14.2 – 19.9	19.6	1130	0.12	0.29[f]

(a) Data from Spane et al. (2001a, b).
(b) Slug test data.
(c) Constant rate pumping test data.
(d) Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and specific yield from this Table. Specific yield was used because downward flow in the well resulted in uncertain effective porosity.
(e) Estimated using maximum hydraulic conductivity value, a gradient of 0.001 and effective porosity values of 0.1.
(f) Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and effective porosity value from Table 3.2.
ND = Not determined.

The existence of vertical flow in a well does not necessarily reflect actual groundwater flow conditions within the surrounding aquifer, but its presence implies a flow gradient and has implications pertaining to the representativeness of groundwater samples collected from the wells. Thus, the vertical gradient detected along the eastern edge of WMA TX-TY may have an impact on contaminant distribution patterns in the area. The peak in technetium-99 observed at a depth of 14.5 meters below the water table during drilling of well 299-W14-14 (see Section 4.1.2) may represent contaminants from within the WMA drawn deeper into the aquifer as a result of this gradient.

A second feature of the hydrologic test data is the suggestion of higher hydraulic conductivity in the middle and lower portions of the screened interval in well 299-W15-41. The data are shown in Table 3.4 (from Spane et al. 2001b). Also, development pumping data (see Table 2.2) indicates that the upper part of the screened interval in well 299-W15-763, located near well 299-W15-41, is less permeable than the lower part. Such hydraulic irregularities have been previously reported for the Ringold Formation at the north end of 200 West Area (Swanson 1994, pages 81 and 82; Lindsey and Mercer 1994, page 54). The

Table 3.4. Tracer-Dilution Test Results for Well 299-W15-41 at Waste Management Area TX-TY (data from Spane et al. 2001b)

Well Sensor/Depth Setting (m, below top of casing)	Calculated Well-Screen Flow Velocity (m/d)
67.0	0.232
67.9	0.257
68.8	0.401
69.7	0.382
70.6	0.353
Average	0.311

apparent zone of lower hydraulic conductivity at the top of the screened intervals in wells along the southern part of the WMA may be the result of cementation or increased silt content in the upper part of the aquifer at this well. The geologist's log for well 299-W15-763 notes zones of iron oxide and silica cementation at the top and bottom of the screened interval in that well.

Taken as a whole, the geologist's logs, geophysical logs, development pumping data, and the hydrologic testing data all indicate heterogeneity in the aquifer properties within the screened intervals of several individual wells and among wells at WMA TX-TY. No widespread trends have been identified.

3.3 Darcy Velocity

The Darcy equation for estimating velocity (v) requires measurements of hydraulic conductivity (K), effective porosity (n_e) and hydraulic gradient (i). The velocity is calculated from the following relationship:

$$v = Ki/n_e$$

For the WMA TX-TY assessment, new hydraulic conductivity data were obtained from slug tests and drawdown tests conducted in five new wells installed for this study. Effective porosity was determined using tracer drift and tracer pumpback test methods. Hydraulic properties determined for this study are discussed in detail by Spane et al. (2001a, b) and are presented in Tables 3.2 and 3.3.

Calculated Darcy velocities from tests in five new wells are shown in Table 3.3. There is approximately one order of magnitude variation in the data. Spane et al. (2001a) report vertical flow conditions in wells 299-W10-26 and 299-W14-13 so that the effective porosity from those field tests are questionable. Spane et al. (2001a) state that vertical flow in the wells likely introduces an underestimate of the effective porosities. For that reason, the Darcy velocity for wells 299-W10-26 and 299-W14-13 were calculated using the specific yield (Table 3.3) instead of the effective porosity. Using the specific yield results in a fairly consistent groundwater flow velocity of 0.014 to 0.026 meter per day except for well 299-W15-41, which is influenced by the 200-ZP-1 pump-and-treat operation.

4.0 Extent of Contamination

This section presents discussions on the vertical and lateral extents of contamination at WMA TX-TY. Evaluation of the extent of contamination involves investigation of the type and concentration of contaminants in the groundwater, the depth distribution of contaminants, and the spatial extent of contamination. Monitoring results from new and existing wells, results of depth sampling during installation of new RCRA groundwater monitoring wells, and the comparison of groundwater chemistry in old wells and their adjacent replacement wells, provide new insights into the occurrence and nature of groundwater contamination attributable to WMA TX-TY.

4.1 Depth Distribution

Hodges and Chou (2001) include plans for discrete depth sampling of both new and old wells at WMA TX-TY; however, a sampling device under development was not available in time to provide data for this report. A variety of data, however, including discrete depth sampling during drilling and comparison with adjacent wells that sample different parts of the aquifer provide important information about the depth distribution of contaminants.

4.1.1 Conceptual Model Considerations

Contaminants entering the surface of a homogeneous unconfined aquifer can be dispersed downward as well as laterally and longitudinally. The degree of vertical spreading varies depending on the dispersivities, hydraulic gradients, driving force (local recharge or net drainage to the aquifer), and the density of the waste fluid relative to the density of the groundwater. In the vicinity of WMA TX-TY, this is further complicated by the 200-ZP-1 pump-and treat operation, which may partly redistribute contaminants in the upper portion of the aquifer.

Departure from the theoretical depth distribution in a homogenous aquifer may occur depending on the nature of the aquifer host rock. As noted in Chapters 2 and 3, there are indications of heterogeneous conditions in the Ringold Formation in the area of WMA TX-TY. Limited data suggest that local, relatively impermeable zones exist at some wells particularly at wells 299-W10-27, 299-W14-18, and the lower part of 299-W15-763. In these areas, contaminants entering the aquifer from the vadose zone may be restricted to certain parts of the aquifer. Also, contaminants entering the WMA from upgradient sources may be concentrated in the relatively permeable parts of the aquifer. An additional complicating feature is the potential existence of lateral preferential flow paths creating deviations in predicted horizontal plume extent and flow direction. Finally, vertical flow within wells, such as that found at wells 299-W10-26 and 299-W14-13, may cause deviations in expected contaminant distribution. These kinds of local variations in lithology and flow system have not been incorporated into solute transport models for 200 West Area. Therefore, the best alternative is direct observation of vertical and lateral variations found in field data. Field observations made during the reporting period help delineate the vertical and lateral extent of contamination at WMA TX-TY.

4.1.2 Vertical Distribution Data

Sampling at several discrete depths was conducted during drilling of well 299-W14-14 in 1998. Groundwater well 299-W14-14 was initially drilled through the lower mud unit of the Ringold Formation, with discrete sampling at ~15-meter intervals during drilling. Descriptions of the drilling and sampling of the well, as well as chemical results from the discrete level sampling, are presented in Horton and Hodges (1999) and are summarized in the following sections. In addition, samples of groundwater captured during air rotary drilling of wells 299-W14-15, 299-W14-16, 299-W14-18 (cable tool drilled), and 299-W15-765 provide useful information concerning possible vertical contaminant gradients within the aquifer. Finally, comparison of chemical data in new wells with data for the wells they are replacing provides data on chemical variation in the upper portion of the aquifer.

Individual wells with a sequence of vertically distributed samples and well pairs sampling different depths in the aquifer show that contaminants are not evenly distributed in the upper part of the unconfined aquifer at WMA TX-TY. Where greater than regional background amounts of technetium-99 are located, the technetium-99 is found relatively high in the aquifer and tends to be associated with a nitrate maximum. Elsewhere, nitrate concentrations are generally somewhat less and on the order of the concentrations in the regional nitrate plume. In these areas, nitrate maxima occur relatively deep in the upper part of the unconfined aquifer. In the one location with elevated chromium, the chromium maximum is located in a deeper part of the aquifer than the maximum technetium-99 concentration. Details are discussed in the following sections.

The information below concerning the depth distribution of contaminants is discussed relative to depth below the ground surface and not elevation. The surface elevation of all the wells discussed below is between 204.3 and 205.3 meters above mean sea level except for well 299-W15-763 which is at 202.2 meters above mean sea level. The 1-meter difference in elevation is much less than the depths of concentration differences observed in the wells and should not greatly affect the conclusions.

4.1.2.1 Comparison of Chemical Data from New and Replaced Wells

Replacement wells, when located immediately adjacent to an older, shallower well, offer an opportunity to look for vertical variation within the upper part of the aquifer. Three well pairs at WMA TX-TY are discussed in this section.

In each case discussed below, the old well and its replacement well are separated by only a few meters. In addition, in each case, the older well was last sampled when there was a fraction of a meter of water within the screened interval and the replacement well was sampled with a pump placed at least 3 meters below the water table within a 10.7-meter screened interval. Thus, the sample from the old well represents the top of the aquifer and the sample from the replacement well represents a composite of water taken over the length of the screened interval that includes both the water table and deeper parts of the aquifer.

Wells 299-W14-12 and 299-W14-13. Wells 299-W14-12 and 299-W14-13 are located ~5 meters apart at the central part of the downgradient (east) side of WMA TX-TY. Well 299-W14-13 is the replacement well for well 299-W14-12 that went dry in early 1999. The last sampling of well 299-W14-12 took place in January 1999 and sampling of replacement well 299-W14-13 started in December 1998, allowing a sampling overlap between the two adjacent wells. The last samples collected from well 299-W14-12 represent the top of the aquifer. The samples collected from well 299-W14-13 represent water throughout the screened interval, which extends from the water table to 10 meters below the water table. The pump intake is at 4.8 meters below the water table.

Trend plots for several key constituents are shown in the series of Figures 4.1 to 4.4. The results for technetium-99 are particularly interesting. The concentration of technetium-99 in the last sample from well 299-W14-12 was about 6,000 pCi/L. This represented the concentration of technetium-99 at the top of the aquifer in January 1999. The sample from replacement well 299-W14-13, taken about the same time, contained about 2,500 pCi/L technetium-99. That sample represented the technetium-99 concentration throughout the upper 10 meters of the aquifer. The conclusion is that technetium-99 exists at the top of the aquifer at about 6,000 pCi/L and the concentration decreases with depth in the aquifer. The 2,500 pCi/L technetium-99 value from well 299-W14-13 is a mixture of the technetium-99 from the entire screened interval.

Technetium-99 in the area of well 299-W14-12 began decreasing from a maximum of ~13,500 pCi/L in 1993 and continued to decrease until about January 1997. At that time, technetium-99 began to increase and reached 6,000 pCi/L in January 1999 when the well went dry. The increasing technetium-99 trend was continued in the replacement well until early 2000 when technetium-99 concentrations climbed to ~8,000 pCi/L. In early 2000, technetium-99 again began to decrease and reached about 3,300 pCi/L in early 2001. Since that time, technetium-99 concentration had increased in well 299-W14-13 to about 5670 pCi/L at the end of the reporting period.

The results for nitrate in wells 299-W14-12 and 299-W14-13 show a trend similar to that seen for technetium-99. The concentration of nitrate in the last sample from well 299-W14-12 was about 600,000 µg/L, and this represented the concentration of nitrate at the top of the aquifer. The sample from well 299-W14-13, taken at about the same time, contained only about 315,000 µg/L of nitrate. Just as for technetium-99, that sample represented the nitrate concentration throughout the upper 10 meters of the aquifer. The conclusion is that nitrate existed at the water table at about 600,000 µg/L in January 1999, and the concentration decreases with depth in the aquifer. The 315,000 µg/L nitrate value from well 299-W14-13 is a mixture of the high nitrate-bearing water at the top of the aquifer with lower nitrate-bearing water deeper in the aquifer.

The trends in nitrate concentration through time are the same as those seen for technetium-99. Nitrate began to decrease from a maximum or about 540,000 µg/L in 1993 to about 200,000 µg/L in early 1997. (The analytical result for February 1997, shown on Figure 4.2 is probably an invalid data point, but it is not flagged in the database so it was included on the plot.) Then nitrate began to increase, reaching 580,000 µg/L in January 1999. The increasing nitrate trend was continued in the replacement well until early 2000 when concentrations reached ~440,000 µg/L. Nitrate began to decrease a second time until early 2001, at which time it began a second increasing trend that lasted to the end of the reporting period.

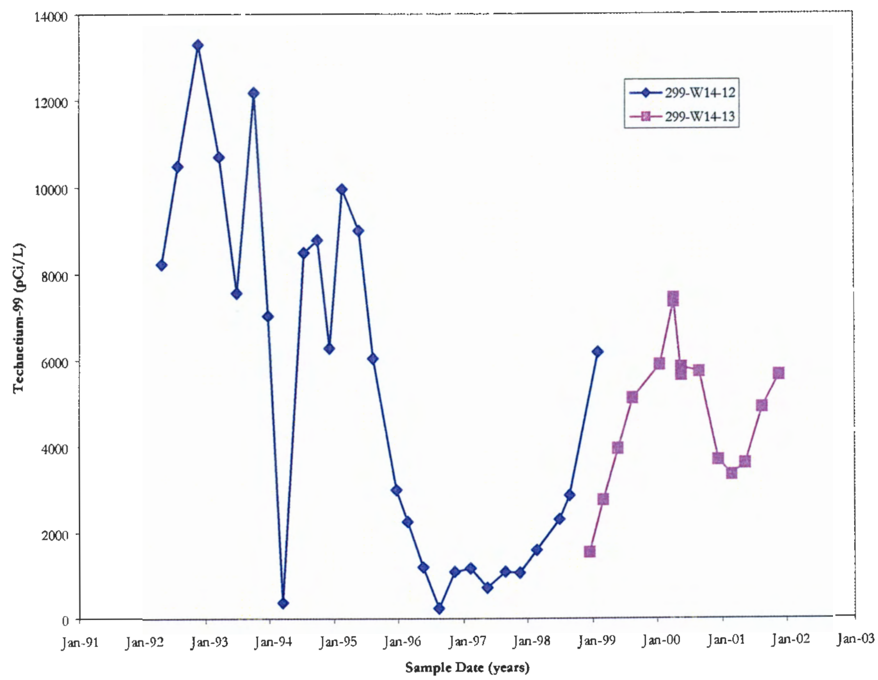

Figure 4.1. Technetium-99 Concentration in Wells 299-W14-12 and 299-W14-13 in Waste Management Area TX-TY

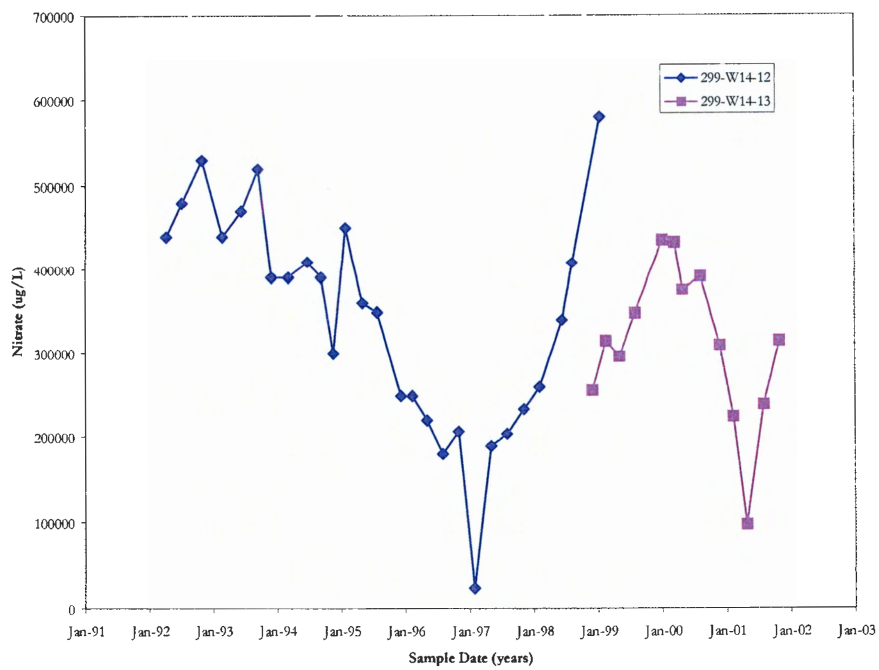

Figure 4.2. Nitrate Concentrations in Wells 299-W14-12 and 299-W14-13 at Waste Management Area TX-TY

