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Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site

S. M. Narbutovskih

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Pacific Northwest National Laboratory
Richland, Washington 99352

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Summary

Pacific Northwest National Laboratory conducted a Phase I (or "first determination") groundwater quality assessment for the U.S. Department of Energy, Richland Operations Office, in accordance with the Federal Facility Compliance Agreement. The purpose of the assessment was to determine if the Single-Shell Tank Waste Management Area (WMA) B-BX-BY has impacted groundwater quality. This report will document the evidence demonstrating that the WMA has impacted groundwater quality.

The WMA is located in the northwest corner of the 200 East Area and consists of the 241-B, 241-BX, and 241-BY Tank Farms and ancillary waste systems. The unit is regulated under RCRA interim-status regulations (40 CFR 265, Subpart F) and was originally placed in assessment groundwater monitoring (40 CFR 265.93 [d]) in June 1996 when elevated conductivity in downgradient monitoring well 299-E33-32 was confirmed by verification sampling. A rise in conductivity was initially observed in this well in February 1996. A first determination, allowed under 40 CFR 265, provides the owner-operator with an opportunity to demonstrate that the regulated unit is not the source of groundwater contamination.

During the Phase I investigation, elevated conductivity was also observed in the February 1997 sample for downgradient well 299-E33-41. Increases in nitrate, chloride, sulfate and sodium are the cause of the elevated conductivity. The concentration of technetium-99, a non-RCRA co-contaminant, also rose above the drinking water standard of 900 pCi/L for the February 1997 sample. In August 1997, technetium-99 in this well reached a maximum of 12,000 pCi/L. Furthermore, increases in nitrate and technetium-99 were found in 1997 samples for three other downgradient wells. In these wells, technetium-99 has not exceeded the 900 pCi/L drinking water standard.

Remobilized single-shell tank waste, either from past tank-related spills or leaks in the 241-BX Tank Farm, was identified as the likely source of the highest groundwater contaminant concentrations observed. Comparisons of groundwater chemistry between well 299-E33-41 and wells located close to nearby past-practice liquid effluent discharge facilities (cribs) demonstrate that the contamination at this well is uniquely different from crib contamination. The trend plot characteristics of high amplitude, high frequency events, the well's proximity to a known tank-leak vadose plume along with documentation of local driving forces supports this conclusion.

The contamination observed at well 299-E33-41 has only recently entered the groundwater as evidenced by the sudden sharp rise in anion and technetium-99 concentrations. The overall effects on the groundwater quality of this contamination are likely to be small when compared to the large regional contaminant plumes that have preceded this isolated event.

Rising trends of technetium-99 and nitrate seen in other downgradient wells, including well 299-E33-32, may be related to WMA B-BX-BY. The situation, however, is still dynamic. Consequently source determination is not yet possible.

A more detailed investigation of the source(s), nature and extent of groundwater contamination attributable to WMA B-BX-BY will be conducted in a Phase II assessment.

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1.0 Introduction

The single-shell tanks (SST) at the U. S. Department of Energy (DOE) Hanford Site have been designated as dangerous waste management units as described by the Resource Conservation and Recovery Act (RCRA) of 1976 and have been incorporated by reference into the State of Washington Dangerous Waste Regulations (Figure 1.1). As such, these facilities are subject to interim-status regulations, Title 40, Code of Federal Regulations Part 265, Subpart F (40 CFR 265.92).

This document contains the first determination (Phase I) results of a groundwater quality assessment as required by 40 CRF 265.93(d)(5). This assessment was conducted from June 1996 to August 1997 by the Pacific Northwest National Laboratory (PNNL). Waste Management Area (WMA) B-BX-BY is located in the northwest section of the 200 East Area and consists of 40 underground storage tanks in three separate farms; 241-B Tank Farm, 241-BX Tank Farm and 241-BY Tank Farm (Figure 1.2). In addition to the tanks, the regulated unit includes ancillary catch tanks, diversion boxes, vaults and the various waste transfer pipelines that support the SST system.