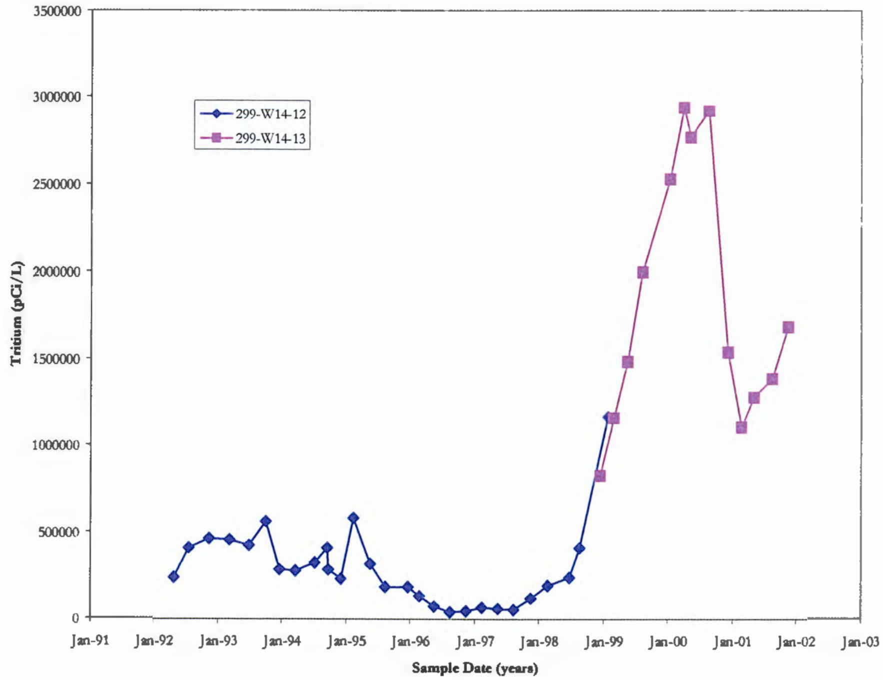

Figure 4.3. Tritium Concentrations in Wells 299-W14-12 and 299-W14-13 at Waste Management Area TX-TY

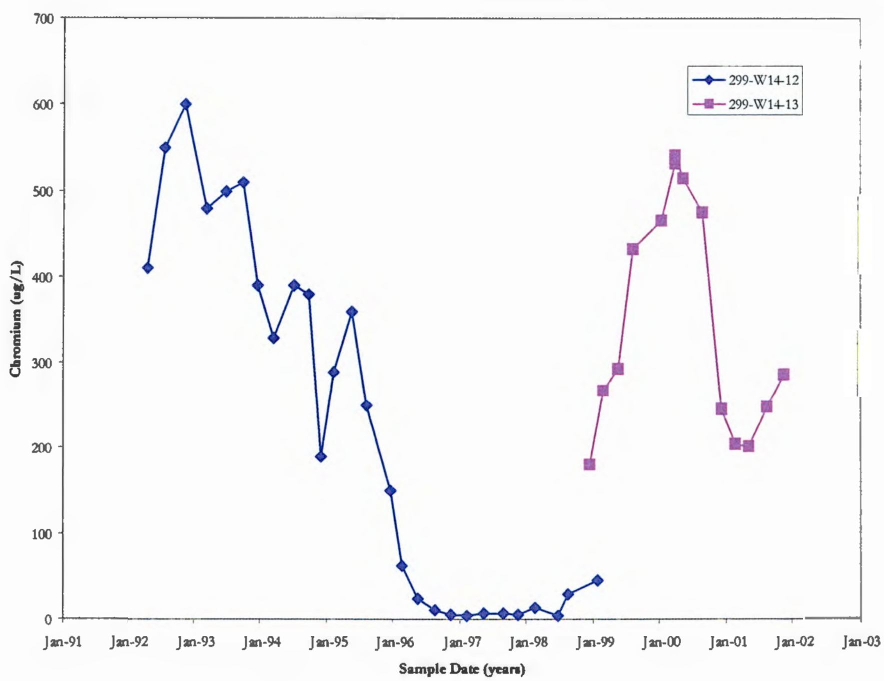

Figure 4.4. Chromium Concentrations in Wells 299-W14-12 and 299-W14-13 at Waste Management Area TX-TY

The analytical results for tritium in wells 299-W14-12 and 299-W14-13 show a different situation than that seen for technetium-99 and nitrate. Tritium concentrations in the well pair are shown on Figure 4.3. The concentration of tritium in the last sample from well 299-W14-12 was 1,170,000 pCi/L. The sample from well 299-W14-13, obtained about one month later, contained 1,160,000 pCi/L tritium. Following the same logic as used for technetium-99 and nitrate, the sample from well 299-W14-12 represents the tritium concentration at the top of the aquifer, whereas the sample from well 299-W14-13 represents the upper 10 meters of the aquifer. Both results are the same, indicating little, if any, vertical concentration differences for tritium. Thus, unlike nitrate and technetium-99, the upper part of the aquifer is homogeneous with respect to tritium concentration.

Tritium does show the same trends with time as shown by nitrate and technetium-99. Tritium began to decrease in concentration in 1993 and began to increase in early 1997 to a maximum of 2,940,000 pCi/L in early 2000. At that time, tritium began to decrease until early 2001 when tritium concentrations began to increase again.

The concentrations of chromium in filtered samples from wells 299-W14-12 and 299-W14-13 are shown in Figure 4.4. The data show a different distribution of chromium in the upper part of the aquifer than the distributions of nitrate, technetium-99, and tritium. The concentration of chromium in the last sample from well 299-W14-12 was about 45 μg/L. This represented the concentration of chromium at the top of the aquifer. The sample from replacement well 299-W14-13 contained 180 μg/L chromium. That sample represented the chromium concentration throughout the upper part of the aquifer. The conclusion reached from the chromium data is the opposite as that concluded from the technetium-99 and nitrate data. That is, the concentration of chromium is small at the top of the aquifer and increases to a maximum at some depth below the water table. The 180 μg/L chromium value from well 299-W14-13 is a mixture of the low chromium-bearing water found at the water table with water containing higher chromium concentrations deeper in the aquifer.

Finally, chromium concentrations through time display the same increasing and decreasing trends noted for technetium-99, nitrate, and tritium. If the chromium plume and the technetium-99 plume are from separate sources, it is unclear why the two (and tritium and nitrate) show parallel fluctuations in concentration through time. Depth discrete sampling is planned for well 299-W14-13 to learn more about the vertical distribution of technetium-99 and chromium in the well.

Wells 299-W10-18 and 299-W10-26. Wells 299-W10-18 and 299-W10-26 are located ~5 meters apart on the downgradient side of 241-TY tank farm. Well 299-W10-26 is the replacement well for well 299-W10-18 that went dry after last being sampled in August 1999. Sampling of the replacement well 299-W10-26 started in December 1998, allowing a sampling overlap of four samples between the two adjacent wells. The last samples collected from well 299-W10-18 represent the top of the aquifer. The samples collected from well 299-W10-26 represent water throughout the screened interval, which extends from 0.1 meter above the water table to 10.6 meters below the water table. The sampling pump intake is at 4.3 meters below the water table in well 299-W10-26.

Concentrations of technetium-99, tritium, nitrate, and chromium in samples from both wells in the well pair are shown on Figures 4.5 through 4.8. The graphs of data from this well pair are much different

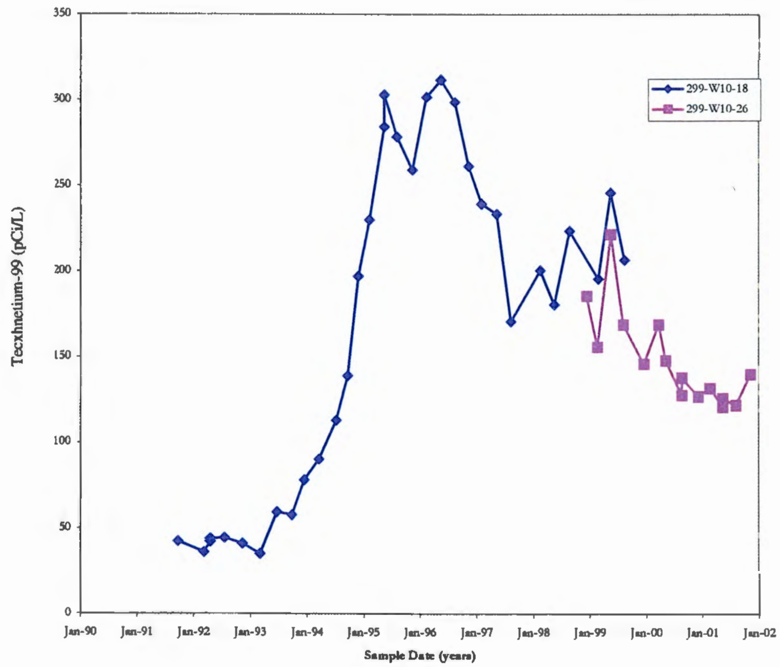

Figure 4.5. Technetium-99 Concentration in Wells 299-W10-18 and 299-W10-26 at Waste Management Area TX-TY

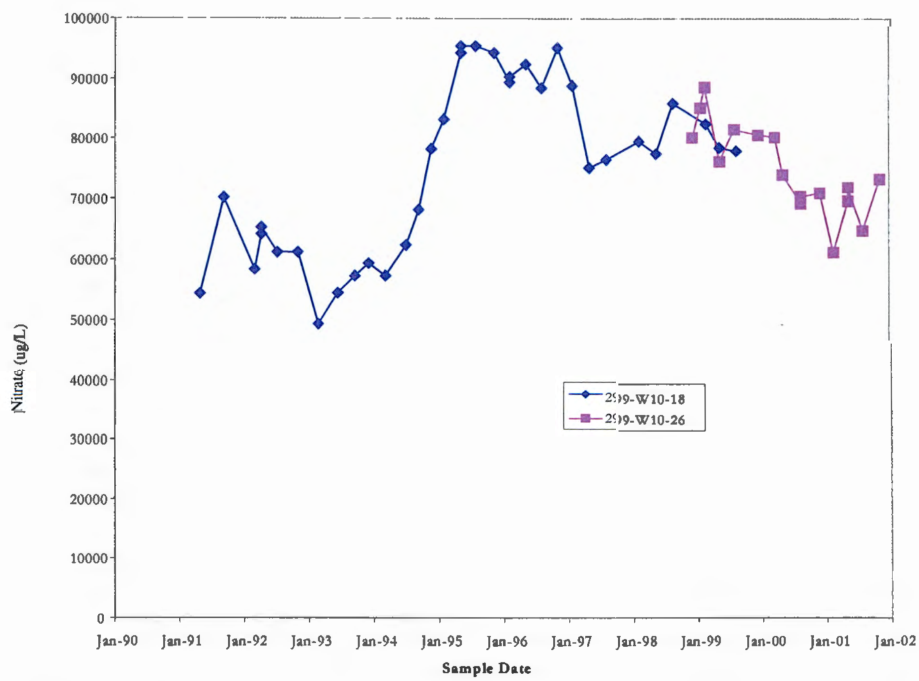

Figure 4.6. Nitrate Concentrations in Wells 299-W10-18 and 299-W10-26 at Waste Management Area TX-TY

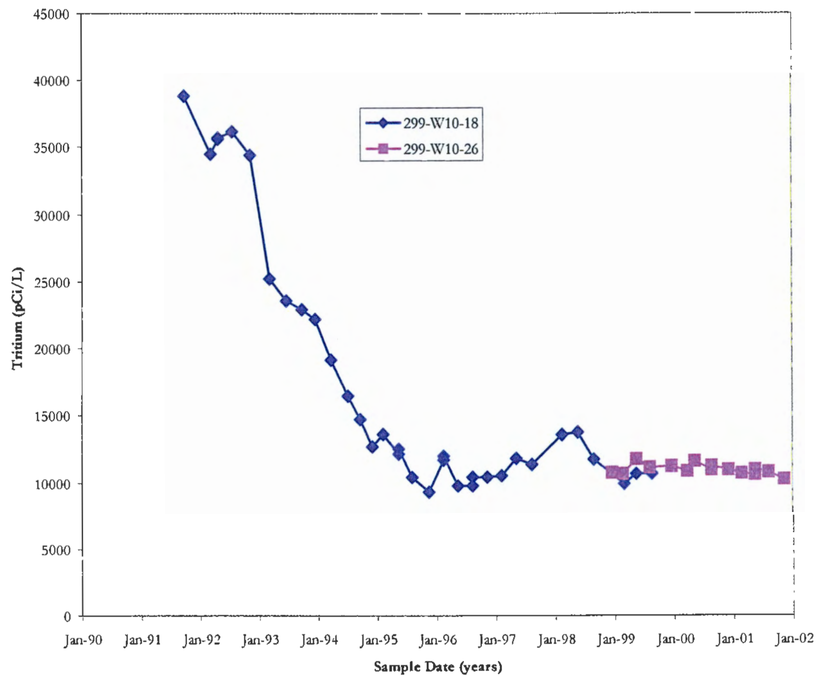

Figure 4.7. Tritium Concentration in Wells 299-W10-18 and 299-W10-26 at Waste Management Area TX-TY

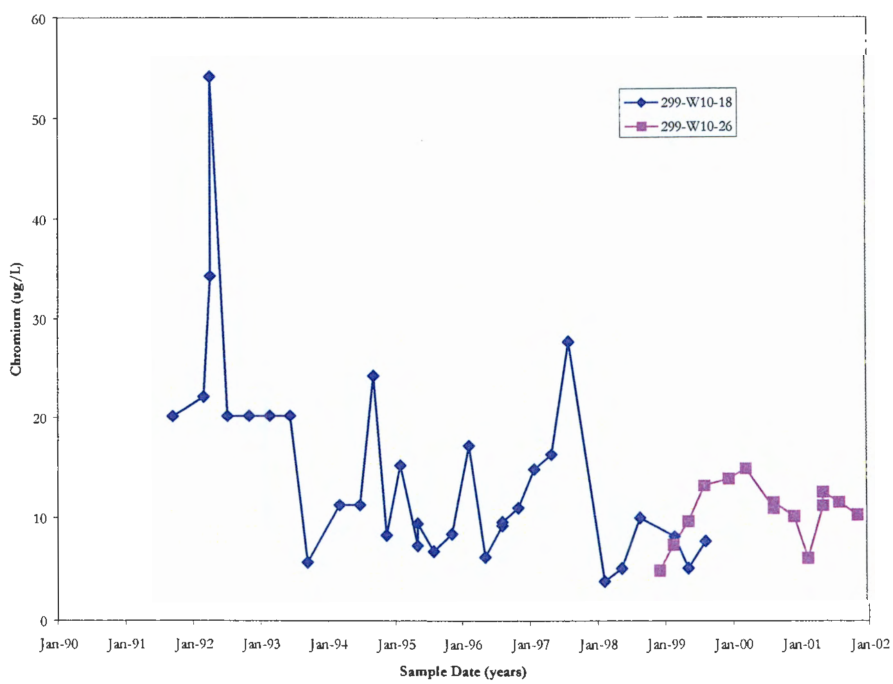

Figure 4.8. Chromium Concentrations in Wells 299-W10-18 and 299-W10-26

than those shown for well pair 299-W14-12 and 299-W14-13. None of the constituents shown for wells 299-W10-18 and 299-W10-26 show significant stratification with depth in the aquifer.