1.1 Statement of the Problem

The SSTs at the DOE Hanford Site are part of a RCRA treatment, storage and disposal (TSD) unit used to store high-level, radioactive nuclear and chemical wastes. Of the total 149 SSTs at the DOE Hanford Site, 67 are known or assumed to be leaking. These SSTs are referred to as "leakers" (Hanlon 1997). Twenty of these "leakers" are located in WMA B-BX-BY (Figure 1.2).

In 1991, a system of RCRA compliant wells was installed around the WMA B-BX-BY to monitor the quality of the groundwater. In February 1996, and confirmed in June 1996 by verification sampling, the indicator parameter, conductivity (specific conductance), was found to be elevated above the upgradient/downgradient statistical critical mean (365.7 umhos/cm) in downgradient well 299-E33-32 (Figure 1.3). This WMA was placed in a groundwater quality assessment program as required because of this elevated conductivity. In August 1996 the level dropped to 334 umhos/cm. At this time a false positive claim was considered. This would have allowed the site to return to detection-level monitoring.

In February 1997, however, elevated conductivity was observed in the groundwater sample for downgradient well 299-E33-41. Since that time, the conductivity has been above the critical mean in well 299-E33-31 and again, in well 299-E33-32. Meanwhile, no appreciable changes have been observed in the upgradient well 299-E33-33 (Figure 1.3).

Along with the conductivity increases, technetium-99, a non-RCRA co-contaminant, was observed above the 900 pCi/L Drinking Water Standard (DWS) for well 299-E33-41 (Figure 1.4). Technetium-99 values rose from 506 pCi/L to 5740 pCi/L from November 1996 to February 1997. For the next quarterly sampling, the value dropped to 523 pCi/L only to rise again in August 1997 to 12,000 pCi/L.

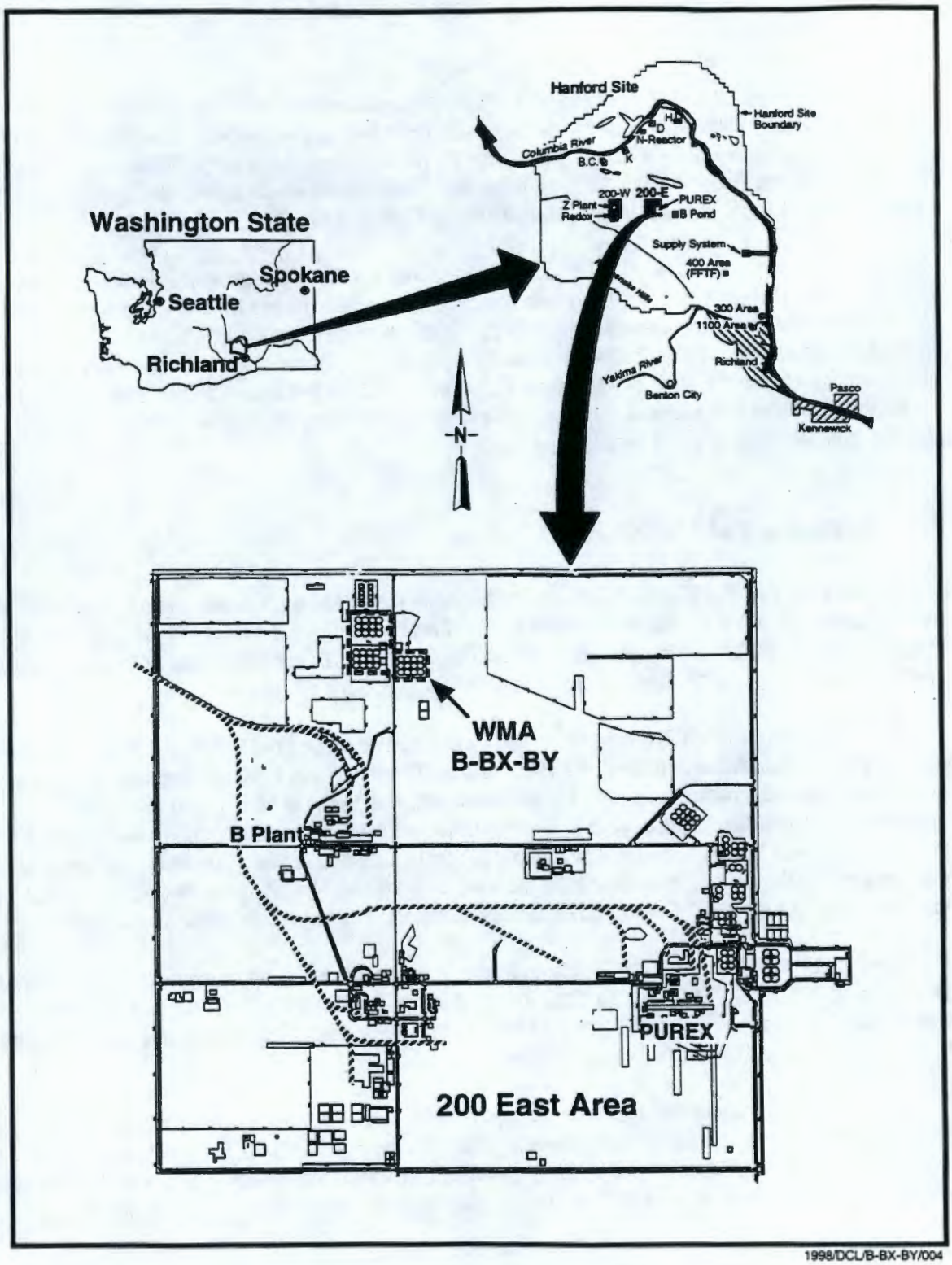

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Figure 1.1. Location Map of WMA B-BX-BY at the DOE Hanford Site in Eastern Washington State.