The concentrations of technetium-99 (see Figure 4.5) are much lower than those seen in well 299-W14-13 and are very similar to the regional background in the area of WMA TX-TY. Thus, the technetium-99 plume found in the upper part of the aquifer at well 299-W14-13 is not present at well 299-W10-26.

The values for nitrate in Figure 4.6 are within the range of the regional background. They are lower, however, than the values found in well 299-W14-13. Thus, the nitrate seen in well 299-W14-13 is a mixture of the regional nitrate plume with nitrate associated with the technetium-99 plume.

The concentration of tritium (see Figure 4.7) and the concentration of chromium (see Figure 4.8) in well 299-W10-26 are within the range of the regional background near WMA TX-TY. Thus, the tritium and chromium plumes noted at well 299-W14-13 are not found 130 meters to the north at well 299-W10-26.

Wells 299-W15-765 and 299-W15-12. Wells 299-W15-12 and 299-W15-765 are located ~4.5 meters apart upgradient of the north part of the WMA. Well 299-W15-765 is the replacement well for well 299-W15-12 that went dry after last being sampled in March 2000. Sampling the replacement well 299-W15-765 began in November 2001 so that no overlap occurs among samples from the two wells. The last samples collected from well 299-W15-12 represents the top of the aquifer. The samples collected from well 299-W15-765 represent water throughout the screened interval that extends from the water table to 10.7 meters below the water table. The sampling pump intake is at 2.9 meters depth in the aquifer.

Concentrations of technetium-99, tritium, nitrate, and chromium in groundwater samples from wells 299-W15-12 and 299-W15-765 are shown in Figures 4.9 through 4.12. The technetium-99 in the last sample from well 299-W15-12 was ~960 pCi/L, representing the concentration of technetium-99 at the top of the aquifer at that time. The sample from replacement well 299-W15-765, taken about eight months later, was ~120 pCi/L technetium-99. That sample represented the technetium-99 concentration throughout the upper 10 meters of the aquifer. The conclusion is that technetium-99 existed at the water table at ~960 pCi/L at the time upgradient well 299-W15-12 went dry, and technetium-99 concentration decreased with depth in the aquifer. The 120 pCi/L technetium-99 value from well 299-W15-765 is a mixture of the relatively high technetium-99 water at the top of the aquifer with lower technetium-99 water deeper in the aquifer. Alternatively, a less probable explanation is that the technetium-99 concentration decreased at the well pair during the eight months between sampling events.

Nitrate data from wells 299-W15-12 and 299-W15-765 are shown in Figure 4.10. Nitrate concentrations in the new well 299-W15-765 are similar to the latest values from the now dry well 299-W15-12. This suggests that is no vertical concentration gradient for nitrate at the location of well 299-W15-765. Data from samples collected during drilling appear to contradict this conclusion (see Section 4.1.2.3).

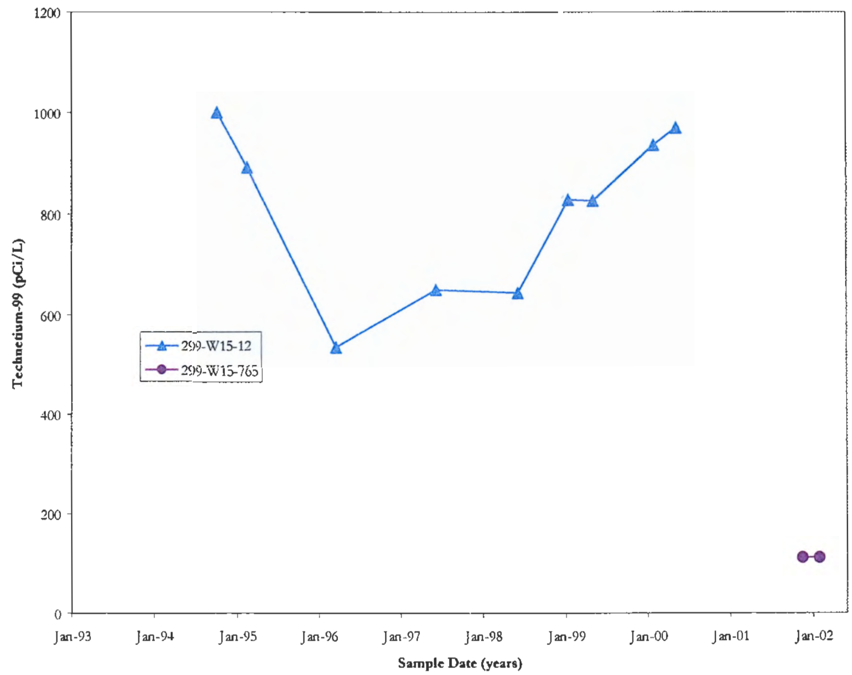

Figure 4.9. Technetium-99 Concentration in Wells 299-W15-12 and 299-W15-765 at Waste Management Area TX-TY

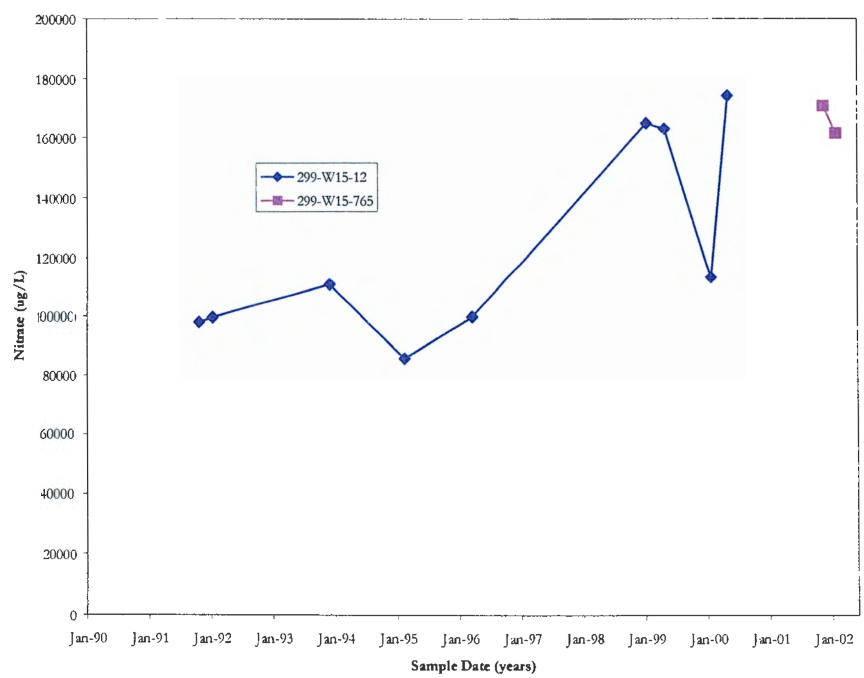

Figure 4.10. Nitrate Concentrations in Wells 299-W15-12 and 299-W15-765 at Waste Management Area TX-TY

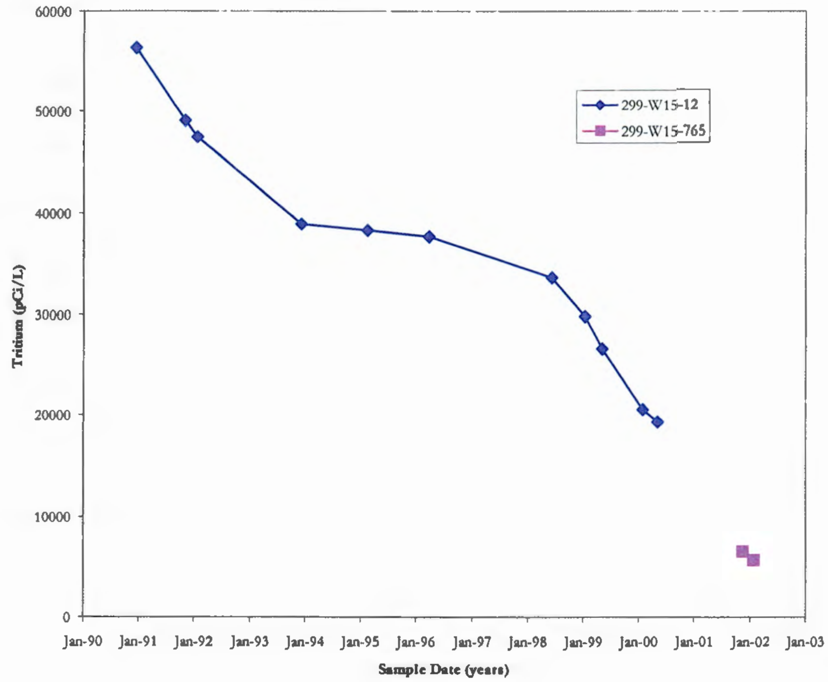

Figure 4.11. Tritium Concentration in Wells 299-W15-12 and 299-W15-765 at Waste Management Area TX-TY

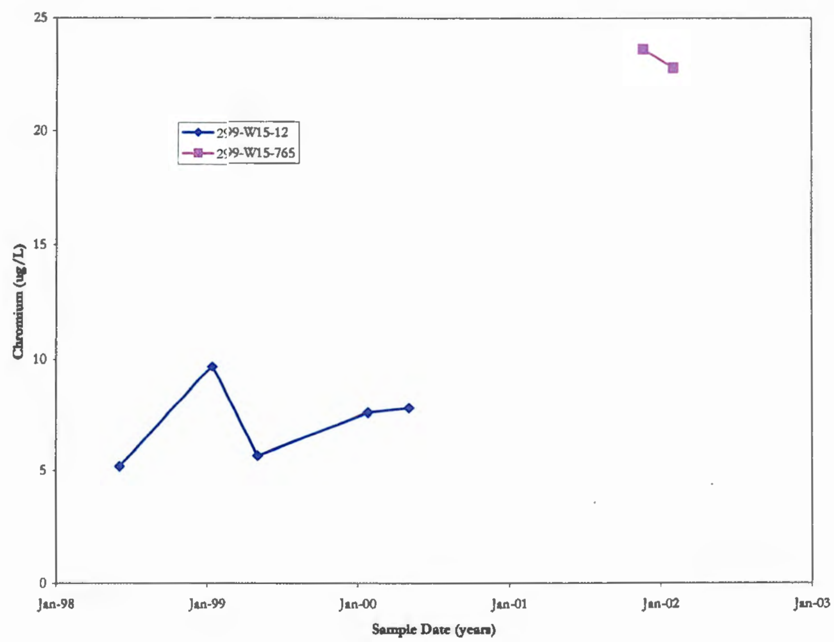

Figure 4.12. Chromium Concentrations in Wells 299-W15-12 and 299-W15-765 at Waste Management Area TX-TY

However, it is difficult to compare the two data sets because the upper sample obtained during drilling of 299-W15-765 was from 5.5 meters below the water table such that contaminant concentrations near the water table at that time are not known.

The tritium data from wells 299-W15-12 and 299-W15-765 are shown on Figure 4.11. The tritium data show a continued decrease in concentration throughout the history of well 299-W15-12. Extrapolation of the trend to the time of the first sampling of well 299-W15-765 shows an apparent continuation of the trend in the new replacement well. The data suggest no vertical concentration gradient with respect to tritium upgradient of the TY tank farm.

Chromium data from wells 299-W15-12 and 299-W15-765 are shown in Figure 4.12. Comparison of the chromium concentrations in the new well, 299-W15-765, with those in the older well, 299-W15-12, indicates that chromium may be present at higher concentrations at depth within the aquifer. However, the maximum concentration of chromium found in well 299-W15-765 (23 μg/L) is much less than that found at depth in downgradient well 299-W14-13 (287 μg/L at the end of the reporting period in December 2001).

Alternatively, the relatively high chromium at depth in well 299-W15-765 as compared with the top of the aquifer sample from well 299-W15-12 may result from the fact that the well was recently drilled. Frequently, groundwater from new wells show high concentrations of some trace metals. This is particularly true if the well was drilled by cable tool methods. Well 299-W15-765 was drilled by air rotary and groundwater from the well does not have high concentrations of iron, manganese, nickel or other metal. Thus the chromium concentration in the well is probably not an artifact of drilling.

4.1.2.2 Depth Discrete Groundwater Sampling at Well 299-W14-14

Well 299-W14-14 was drilled through the lower mud unit of the Ringold Formation, prior to being completed as a top-of-the-aquifer monitoring well with a 10.7-meter long screen. An air rotary drilling method was used to advance the borehole. When the desired depths were reached, the drill string was replaced with a submersible pump-and-packer assembly consisting of a 1.5-meter length of slotted PVC that served as a temporary screen. The inflatable packer was used to isolate standing water in the drive casing from the water pumped to the surface. Water was purged until indicator parameters (pH, specific conductance, and temperature) were stabilized. Purge volumes were on the order of 400 liters. The water samples were filtered in the field to remove particulates.

Results from the pump-and-packer sample depths are shown in Table 4.1 and Figure 4.13. The maximum concentrations of technetium-99 and nitrate were found at 14.5 meters below the water table. The maximum concentrations of tritium and carbon tetrachloride were found at about 40 meters below the water table. Detectable contamination extends through the unconfined aquifer and beneath the lower mud unit. (The lower mud unit extends from 56 to 67 meters below the water table in well 299-W14-14.) The concentrations of tritium and carbon tetrachloride in the water samples obtained from the lower mud unit (about 60 meters on Figure 4.13) are less than concentrations in samples collected above and below the unit. The depth distribution of tritium and carbon tetrachloride allow that concentrations might continue

Table 4.1. Discrete Depth Sampling Results from Well 299-W14-14

Depth Below Water Table (m)	Specific Conductance (µS/cm)	Technetium-99 (pCi/L)	Tritium (pCi/L)	Nitrate (mg/L)	Carbon Tetrachloride (µg/L)
4.3[(a)]		110	4,230	62,900	
14.51	687	556	893	226,000	180
30.05	382	81	5,380	41,400	380
39.81	467	32	9,010	32,500	920
56.88	541	29	7,180	42,800	380
68.46[(b)]	430	33	8,460	40,200	590

(a) Sample from screened interval after well completion.
(b) Sample from below Ringold lower mud unit.

to increase with depth below the lower mud unit at well 299-W14-14. The tritium and carbon tetrachloride encountered at depth in well 299-W14-14 are probably part of the regional plumes in the area of WMA TX-TY.