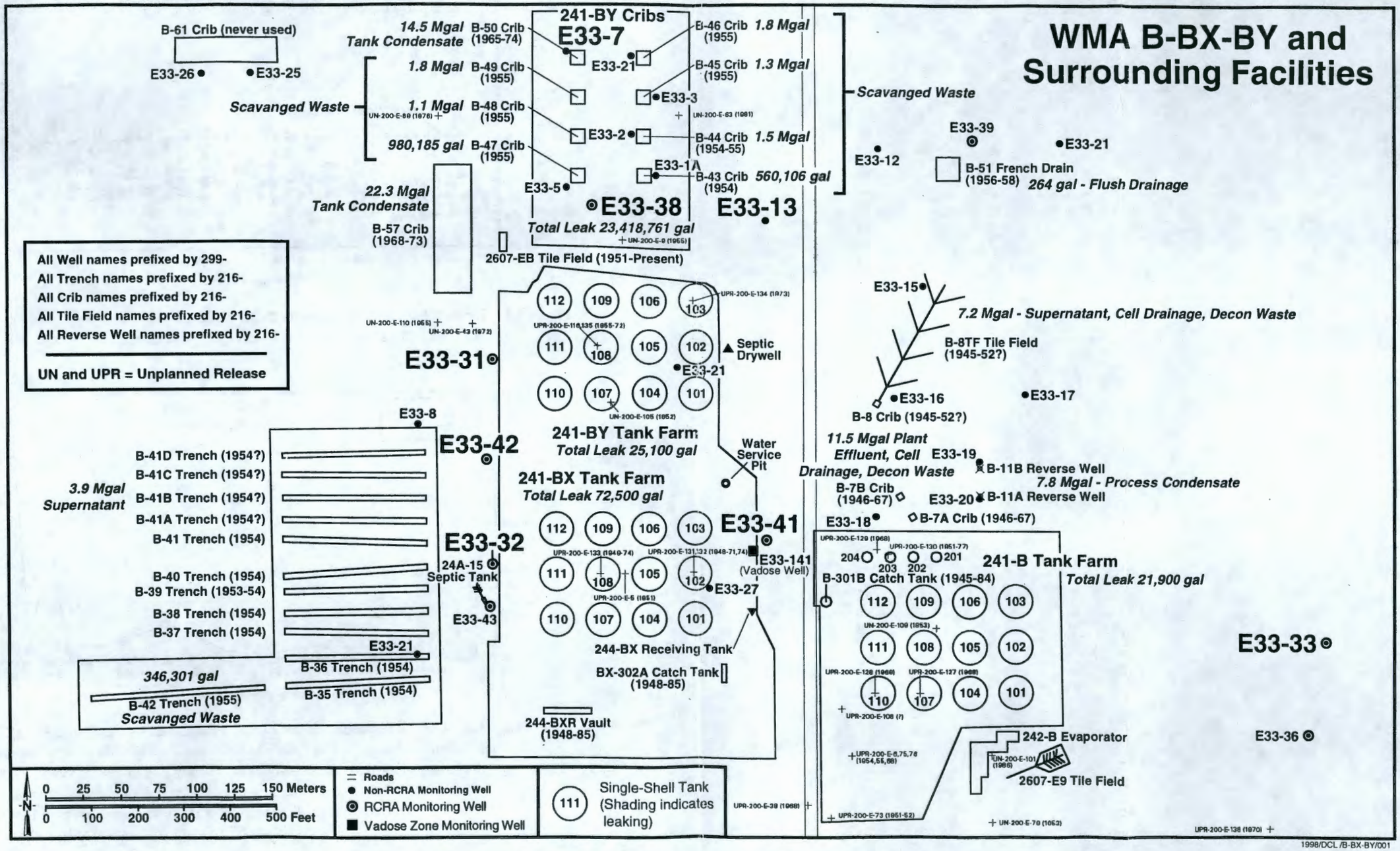

Figure 1.2. Location Map of Waste Management Area B-BX-BY in the 200 East Area.

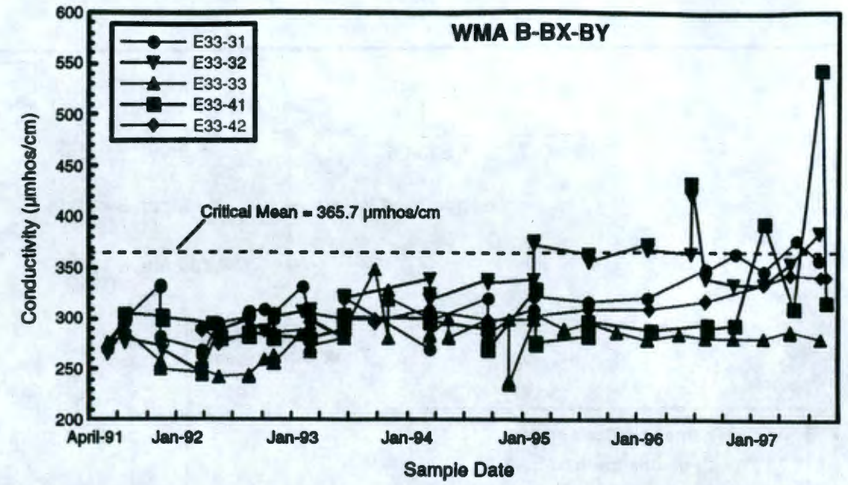

Figure 1.3. Trend Plot of Conductivity for the RCRA Groundwater Monitoring Network at WMA B-BX-BY. The statistical critical mean is 365.7 umhos/cm.

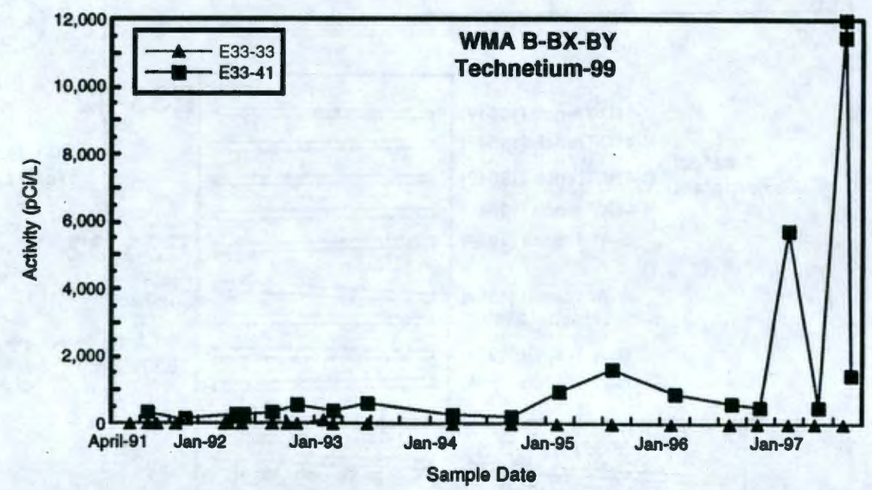

Figure 1.4. Trend Plots of Technetium-99 for RCRA Wells 299-E33-41 and 299-E33-33. Technetium-99 rose from 506 pCi/L in November 1996 to 5740 pCi/L in February 1997 dropping to 523 pCi/L in May 1997. In early August 1997 it rose to 12,000 pCi/L. This is the only well in the area that displays this high amplitude, high frequency character. In upgradient well 299-E33-33, values are less than 10 pCi/L.

It was also found that technetium-99 is rising in downgradient wells on the northwest side of the WMA. This rise began sometime during the last half of 1996 (Figure 1.5). Samples from well 299-E33-42 reflect the largest activity at 751 pCi/L.

Although it was elevated conductivity in well 299-E33-32 that initially triggered the site into interim assessment, it is the presence of elevated conductivity at well 299-E33-41 and the associated technetium-99 activity that has kept the WMA under investigation.

1.2 Project Objectives

If it can be determined, based on the results of the Phase I investigation, that no hazardous wastes from the WMA have entered the groundwater, the indicator evaluation program may be reinstated. If, however, it is determined that dangerous waste constituents from the facility have entered the groundwater, then an investigation (i.e., Phase II) must be implemented to define the rate of migration, the areal extent of the resultant groundwater plume, and the concentration of the hazardous constituents.

An assessment plan for WMA B-BX-BY was submitted to the Washington State Department of Ecology in October 1996 (Caggiano 1996). According to 40 CFR 265.93 (d), a short-term sampling program was conducted to substantiate a false positive claim. Thus, the project objective was to determine if changes in groundwater quality are attributable to the regulated unit. That is, to address the question "Is waste from the regulated unit reaching groundwater?"