The maximum technetium-99 in well 299-W14-14 was ~14.5 meters below the water table. This is in contrast to other wells in the area with elevated technetium-99 that have the technetium-99 maximum closer to the top of the aquifer. A downward hydraulic gradient was noted in wells 299-W10-26 and 299-W14-13 during aquifer testing. It is possible that a downward hydraulic gradient also exists in other wells on the east side of WMA TX-TY and that a downward hydraulic gradient in well 299-W14-14 is pushing the technetium-99 maximum to 15 meters depth in the aquifer. In-well vertical flow measurements are needed to show whether or not this is true.

The maximum concentration of nitrate found in well 299-W14-14 was 226,000 µg/L at a depth coinciding with the maximum technetium-99. The nitrate in the sample is probably a mixture of nitrate associated with the technetium-99 plume and regional nitrate, which is about 100,000 µg/L in the WMA TX-TY area.

4.1.2.3 Sampling During Drilling

Sampling of water brought to the surface during air rotary drilling can give an indication of vertical variations within the aquifer (Johnson and Chou 2001). During drilling in calendar year 2000 and 2001, limited sampling during drilling was completed at five wells in WMA TX-TY.

Well 299-W14-15. In August 2000, three groundwater samples were separated from airlifted slurry during drilling of downgradient well 299-W14-15, east of WMA TX-TY. The samples were filtered using a peristaltic pump and a 0.45-µm filter cartridge prior to analysis in the field. Specific conductance and nitrate concentrations were measured. Analytical results as a function of depth below the water table are shown in Table 4.2.

Between the depths of 3.4 to 9.6 meters below the water table, specific conductance increased from 540 to 571 µS/cm and nitrate concentration increased from 64,000 to 111,000 µg/L. All intervals sampled are within the current screened interval. During the first routine sampling of this well in

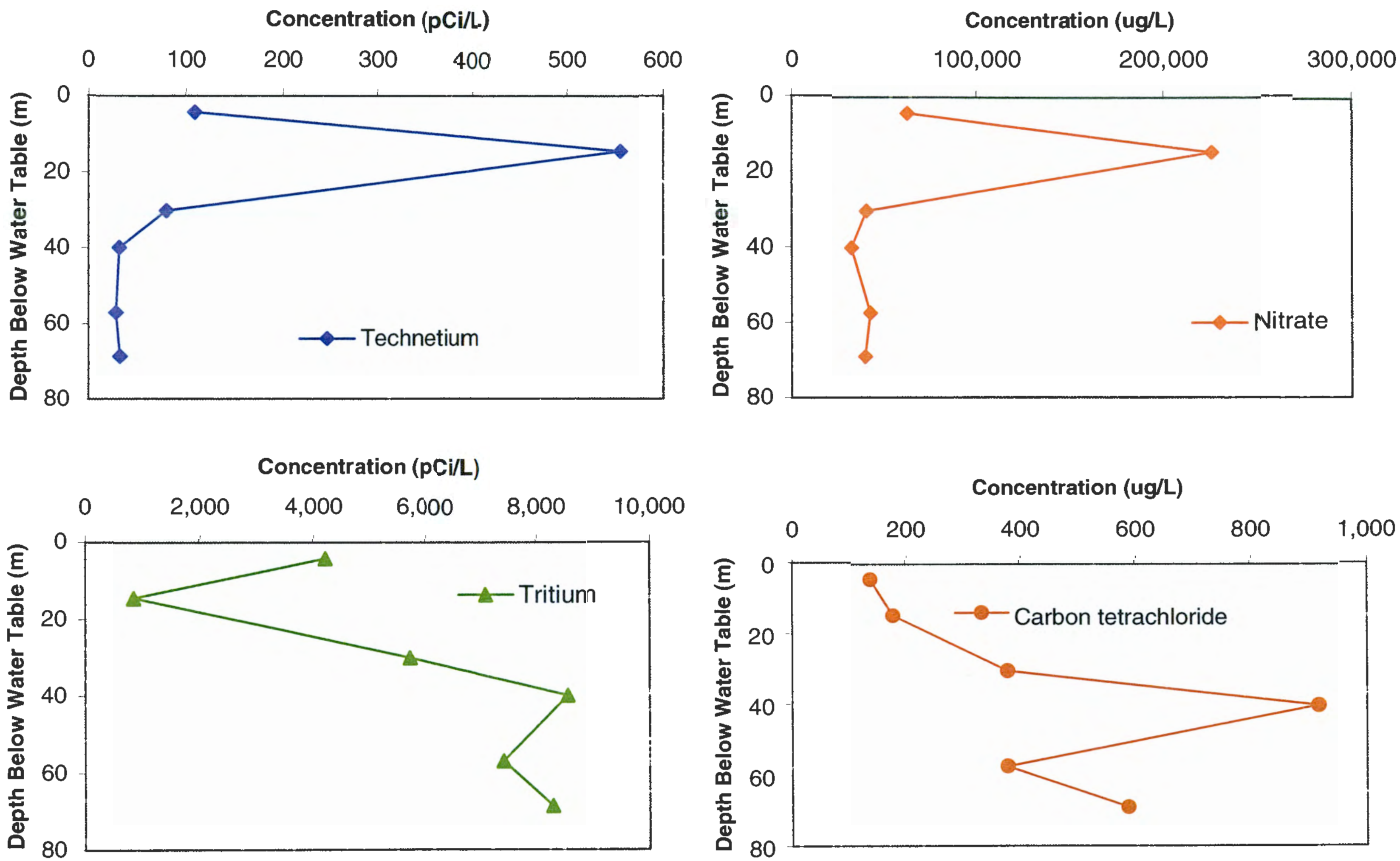

Figure 4.13. Distribution of Key Contaminants, Well 299-W14-14, Waste Management Area TX-TY

Table 4.2. Analytical Results for Groundwater Samples Taken During Drilling of New Wells at Waste Management Area TX-TY

Well	Depth Below Water Table (m)	Specific Conductance (μS/cm)	Nitrate (μg/L)[a]
299-W14-15	3.4	540	64,000
	5.1	556	94,000
	9.6	571	111,000
299-W14-16	3.1	304	30,000
	6.1	403	46,000
	9.1	533	80,000
	13.1	680	149,000
299-W14-17	12.2	680	275,000

(a) Nitrate as NO_3^-. Analyzed by HACH cadmium reduction method (method 8039) using a DR/2010 portable spectrophotometer. Reagent blank corrected.

December 2000, the measured specific conductance value was 586 μS/cm and the nitrate concentration was 98,700 μg/L. (Sampling pump intake is at about 2.2 meters below the water table.) Subsequent routine sampling during four quarters of 2001 yielded nitrate concentrations between 77,000 and 94,700 μg/L. All nitrate values from routine groundwater sampling are reasonable averages of the values obtained during drilling from the top and bottom of the screened interval.

The analytical data obtained during drilling show an increase in nitrate concentration with depth. Sampling stopped at 9.6 meters below the water table before penetrating the bottom of the nitrate plume. Thus, the maximum nitrate concentration in the area of well 299-W14-15 is not known. The nitrate concentration of 111,000 μg/L at 9.6 meters below the water table is comparable to the concentrations found in the regional nitrate plume (from upgradient sources) at WMA TX-TY.

Well 299-W14-16. Four groundwater samples were collected in October and November of 2000 from slurry samples air lifted during the drilling of downgradient well 299-W14-16, east of WMA TX-TY. The samples were filtered using a peristaltic pump and a 0.45-μm filter cartridge prior to analysis in the field. Specific conductance and nitrate concentrations were measured. Analytical results as a function of depth below the water table are shown in Table 4.2. Water, added to the borehole to facilitate drilling just above the water table, may have diluted the results from the shallowest sample.

The most significant finding is a continuous increase in both specific conductance (304 to 680 μS/cm) and nitrate (30,000 to 149,000 μg/L) between 3 and 13.1 meters beneath the water table. The highest values are at a depth of 13.1 meters, about 2.3 meters below the bottom of the 10.7-meter screen installed in the well. (The screened interval is 0.1 to 10.8 meters below the water table.) Groundwater from the first year of quarterly, routine sampling of this well yielded specific conductance values between 574 and 611 μS/cm and nitrate concentrations between 81,900 and 90,300 μg/L. These data suggest that a greater proportion of water in the routine samples is contributed from the lower portion of the screened interval than from the upper portion of the interval. This suggests that the aquifer in the lower portion of the screened interval is more permeable than that in the upper portion. This is substantiated by the geophysical log and sieve analyses that indicate less silt in the formation around the lower part of the screened interval relative to the upper part of the screened interval.

The nitrate concentrations obtained during drilling of well 299-W14-16 show an increase in concentration with depth. Sampling stopped at 13.1 meters below the water table before penetrating the bottom of the nitrate plume. Thus, the maximum nitrate concentration in the area of the well is not known. The nitrate concentration of 149,000 µg/L at 13.1 meters below the water table is somewhat greater than the regional plume in the area. However, most wells used to define the regional plume are screened over the interval in which a nitrate concentration gradient has been shown to exist at WMA TX-TY, thus diluting the high nitrate water with lower nitrate-bearing water near the water table. Upgradient well 299-W15-765, screened from the water table to 10.7 meters below the water table had nitrate concentrations between 160,000 and 170,000 µg/L.

Well 299-W14-17. In October 2000, one groundwater sample was recovered from airlifted slurry near the bottom of well 299-W14-17, a downgradient well east of WMA TX-TY. The sample was filtered in the field prior to analysis for specific conductance and nitrate concentration. The groundwater sample, from 12.2 meters below the water table, yielded a specific conductance value of 680 µS/cm and a nitrate concentration of 275,000 µg/L (see Table 4.2). Analysis of groundwater from the first four quarters of routine sampling of this well in 2001 yielded specific conductance values between 657 and 707 µS/cm and nitrate concentrations that steadily increased from 157,000 to 182,000 µg/L. (The sample pump intake for routine sampling is at 3.4 meters below the water table.) The sample results for specific conductance are somewhat inconclusive, but the results for nitrate indicate a downward increase in nitrate concentrations in uppermost aquifer, with the highest nitrate concentrations occurring below the 10.7-meter screened interval. Nitrate in this well is considered as part of a regional plume of nitrate located at depth.

Well 299-W14-18. Two groundwater samples were collected in October 2001, during drilling of well 299-W14-18 downgradient of WMA TX-TY. The samples were collected at the top of the aquifer and at total drill depth. The samples were transported to laboratories at PNNL. In the laboratory, the samples were filtered and analyzed for specific conductivity and anions using the laboratory's standard operating procedures (AGG-SST-VZC)[(a)] Analysis results are shown in Tables 4.3 and 4.4.

The specific conductivity from the water-table sample in well 299-W14-18 is about twice as high as that in the 12.6 meter sample. Also, nitrate concentration in the water-table sample is an order of magnitude greater than that of the 12.6 meter deep sample. Two routine groundwater samples collected subsequent to drilling had specific conductivity values of 566 and 602 µS/cm and nitrate concentrations of 65,100 and 96,500 µg/L.

(a) AGG-SST-VZC. Applied Geology and Geochemistry Group Procedures for Single-Shell Tank Vadose Zone Characterization, Pacific Northwest National Laboratory, Richland, Washington.

Table 4.3. Specific Conductance and pH for Samples from Wells 299-W14-18 and 299-W15-765 at Waste Management Area TX-TY

Well Name and Depth (meters below the water table)	pH	Specific Conductivity (µS/cm)
299-W14-18		
At the water table	7.65	543
12.6	7.61	269
299-W15-765		
5.5	7.39	352
13.8	7.46	674

Table 4.4. Anions in Samples from Wells 299-W14-18 and 299-W15-765 at Waste Management Area TX-TY

Well Name and Depth[(a)]	Fluoride	Chloride	Nitrite	Bromide	Nitrate	Sulfate	Phosphate	Carbonate
299-W14-18								
At the water table	870	31,710	4,270	<1,000	56,850	55,580	<1,500	64,240
12.6	700	7,590	<1,000	<1,000	3,260	32,220	<1,500	73,010
299-W15-765								
5.5	950	14,100	2,050	<1,000	24,270	42,930	<1,500	77,590
13.8	420	19,390	2,770	<1,000	174,110	52,110	<1,500	95,970
(a) Depths are meters below the water table.								
(b) All data are µg/L.								

The nitrate data from well 299-W14-18 are inconclusive. Although the data appear to indicate that nitrate concentration is higher at the top of the aquifer than at depth, the nitrate value from the sample collected at 12.6 meters below the water table is unreasonably low and on the order of uncontaminated, site wide background (DOE/RL 1992) and not the level of the immediate background in the vicinity of WMA TX-TY. The chloride and sulfate concentrations are also on the order of uncontaminated, sitewide background and unlike the concentrations found in other wells in this area. Thus, the nitrate value of 3,260 µg/L in the 12.6 meter sample is probably not a valid analytical result. The nitrate concentration in the water-table sample from this well is similar to that in nearby wells.

Well 299-W15-765. Two groundwater samples were collected in September 2001, during drilling of well 299-W15-765 upgradient of WMA TX-TY. The samples were collected from 5.5 and 13.8 meters below the water table. The samples were transported to laboratories at PNNL. In the laboratory, the samples were filtered and analyzed for specific conductivity and anions using the laboratory's standard operating procedures (AGG-SST-VZC).[(a)] Analysis results are shown in Tables 4.3 and 4.4.

(a) AGG-SST-VZC. Applied Geology and Geochemistry Group Procedures for Single-Shell Tank Vadose Zone Characterization, Pacific Northwest National Laboratory, Richland, Washington.

The specific conductivity from the shallower sample is about one-half the value from the deeper sample, and the nitrate concentration in the shallower sample is much lower than that of the deeper sample. Two routine groundwater samples collected subsequent to drilling had specific conductivity values of 691 and 687 µS/cm and nitrate concentrations of 170,000 and 161,000 µg/L, which are similar to the deeper sample collected during drilling.

As a whole, the limited data from well 299-W15-765 do not seem to define a linear nitrate concentration gradient with depth. Analysis of routine, quarterly groundwater samples from the well pair 299-W15-12 and 299-W15-765 (discussed in Section 4.1.2.1) do not indicate the presence of a nitrate concentration gradient with depth. However, the data collected during drilling of well 299-W15-765 suggest that the aquifer is stratified with respect to nitrate concentration. Only two depth discrete samples were collected during drilling and the shallowest was from 5.5 meters below the water table. Additional depth discrete sampling is needed to better define any potential nitrate concentration gradient at well 299-W15-765.

This apparent nitrate distribution at well 299-W15-765 may be related to the heterogeneous formation in the upper part of the aquifer at that well. The last sample from well 299-W15-12, representing the water table, had 173,000 µg/L nitrate and was taken from a silty sandy gravel with about 10% silt and clay. The sample from 5.5 meters below the water table in well 299-W15-765 had only 24,000 µg/L nitrate and was collected from a silty gravel zone with about 30% silt and clay. Finally, the sample from 13.8 meters below the water table in well 299-W15-765 had 174,110 µg/L nitrate and was from a sandy gravel zone with no silt and clay. Apparently, the aquifer at well 299-W15-765 contains nitrate concentrations in accordance with the regional nitrate plume (100,000 to 200,000 µg/L) except in a zone with high silt and clay between about 5 and 6.4 meters below the water table.

4.2 Geographic Distribution

This section summarizes the areal distribution of contaminants in groundwater at WMA TX-TY. The discussion must consider not only the contaminant distribution but also the uncertainty associated with the distribution from changes in the direction of groundwater flow, well coverage, and vertical heterogeneity in both contaminant distribution and hydraulic properties.

Technetium-99, the best indicator of tank waste contamination, occurs at low concentrations in groundwater across the area surrounding WMA TX-TY, along with elevated concentrations of carbon tetrachloride, chromium, fluoride, nitrate, sodium, and tritium. This background is a result of mixing of contaminants from a number of past waste-disposal practices, including the disposal of tank waste and evaporator condensate to nearby cribs and trenches and disposal of plutonium processing waste at cribs and trenches associated with the Plutonium Finishing Plant (Hodges 1998; Hodges and Chou 2001). Within this background groundwater, technetium-99 seldom exceeds about 100 pCi/L.

Contamination from two areas near WMA TX-TY warrants consideration: east and downgradient of the WMA in the area of well 299-W14-13 and south of the WMA near well 299-W15-41. The contaminants of interest east of WMA TX-TY are technetium-99, tritium, iodine-129, nitrate, and chromium. The contaminant of interest south of the WMA is technetium-99.

4.2.1 Contaminants Upgradient of WMA TX-TY

Wells 299-W15-40 and 299-W15-765 are the current upgradient wells at WMA TX-TY. Figures 4.14 through 4.17 show the levels of technetium-99, tritium, nitrate, and chromium in these wells. In addition, well 299-W15-22 was used as an upgradient well from September 1991 to August 1998 when it went dry and well 299-W15-12 was used as an upgradient well from 1988 to May 2000 when it went dry. Data from those wells also are shown in Figures 4.14 through 4.17.

The increase in technetium-99 in well 299-W15-22 beginning in mid-1997 (Figure 4.14) is the result of the 200-ZP-1 pump-and-treat operations causing technetium-99-bearing groundwater to be moved southwest from under the 241-TX tank farm. The source of the technetium-99 is most likely WMA TX-TY.

Well 299-W15-12 was an upgradient well until it went dry after being sampled in May 2000. The decreasing and later increasing trend of technetium-99 in well 299-W15-12 through time is difficult to explain because there is no easily identifiable upgradient source for the technetium-99. Figure 4.18 shows hydraulic head elevations in four wells around the north end of WMA TX-TY. Hydraulic head data show that flow direction was to the north prior to mid 1995. After mid-1997, flow direction was to the east. Before mid-1995, the only nearby potential source for technetium-99 in upgradient well 299 W15-12 is the series of specific retention trenches west of 241-TX tank farm. The decrease in technetium-99 occurred during the time period that flow changed from northerly to easterly, which would be expected if these trenches were the technetium-99 source. However, this does not explain the increase in technetium-99 beginning in 1998 after groundwater flow shifted toward the east.

Alternatively, the increasing technetium-99 beginning in 1998 could be from the specific retention trenches west of 241-TX tank farm if the plume existed west of well 299-W15-12 prior to 1998. This, however, cannot explain the increased technetium-99 concentration prior to 1995.

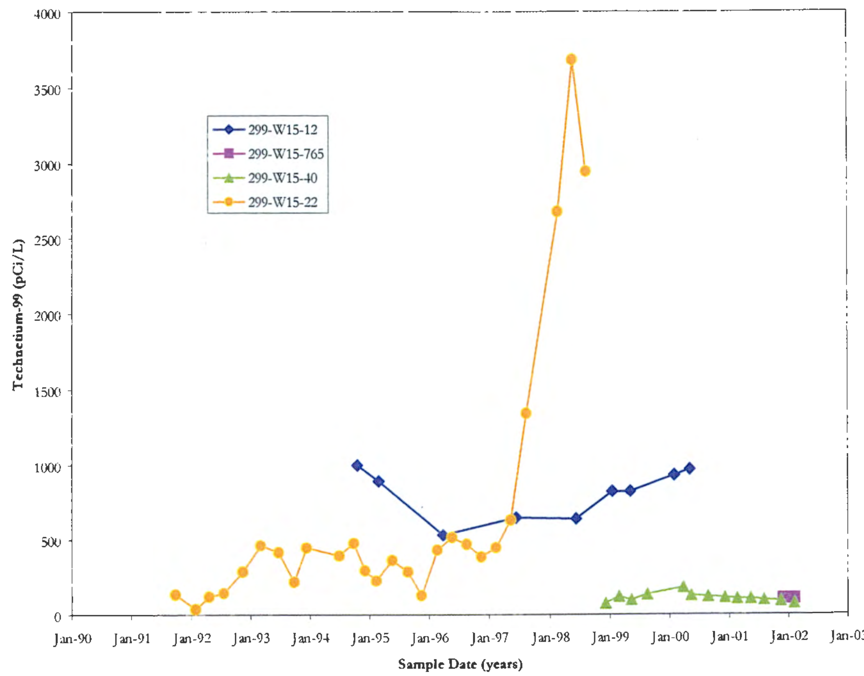

Figure 4.14. Technetium-99 Concentration in Upgradient Wells at Waste Management Area TX-TY

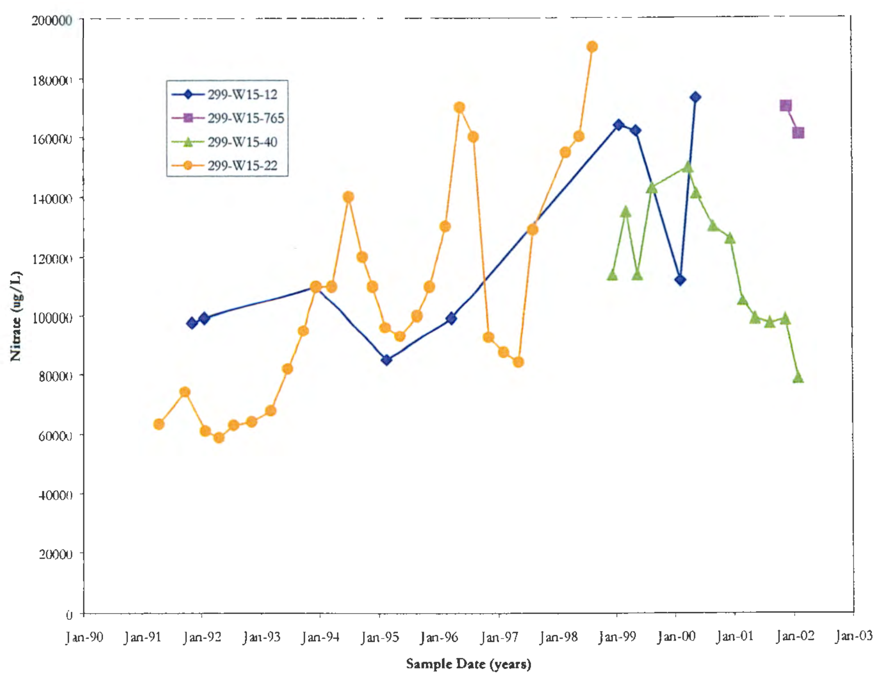

Figure 4.15. Nitrate Concentrations in Upgradient Wells at Waste Management Area TX-TY

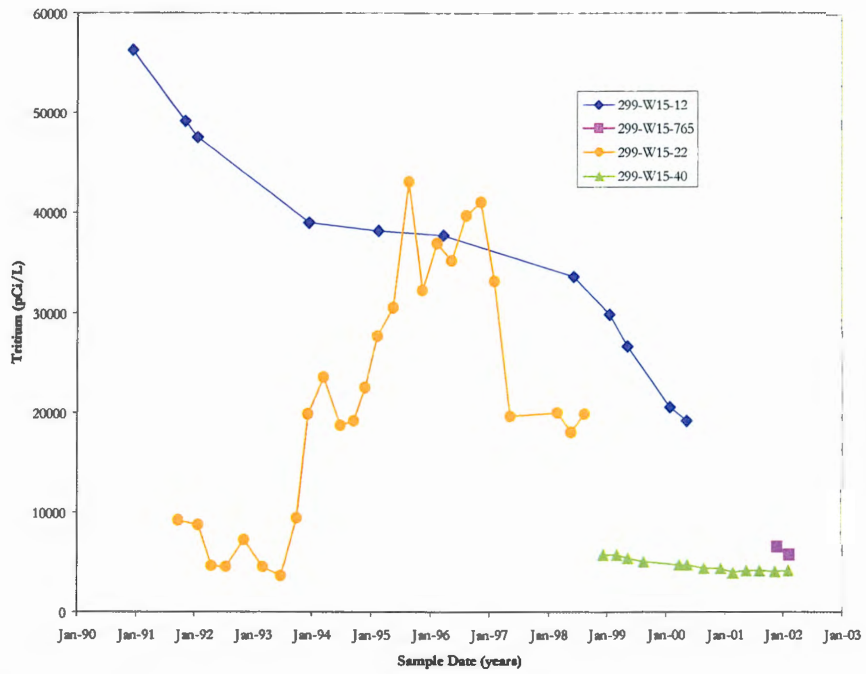

Figure 4.16. Tritium Concentrations in Upgradient Wells at Waste Management Area TX-TY

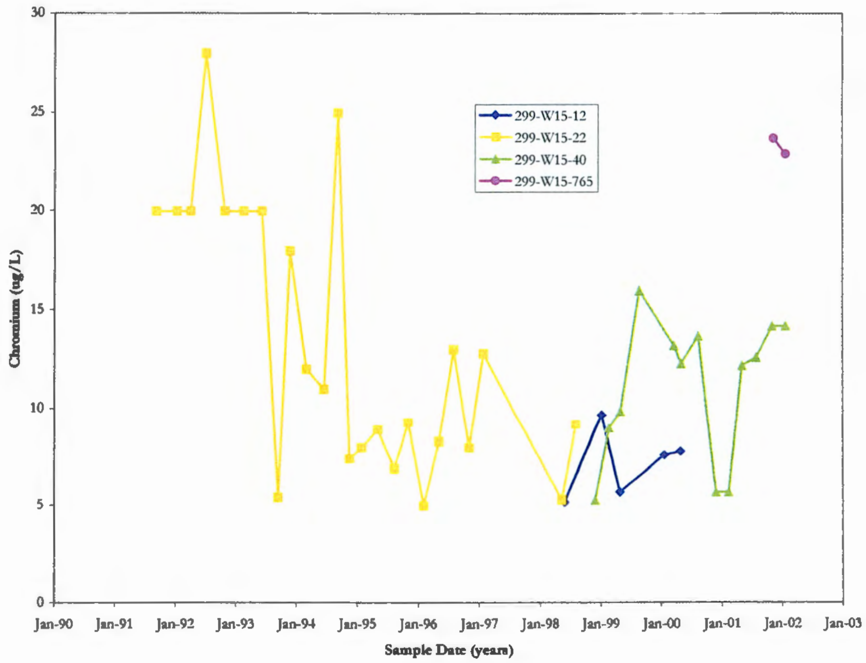

Figure 4.17. Chromium Concentrations in Filtered Samples from Upgradient Wells at Waste Management Area TX-TY

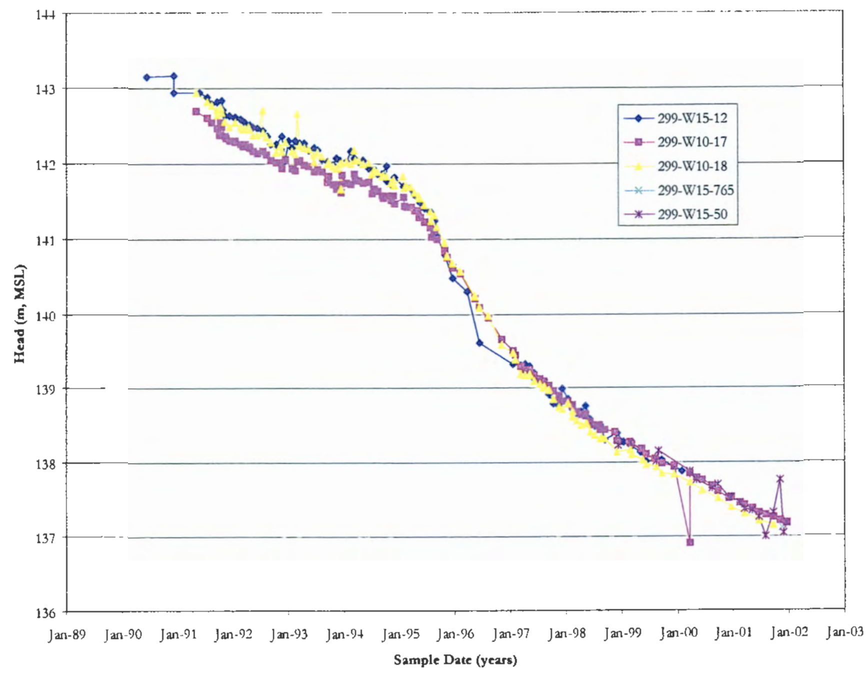

Figure 4.18. Water-Table Elevations in Four Wells at the Northern Part of Waste Management Area TX-TY

The current upgradient levels of technetium-99 in the groundwater are between 50 and 100 pCi/L and less than the drinking water standard of 900 pC/L.

Figure 4.15 shows the nitrate concentrations in the upgradient wells at WMA TX-TY. Three periods of elevated nitrate were intercepted by well 299-W15-22 between early 1993 and the end of the life of the well. The highest nitrate concentrations from well 299-W15-22 are somewhat greater than nitrate concentrations in the new upgradient well west of 241-TX tank farm but are comparable with nitrate concentrations in the new upgradient well west of the 241-TY tank farm and now dry well 299-W15-12. Data from the upgradient wells show that regional nitrate concentrations at WMA TX-TY are on the order of 100,000 to 200,000 µg/L.

Figure 4.16 shows the tritium concentration in the upgradient wells. The data from well 299-W15-22 show that a tritium plume passed through the area between mid-1993 and near the end of the life of the well (August 1998). Current upgradient concentrations of tritium at WMA TX-TY are below the drinking water standard of 20,000 pCi/L and on the order of 4,300 to 6,000 pCi/L.

Figure 4.17 shows the chromium concentrations in upgradient wells. Current chromium concentrations upgradient of WMA TX-TY are below the drinking water standard of 100 µg/L and between 5 and 25 µg/L.

4.2.2 East of Waste Management Area TX-TY

Contaminant levels for chromium, nitrate, technetium-99, and tritium were high in well 299-W14-12 when RCRA monitoring began in April of 1992 (Caggiano and Chou 1993). Contaminant levels peaked in late 1992 and then declined until 1997, the steepest decline corresponding to the rapid drop in the water table after 1995. Contaminant concentrations reached their minimum values in the 1996 to 1997 time period and began to increase in 1997 and 1998, at about the time of the change in groundwater flow direction from northeast to southeast. Concentration levels continued to increase until the well became unsamplable in January 1999. The contaminant histories for technetium-99, nitrate, tritium, and chromium in well 299-W14-12 are shown in Figures 4.1 through 4.4. Iodine-129 and cobalt-60 were also present and showed similar trends. The upward trends observed in well 299-W14-12 continued in well 299-W14-13, with the offsets discussed above in Section 4.1.2.1 (see Figures 4.1 through 4.4).

Figure 4.19 shows a plume map for chromium at the end of the reporting period. The figure shows that, at the end of the reporting period, chromium was detected in one downgradient well (299-W14-13) above the drinking water standard of 100 μg/L. The nearest potential source for the chromium is WMA TX-TY. However, data from the well pair 299-W14-12 and 299-W14-13, discussed in Section 4.1.2.1, suggest that technetium-99 is concentrated near the water table whereas chromium is more concentrated at depth in the aquifer. If the source of chromium (and technetium-99) in well 299-W14-13 is WMA TX-TY, it is unclear what mechanism caused the apparent fractionation of the two contaminants. Depth discrete sampling in well 299-W14-13 is planned to obtain detailed information about the vertical distribution of chromium (and technetium-99) in the well to more fully understand the source for the contamination.

Figure 4.20 shows a plume map for technetium-99 at the end of the reporting period. Technetium-99 was detected in one downgradient well (299-W14-13) above the drinking water standard of 900 pCi/L. The most likely source for most of the technetium-99 is WMA TX-TY.

Three other sources also may have contributed some technetium-99 to groundwater contamination east of WMA TX-TY. First, Fecht et al. (1977) state that data from gross gamma-ray logs in well 299-W14-1, located 38 meters southeast of the 216-T-28 crib show lateral spreading of radioactive contaminants from the crib to the well. They also state that the data indicate breakthrough to the groundwater could have occurred at that site. The 216-T-28 crib received about 10.9 curies of technetium-99 (Kincaid et al. 1998). Thus, some of the technetium in groundwater may be from the 216-T-28 crib.

The 216-T-19 tile field is also a potential source for some of the technetium-99 east of WMA TX-TY. The tile field received 455 million liters of primarily steam condensate from the 242-T evaporator (DOE/RL 1991), which contained 9.89 curies of technetium-99. A third potential source for some of the technetium-99 east of the WMA is leaks from the 242-T evaporator itself.

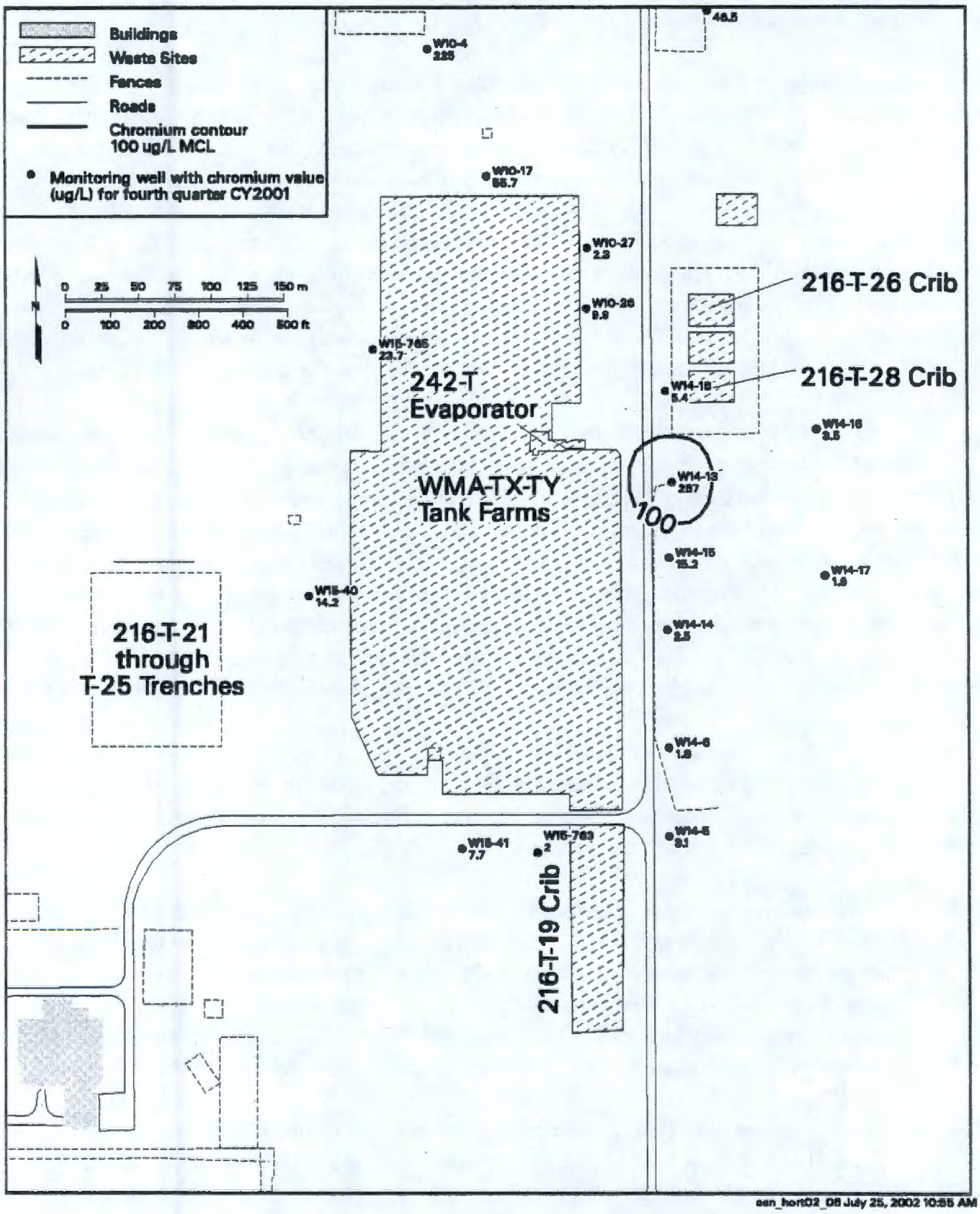

Figure 4.19. Chromium Plume Map at Waste Management Area TX-TY for the Fourth Quarter of Calendar Year 2001

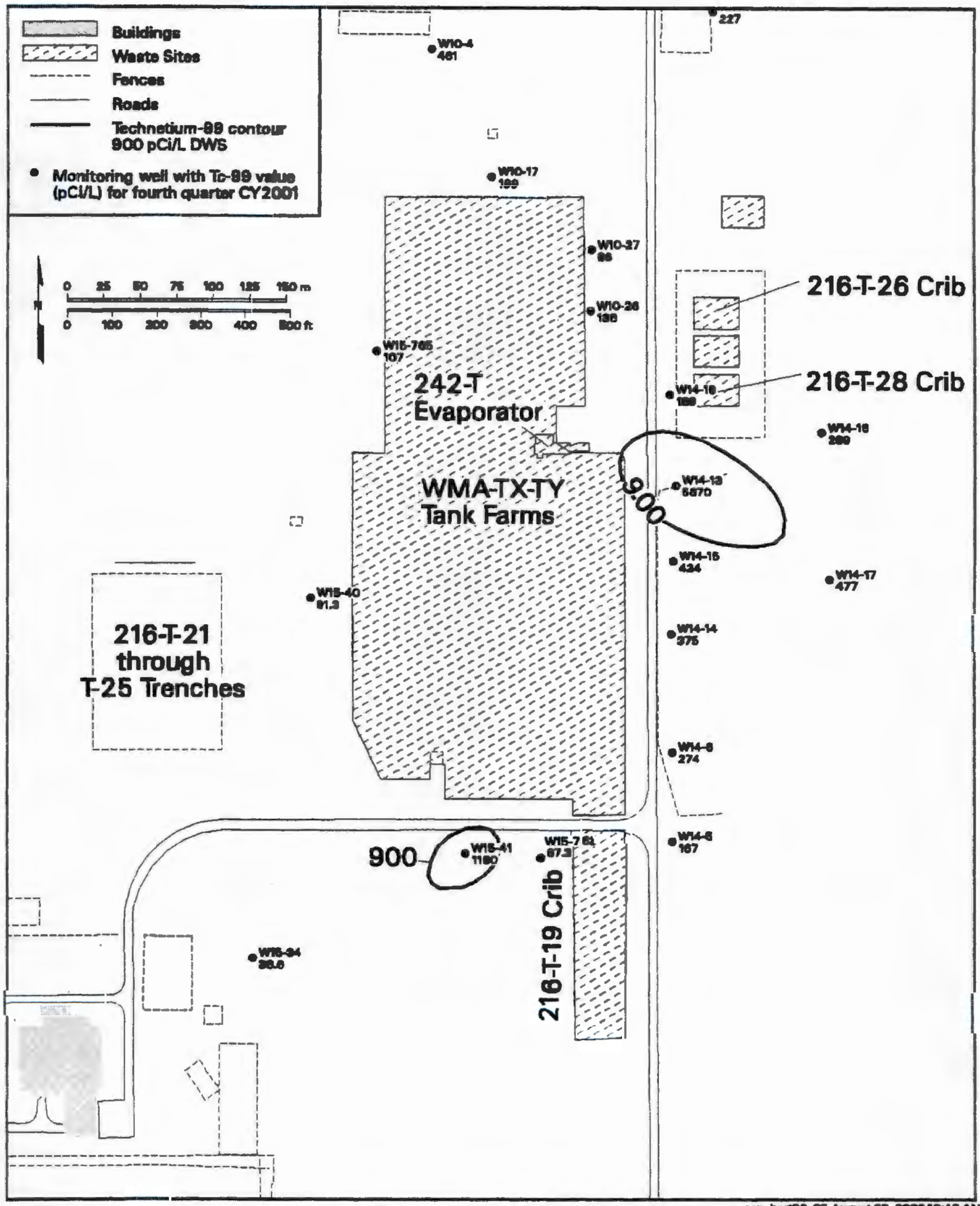

Figure 4.20. Technetium-99 Plume Map at Waste Management Area TX-TY for the Fourth Quarter of Calendar Year 2001

The plume map for technetium-99 (see Figure 4.20) shows that the technetium-99 plume is relatively small and centered near well 299-W14-13. Technetium-99 concentrations drop sharply both to the north and the south. Well 299-W14-17 is downgradient of well 299-W14-13 and technetium-99 concentrations decreased in this well from 576 pCi/L to 477 pCi/L during the reporting period.

Figure 4.21 shows a plume map for nitrate at the end of the reporting period. All wells in the groundwater monitoring network at WMA TX-TY, including the upgradient wells, had nitrate concentrations greater than the MCL of 45,000 μg/L in the fourth quarter of 2001. The highest nitrate concentration was at well 299-W14-13. This well has had nitrate concentrations greater than those in the regional plume since it was drilled in late 1998. Before that time, nitrate in well 299-W14-12 (now dry but adjacent to well 299-W14-13) was between 450,000 and 550,000 μg/L when it was drilled in 1992. Subsequently, nitrate in well 299-W14-12 decreased to about 200,000 μg/L in 1997 before increasing to about 580,000 μg/L when it went dry in late 1998.

Nitrate in the area of wells 299-W14-12 and 299-W14-13 is probably from several sources including the regional nitrate plume, WMA TX-TY, the 216-T-19 crib and tile field, and possibly the 216-T-28 trench and the 241-T evaporator. A plot of nitrate versus the technetium-99/nitrate ratio from samples from wells 299-W14-12 and 299-W14-13 (Figure 4.22) shows no relationship between the two suggesting there are sources for nitrate that are not tied to the source for technetium-99.

The area of relatively low nitrate, north of well 299-W14-13, has existed since at least the mid 1990s. Dilution by liquids disposed to the 216-T-26 through 216-T-28 cribs is probably not the cause of the low nitrate in the area because 1,000,000 kilograms of nitrate were in the waste stream sent to the 216-T-26 crib (DOE/RL 1991). The cause of the low nitrate in that area is not known.

Figure 4.23 shows a plume map for tritium at the end of the reporting period. Tritium was detected in one downgradient well (299-W14-13) above the drinking water standard of 20,000 pCi/L. Like nitrate, tritium most likely has several sources that include WMA TX-TY and several cribs and trenches in the area. Hodges (1998) used tritium/technetium-99 ratios to show that contamination in the area of well 299-W14-13 (in well 299-W14-12) was probably a mixture of regional contamination with tank waste.

The plume east of WMA TX-TY was moving toward the northeast prior to the most recent shift in flow direction in the late 1990s. The decline in contaminant concentration up until 1998 (see Figures 4.1 through 4.4) could be the result of a declining source term, vertical contaminant concentration gradients in a declining aquifer (Hodges 1998), or lateral shift in the plume away from well 299-W14-12.

The increasing technetium-99 concentrations since 1998 may be attributed to the latest change in groundwater flow direction. Comparison of older water-table maps shows that groundwater flow direction changed from northeast to southeast at the eastern part of WMA TX-TY in the 1997 to 1998 time frame. If the main portion of the plume was to the north of well 299-W14-12 prior to 1998, the change in flow direction would have caused the plume to drift south across the well. Alternatively, it is possible that a new contaminant plume migrating southeast from the 241-TY tank farm. Assuming a groundwater flow rate of 0.2 meter per day (see Section 3.3), a plume would take about 400 days to travel

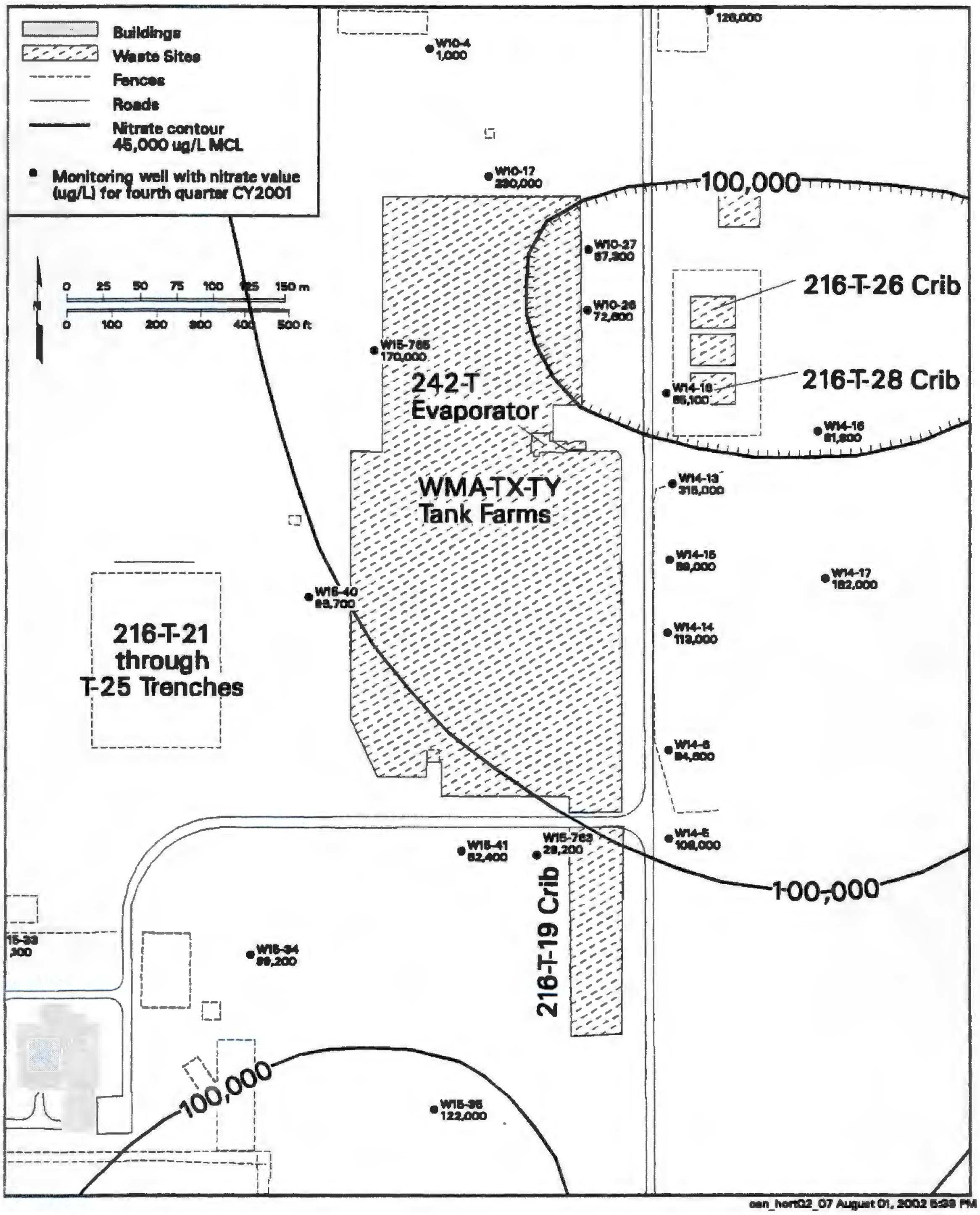

Figure 4.21. Nitrate Plume Map at Waste Management Area TX-TY for the Fourth Quarter of Calendar Year 2001

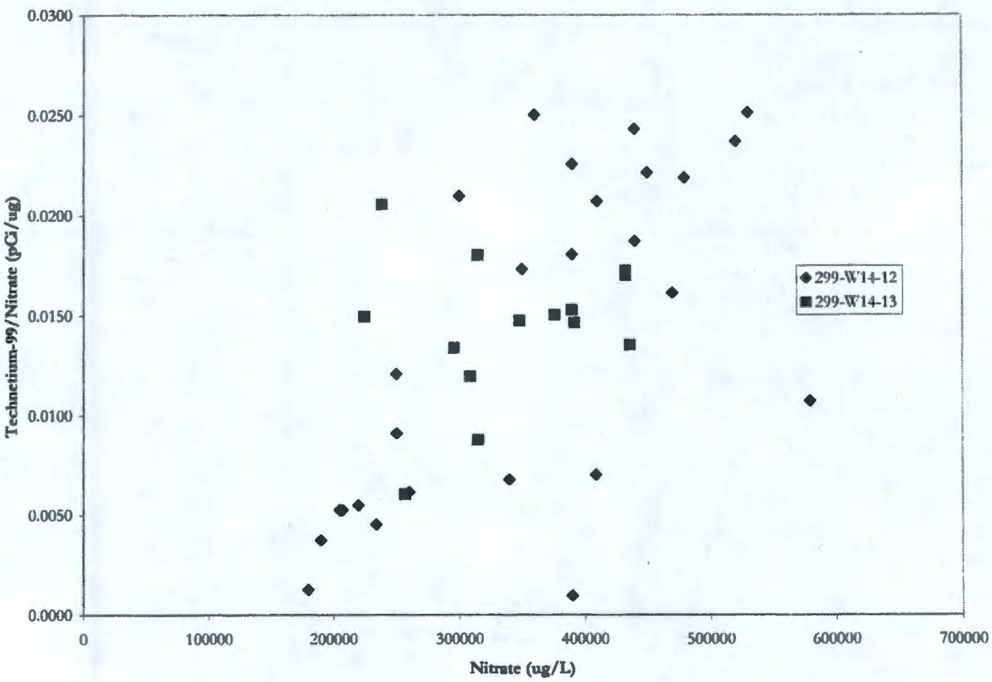

Figure 4.22. Nitrate Concentration Versus Technetium-99/Nitrate Concentration Ratio for Samples from Wells 299-W14-12 and 299-W14-13 at Waste Management Area TX-TY

the ~80 meters from the fence line at 241-TY tank farm to well 299-W14-13. However, high levels of technetium-99 have not been observed in wells 299-W10-26, 299-W10-18 (before it went dry), or 299-W14-18.

4.2.3 Southern Boundary of Waste Management Area TX-TY

The 200-ZP-1 pump-and-treat operation began in 1994 with one extraction well. The operation was expanded to three wells in 1996 and, finally, to six wells in August 1997. The first effects of the pump-and-treat operation on groundwater flow direction beneath WMA TX-TY shows on the June 1998 water-table map (Hartman 1999). Well 299-W15-22, located at the southwest corner of the WMA, and originally drilled as an upgradient well, was the closest to the 200-ZP-1 pump-and-treat extraction wells before it went dry in 1998. Technetium-99 began to increase in this well in May 1997, exceeded the maximum contaminant level in August 1997, and reached a high of 3,680 pCi/L in May 1998. The well was last sampled in August 1998.

Well 299-W15-4 is an older pre-RCRA well originally drilled to monitor the 216-T-19 crib at the southeast corner of the WMA. Prior to May 1998, the well was sampled on an annual basis; however, available data indicate that technetium-99 started to increase in this well in mid-1997 and reached a peak value of 980 pCi/L in July 1999. The last sampling in October 1999 yielded a 640 pCi/L technetium-99.

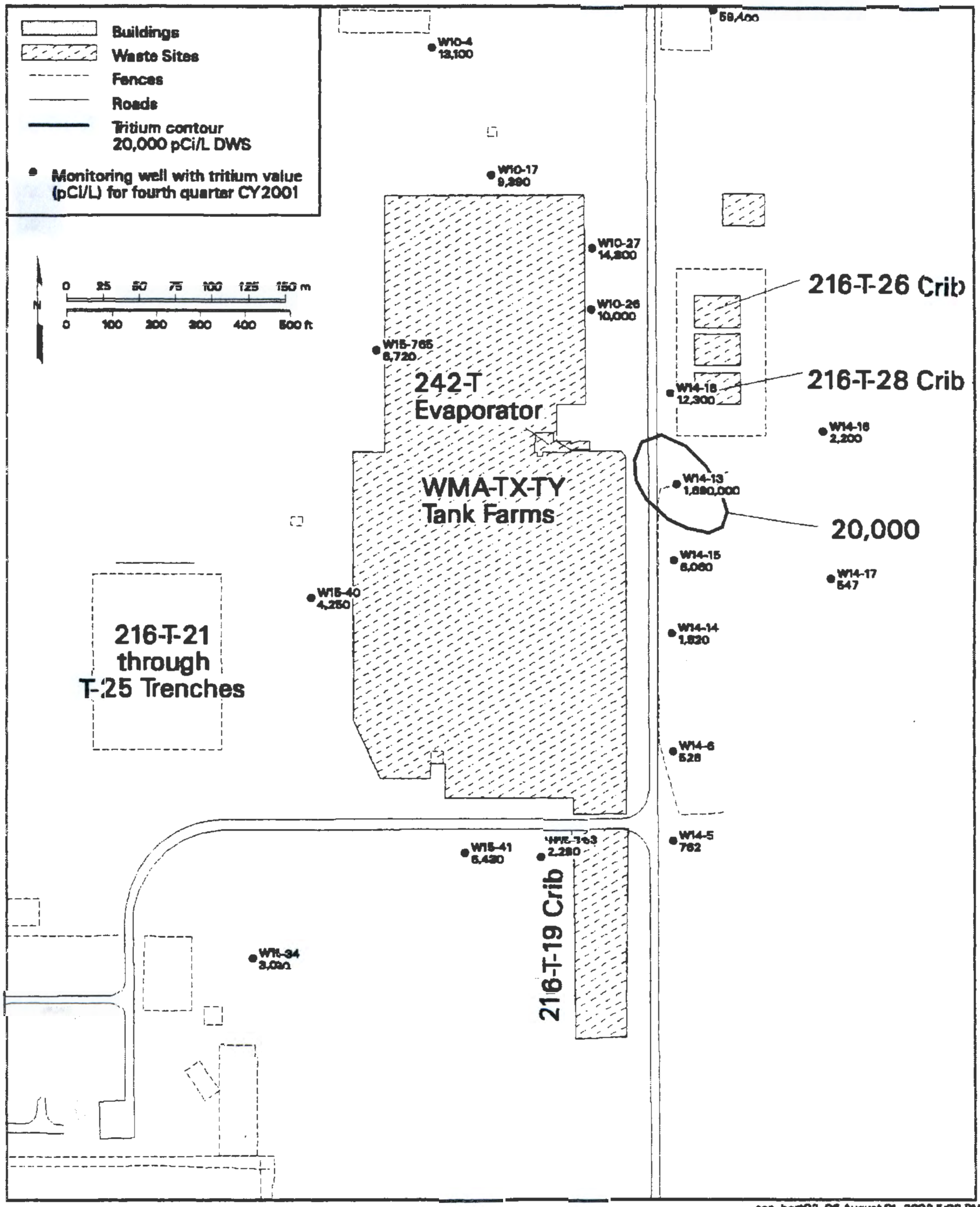

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Figure 4.23. Tritium Plume Map at Waste Management Area TX-TY for the Fourth Quarter of Calendar Year 2001

Chromium began to increase in well 299-W15-4 in 1999, but the peak concentration of chromium (20 μg/L) was below the maximum contaminant level in the last samples from the well.

Well 299-W15-763 was completed as a replacement well for 299-W15-4 in 2001. The first routine sample from this well, taken in May 2001, indicated a technetium-99 level of 57 pCi/L. The last sample taken during the reporting period contained 67 pCi/L. Technetium-99 concentrations in this well are anomalously low when compared to other wells in the area. The geologist's log noted cemented zones in the screened interval of this well. Thus, changes in lithology may account for the difference between technetium-99 concentrations in this and adjacent wells.

Well 299-W15-41 was completed in January 2000 and was first sampled in March 2000. The initial sampling yielded a technetium-99 concentration of 1,980 pCi/L. Subsequent analyses have ranged between 850 and 1,360 pCi/L. No significant concentrations of chromium have been found in samples from this well.

Technetium-99 in wells along the southern boundary of WMA TX-TY started to increase ~1 year after Phase II of the 200-ZP-1 pump-and-treat operation began south and southwest of the WMA. (Phase II, consisting of three extraction wells, began the use of the closest extraction wells to the WMA, 299-W15-34 and 299-W15-35.) Given the groundwater flow directions imposed on the southern portion of the WMA by the pump-and-treat operation, the most reasonable explanation for the increasing technetium-99 is that groundwater contaminated with technetium-99 is being drawn from beneath the WMA into the pump-and-treat system. Alternatively, technetium-99 may be originating from the 216-T-19 crib and tile field (DOE/RL 2001). Given the changing groundwater flow direction along the southern boundary of the WMA, the few available monitoring wells, and the lack in continuity of monitoring data due to dry wells and new wells, it is currently impossible to fully evaluate this problem.

If the plume south of WMA TX-TY is from tank waste, the lack of chromium associated with the plume suggests that the tank waste is low-chromium waste. If this is the case, the chromium found east of the WMA may be from a source other than WMA TX-TY. More detailed vertical sampling is planned for wells east of WMA TX-TY to better understand the chromium distribution in the area and more definitively determine its source.

5.0 Maximum Contaminant Concentrations

This section presents discussions on the maximum contaminant levels encountered at WMA TX-TY during the reporting period.

Table 5.1 shows the maximum concentrations detected for the primary constituents of concern identified for this assessments for each well included in the monitoring network for the period January 1, 1998, to December 31, 2001. Non-RCRA wells are included as well as the RCRA compliant wells in the network. Samples collected during drilling of new wells were not included in Table 5.1. Only filtered (0.45 µm) metal results were included in the summary. Results for anions, volatile organic compounds, and radionuclides are all based on unfiltered samples. The last column shows the highest maximum contaminant concentration (values in bold type) divided by the applicable maximum contaminant level or drinking water standard. The ratio is referred to as the relative hazard index for purposes of this report.

The highest relative hazard index at WMA TX-TY is a result of carbon tetrachloride. The high relative hazard index, a value of 560 (2,800 µg/L) for well 299-W15-40 at WMA TX-TY, is believed to be the result of disposal of carbon tetrachloride in cribs and trenches associated with the Plutonium Finishing Plant. Therefore, it is not associated with contamination from WMA TX-TY.

The second highest relative hazard index value is for tritium at WMA TX-TY with a value of 161 (3,200,000 pCi/L) from well 299-W14-2. This well also has a hazard index of 81 (81 pCi/L) for iodine-129. The combination of high tritium and high iodine-129, coupled with relatively low technetium-99, points to either the 216-T-28 crib (at which the well is located) or to an evaporator source (either the 242-T evaporator or to the 216-T-19 crib and tile field) for the tritium and iodine-129. This contaminant source apparently also has affected nearby well 299-W14-13 with maximum tritium levels of 2,940,000 pCi/L (relative hazard index = 147) and iodine-129 of 51 pCi/L (relative hazard index = 51).

The highest relative hazard index for chromium is 5.4 resulting from 542 µg/L in well 299-W14-13. The source of chromium is most likely the WMA.

The high relative hazard index for manganese (value 17.2) is from the first quarterly sample from well 299-W10-27 and is believed to result from well being recently drilled at the time of sampling. Samples from the well at that time were also high in iron and nickel.

The highest relative hazard index for nitrate at WMA TX-TY is 12.9, resulting from a concentration of 580,000 µg/L in well 299-W14-12. Its replacement, well 299-W14-13, has had a maximum nitrate concentration of 436,000 µg/L. The elevated nitrate at WMA TX-TY is part of a regional contaminant plume (see Figure 2.8-10 in Hartman et al. 2002), which in addition to nitrate contains elevated

Table 5.1. Maximum Contaminant Concentrations for Groundwater Samples Collected from Waste Management Area TX-TY Network Wells (January 1998 to December 2001)

Analyte	MCL	W10-17	W10-18	W10-26	W10-27	W14-2	W14-5	W14-6	W14-12	W14-13	W14-14	W14-15
Carbon tetrachloride (µg/L)	5	1,200	NA	NA	NA	75	NA	230	NA	110	280	
Chromium[(a)] (µg/L)	100	56	10	15	2	<	24	51	46	**542**	3	NA
^{99}Tc (pCi/L)	900	524	244	220	86	1,450	435	282	6,200	**7,450**	461	27
Gross alpha (pCi/L)	15	2.9	27.6	3.1	<	3.7	<	1.8	26.4	6.6	<	
Gross beta (pCi/L)	50	139	103	55.3	31.2	567	97.2	75.7	756	**2,110**	131	424
Tritium (pCi/L)	20,000	32,600	13,600	11,500	14,300	**3,210,000**	1,200	508	1,170,000	2,940,000	2,90	<
^{90}Sr (pCi/L)	8	NA	NA	<	<	NA	NA	NA	NA	<	NA	110
^{137}Cs (pCi/L)	200	<	<	<	<	<	<	<	<	<	<	19,100
^{60}Co (pCi/L)	200	<	<	<	<	<	<	<	**16**	<	<	NA
^{129}I (pCi/L)	1	<	<	<	NA	**81**	<	<	22	51	<	<
Nitrate (as NO_3) (µg/L)	45,000	264,000	85,400	88,100	67,300	85,400	215,000	109,000	**580,000**	436,000	251,000	<
Nitrite (µg/L)	3,300	<	<	148	197	**5,910**	384	<	164	<	<	<
Iron[(a)] (µg/L)	300	188	68	76	714	**1,050**	455	111	83	125	73	98,700
Manganese[(a)] (µg/L)	50	14.3	56	18	**862**	444	108	8	94	11	4	<
Fluoride (µg/L)	4,000	**2,400**	1,320	1,500	790	370	1,100	1,000	640	820	920	85
pH	[6.5, 8.5]	[7.9, 8.4]	[7.4, 8.3]	[7.8, 8.3]	[7.4, 7.7]	[7.4, 9.2]	[7.4, 8.2]	[7.9, 8.4]	[8.0, 8.3]	[7.4, 8.1]	[7.5, 8.0]	14

Table 5.1. (contd)

Analyte	W14-16	W14-17	W14-18	W15-4	W15-12	W15-22	W15-40	W15-41	W15-763	W15-765	Max[c]	Max/MCL
Carbon tetrachloride (μg/L)	NA	NA	NA	510	NA	NA	**2,800**	940	NA	NA	2,800	560
Chromium[a] (μg/L)	4	2	5	19	10	9	16	35	2	24	542	5.4
^{99}Tc (pCi/L)	286	576	189	982	963	3,680	185	1,980	67	107	7,450	8.3
Gross alpha (pCi/L)	<	<	3.2	<	<	**157**	2.6	2.5	<	<	157	10.5
Gross beta (pCi/L)	75.6	125	70.7	418	272	942	46.1	597	41.3	32.2	2,110	42.2
Tritium (pCi/L)	2200	819	12,300	25,600	33,700	20,100	5,900	12,100	2,290	6,720	3,210,000	161
^{90}Sr (pCi/L)	NA	NA	NA	NA	NA	NA	NA	<	NA	NA	<	-
^{137}Cs (pCi/L)	<	NA	NA	<	<	<	<	<	<	NA	<	-
^{60}Co (pCi/L)	<	<	NA	<	<	<	<	<	<	NA	16	0.1
^{129}I (pCi/L)	<	<	<	<	<	<	<	<	<	<	81	81
Nitrate (as NO_3) (μg/L)	90,300	182,000	65,100	132,000	173,000	190,000	150,000	74,800	124,000	170,000	580,000	12.9
Nitrite (μg/L)	<	<	<	<	<	<	280	<	112	<	5,910	1.8
Iron[a] (μg/L)	61	67	<	128	108	32	69	158	72	<	1,050	3.5
Manganese[a] (μg/L)	15	3	521	58	31	76	48	17	263	2	862	17.2
Fluoride (μg/L)	430	470	71	1,750	1,300	520	572	530	630	340	2,400	0.6
pH		[7.7, 7.8]	[7.7, 7.9]	7.84[b]	[7.6, 8.3]	[7.7, 8.4]	[6.6, 7.9]	[7.5, 8.2]	[7.9, 8.2]	[7.7, 7.8]	7.5[b]	[6.6, 9.2]

(a) Filtered sample results.
(b) Only one sample.
(c) Maximum across all network wells.
Note: All well numbers prefixed by 299-. < denotes analytical result is not detected. **Bold** indicates well with maximum. MCL = maximum contaminant level.

concentrations of carbon tetrachloride. The principal sources for these contaminants are probably waste disposal from the Plutonium Finishing Plant operations, but there may be contributions from past-practice disposal of evaporator condensate and tank waste.

The highest hazard index for technetium-99 at WMA TX-TY is 8.8, resulting from a concentration of 7,500 pCi/L in well 299-W14-13. The technetium-99 responsible for the highest relative hazard index is the contaminant most clearly linked to the WMA.

In general, metals (iron, manganese, chromium, nickel) tend to be higher just after a well has been drilled and just before it goes dry. The high metals detected shortly after well completion may be a result of fine particulates left in the well as a result of construction or it may be a result of temporary reducing conditions around the screened interval resulting from the exposure of fresh mineral surfaces by drilling activity. The higher concentration of metals detected as water levels in the well drop near the bottom of the screened interval most likely are a result of fine particulates in the mud at the bottom of the well that can pass through the 0.45 micron filters normally used during sampling for metals.

The relatively few samples with elevated gross alpha, 157 pCi/L in well 299-W15-22 and 28 pCi/L in well 299-W10-18, occurred for highly turbid unfiltered samples taken late in the life of the wells. In all likelihood, the high gross alpha levels represent contaminants sorbed on particulates in the well bottom and not dissolved in groundwater.

6.0 Conceptual Model

An updated conceptual model of processes controlling the extent of contaminant distribution and its rate of movement in groundwater in the vicinity of WMA TX-TY must include the following:

- Complex contaminant plume interactions and concentration-time patterns are due to disposal history and changing flow directions induced by both pump and treat operations and the long-term decline in the water table.
- Flow directions vary beneath WMA TX-TY from southeastward in the north to southward and southwestward in the south
- Vertical and horizontal variations in lithology result in variations in aquifer permeability, which can influence the distribution of contaminants.
- Past-practice disposal of large volumes of wastewater upgradient of the WMAs accounts for most of the deeply distributed contaminants (carbon tetrachloride, nitrate, tritium).
- Downward, vertical hydraulic gradients exist on the east side of WMA TX-TY, which may influence the distribution of contaminants.
- The 200-ZP-1 pump-and-treat operation, south of the WMA, has altered groundwater flow and the distribution of contamination.

Additional details concerning these processes and proposed explanations for observed contaminant distribution patterns are discussed in the following sections.

6.1 Aquifer Properties

The permeability of the upper portion of the aquifer at WMA TX-TY is variable. This variability is attributed to changes in lithology, including silt content and cementation, within the aquifer sediment. These lithology changes and the resulting permeability changes are laterally variable. In some wells, such as 299-W10-27, the entire screened interval appears to be in a low permeability formation. In other wells, such as adjacent well 299-W10-26, the screened interval is in a relatively permeable zone. In still other wells, such as well 299-W15-763, permeability seems to change within the screened interval. Changes in permeability may effect both contaminant distribution and the composition of water sampled from wells (i.e., different amounts of water from permeable and non-permeable zones).

6.2 Contaminants at Waste Management Area TX-TY

Contaminants related to tank waste have been detected in two distinct areas of WMA TX-TY. The first is located in the vicinity of well 299-W14-13 along the eastern margin of the WMA. Tank waste has been present at this location since the inception of RCRA groundwater monitoring in 1992. The second occurrence began with an increase in technetium-99 at the southwest corner of the WMA in well 299-W15-22 in late 1997 and continues in well 299-W15-41. Tank waste in this location is the result of groundwater flowing from the WMA to the extraction wells at the 200-ZP-1 pump-and-treat operation.

Two sources are postulated for the contamination found east of WMA TX-TY. The first is responsible for the tank waste plume detected in wells 299-W14-12 and 299-W14-13. This contamination is characterized by high technetium-99 and chromium concentrations. Contamination from the second source is a high tritium, high iodine-129, and low technetium-99 plume observed in well 299-W14-2.

Elevated levels of chromium, technetium-99, tritium, nitrate, iodine-129, and cobalt-60 were first detected in well 299-W14-12 in 1992, and the plume was apparently moving toward the northeast based on groundwater flow conditions at the time. Contaminant concentrations decreased until 1997, either as a result of a decreasing source term and/or because of a shift in the plume away from well 299-W14-12. In 1998, contaminant concentrations began to increase in well 299-W14-12 and continued to increase in replacement well 299-W14-13.

Analysis of June 1998 samples from well 299-W14-2, located ~70 meters northeast of well 299-W14-13, showed a tritium concentration of 3,210,000 pCi/L, an iodine-129 concentration of 81 pCi/L, and a technetium-99 concentration of 334 pCi/L. Iodine-129 concentrations indicate that the increase started between 1996 and 1998. The most likely source for the high-tritium, high-iodine-129, low-technetium-99 groundwater is either the 216-T-28 crib, the 216-T-19 tile field, or the 242-T evaporator. Subsequently, tritium peaked in well 299-W14-13 in March 2000 at 2,940,000 pCi/L with an iodine-129 concentration of 47 pCi/L.

After the change in groundwater flow direction in 1997 to 1998, the existing plumes would have migrated laterally toward the east or southeast, resulting in the subsequent increase of contaminant concentrations in well 299-W14-13. Assuming a groundwater flow rate of 0.25 meters per day, contamination should have reached well 299-W14-17, located ~125 meters downgradient of well 299-W14-13, ~21 months after the latest shift in flow direction. At the end of 2001, contamination levels were low in well 299-W14-17 with technetium-99 at 477 pCi/L, nitrate at 182,000 µg/L, tritium at 550 pCi/L, and no iodine-129. Although technetium-99 in this well is greater than regional background, it has been decreasing throughout the reporting period so it is uncertain whether contamination from the plume seen at well 299-W14-13 is encountered in well 299-W14-17. If so, the main portion of the plume remains upgradient or is diverted from the well.

Chromium is a mobile constituent found in tank waste and its concentration trend should follow that of technetium-99 and other mobile tank constituents. Elevated chromium has only been found in the well pair 299-W14-12 and 299-W14-13. Comparison of chromium concentrations from these wells suggest an increase in chromium and a decrease in technetium-99 and nitrate with depth in the aquifer. This suggests the possibility that separate sources may be responsible for the observed chromium and technetium-99.

Technetium-99 concentrations began to increase in wells 299-W15-4 and 299-W15-22, located along the southern margin of the WMA in late 1997, coincident with the beginning of 200-ZP-1 pump-and-treat extraction in the area. Both wells are currently dry; however, elevated technetium-99 continues in new well 299-W15-41. The south to southwest groundwater flow direction imposed along the southern margin of the WMA by the pump-and-treat operation, and the timing of the increase in technetium-99 concentrations, indicate that under the new flow patterns, technetium-99 is moving from a source area within the WMA toward the pump-and-treat system. It is uncertain whether or not this source is related to the contaminant source that produced the contamination at wells 299-W14-12 and 299-W14-13. The measured groundwater flow velocity in well 299-W15-41 is the highest at WMA TX-TY and may be a result of higher hydraulic gradients closer to the pump-and-treat operations. In addition, given the proximity of the pump-and-treat operations to the southern margin of the WMA, there is a potential for contaminants in this area to be drawn deeper into the aquifer.

Vadose zone characterization and monitoring, at the 241-TX and TY tank farms with wireline geophysical methods, have shown the distribution of near surface contamination, which is probably the result of spills associated with tank farm operations, and deeper contamination, resulted from tank leaks (GJO-97-30-TAR; GJO-97-13-TAR). Monitoring also has indicated that contaminants continue to move in the vadose zone at some locations. Also, drilling results at WMA S-SX and various modeling studies (Johnson and Chou 2001; Knepp 2001) indicate that major vadose plumes within the tank farms may contribute to groundwater contamination for decades. Thus, it is likely that any vadose zone sources in WMA TX-TY that are responsible for the contamination detected east and south of the WMA are still active.

7.0 Conclusions

Additional characterization and monitoring activities were conducted to evaluate the rate, extent, and concentration of contaminants in groundwater beneath WMA TX-TY. Installation of additional groundwater monitoring wells, hydrologic testing, and sampling and analysis (both vertically and spatially) also provided new information, which resulted in the following conclusions.

7.1 Rate and Extent of Contaminant Migration

Observations made during the drilling of wells at WMA TX-TY, suggest variability in lithologic properties within the screened intervals of both individual wells and among wells. The lithologic changes are reflected in variabilities in hydraulic properties. Hydrologic testing was conducted on newly installed wells. Associated hydraulic conductivities from both drawdown and slug tests, and effective porosities from selected tracer tests (borehole dilution tests), were determined for this assessment. Resulting hydraulic conductivity values vary significantly across the WMA, with the highest values occurring at the south end of WMA TX-TY near the 200-ZP-1 pump-and-treat operations.

The groundwater flow rate was found to be on the order of 0.012 to 0.026 meters per day except in the southern part of the WMA, which is affected by the 200-ZP-1 pump-and-treat operation. There, groundwater flow rate was found to be 0.29 meter per day.

Chromium is a mobile tank constituent found in groundwater at WMA TX-TY and is attributed to the WMA. However, the relatively deep occurrence of chromium in the aquifer and its apparent fractionation from technetium-99, found at the top of the aquifer, allow the possibility that chromium is from a non-WMA source.

Deep drilling at well 299-W14-14 indicates the presence of carbon tetrachloride, nitrate, tritium, and technetium-99 throughout the thickness of the unconfined aquifer, and below the lower mud unit of the Ringold Formation. Maximum concentrations for carbon tetrachloride, nitrate, and tritium occur relatively deep in the aquifer. These contaminants are a result of past-practice disposal adjacent to tank farms and the Plutonium Finishing Plant. Technetium-99, and some of the associated nitrate, along the east side of the WMA at well 299-W14-13 are possibly from the WMA.

Sampling during drilling and comparisons between adjacent wells indicates considerable chemical variability within the upper portion (upper 10 to 12 meters) of the aquifer at WMA TX-TY. The variability is a result of multiple contaminant sources and possibly vertical hydraulic gradients and variable hydraulic conductivity within screened intervals.

The contamination east of WMA TX-TY is manifested in at least two plumes. One plume, characterized by high technetium-99, is very likely a tank farm contaminant plume. The other plume, characterized by high iodine-129, high tritium, and low technetium-99, is likely related to liquid waste disposal at local cribs or to the 242-T evaporator. A third contaminant source may be responsible for the high chromium, low technetium-99 groundwater found deeper in the aquifer at well 299-W14-13.

The technetium-99 detected at the southern end of WMA TX-TY is significant because of its proximity to the 200-ZP-1 pump-and-treat operations. Well 299-W15-22, before going dry, was the first well south of the WMA to have elevated technetium-99. Well 299-W15-41, the well with the highest measured hydraulic conductivity and flow velocities, has exceeded the drinking water standard for technetium-99 since the initiation of sampling.

7.2 Concentration of Contaminants

The maximum concentration of chromium found at WMA TX-TY during the reporting period was 542 µg/L in well 299-W14-13. The maximum concentrations of technetium-99, tritium, and iodine-129 were 7,450 pC/L, 3,210,000 pCi/L, and 81 pCi/L respectively. The highest technetium-99 was in well 299-W14-13 whereas the highest tritium and iodine-129 were in well 299-W14-2. The highest nitrate concentration was 580,000 µg/L and was in well 299-W14-12.

7.3 Well Network

Lateral downgradient coverage is adequate along the northern and central portions of the eastern boundary of WMA TX-TY. However, along the southeastern and southern boundaries, there is a need for additional wells. One new well is planned for the southwestern corner of the WMA to serve as a down-gradient well in response to a southerly flow direction imposed by the 200-ZP-1 pump-and-treat operation. Another new well is planned at the southern part of the eastern boundary of the WMA, south of well 299-W14-14, where no WAC-compliant wells exist. These wells are scheduled for installation in fiscal year 2003.

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