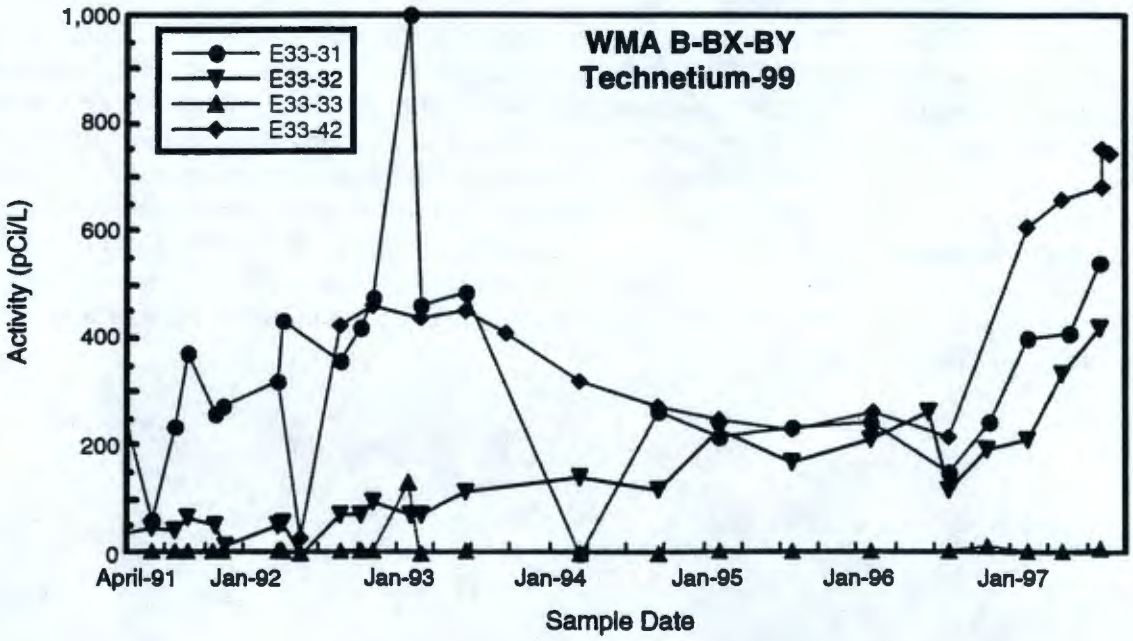

Figure 1.5. Trend Plots of Technetium-99 for RCRA Wells 299-E33-31, 299-E33-32, 299-E33-33, and 299-E33-42. In upgradient well 299-E33-33, values are less than 10 pCi/L.

1.3 Scope of Investigation

This study covers a Phase I investigation as described above. Results are presented for pertinent historic data and for new data collected during the assessment. The emphasis is on elevated, hazardous chemical contaminants and technetium-99 that are site-specific constituents of concern, found in well 299-E33-41. Technetium-99 is a non-RCRA co-contaminant. The elevated conductivity reported in well 299-E33-32 in 1996, which caused the WMA to go into assessment, continues to be under investigation. As seen in Figure 1.3, conductivity in this well continues to fluctuate above the critical mean, requiring continued monitoring. The cutoff date for data to be included in this report is August 1997. Data received in support of this assessment after this date will be analyzed during the Phase II investigation except for pertinent information on cyanide concentrations from the November 1997 sampling event.

Information on tank farm history and waste chemistry is presented as needed to support data analysis and resulting conclusions. A summary of site-specific stratigraphy and hydrogeology are presented to provide a geologic framework for discussion. Further details of tank farm history, waste chemistry, geologic descriptions and the groundwater monitoring network can be found in the assessment plan and other supporting documents (Agnew 1997; Anderson 1990; Caggiano 1996; Caggiano 1992; Caggiano and Goodwin 1991; Lindsey et al. 1992).

1.4 Report Plan

Central to any assessment study is a conceptual model that postulates contaminant sources along with possible migration pathways to the groundwater and local driving forces. The model used in this investigation is given in Chapter 2. The observed data are presented in Chapter 3. Along with examples of the recent contaminant history in the RCRA wells, data from non-RCRA wells is given to further delineate the degree and extent of contamination. Groundwater flow velocities are given in Chapter 3 along with a brief discussion on site stratigraphy. This chapter also contains a short section on recent tank farm occurrence reports and operational history. In Chapter 4, the results are analyzed with respect to the conceptual model. Several scenarios of possible sources, driving forces and migration pathways are presented. Each is discussed with respect to the observed data. Conclusions are reported in Chapter 5 and are based on the analyses given in the preceding chapter. Chapter 6 suggests a plan for the Phase II assessment. It focuses on areas that are key to meeting the required objectives but, as yet, are uncertain. The final chapter, Chapter 7, contains the references.

2.0 Conceptual Model

An assessment of groundwater quality necessarily involves the development of a conceptual model integrating the characteristics of the hydrogeologic system and the waste management unit setting. This model should include the general waste types, the geology, the hydrogeology, and the geochemistry of the vadose zone and the unconfined aquifer. Hence, if a regulated unit is a source of groundwater contamination, the movement of contaminants into and through the vadose zone and the unconfined aquifer could be better understood and possibly predicted. Specifically, the purpose of the conceptual model is to explore the complexity and spatial relationships of three important parameters: the contamination source, the driving force and the migration pathway.

2.1 Potential Sources of Groundwater Contamination

The conceptual model for WMA B-BX-BY is illustrated in Figure 2.1. Various possible contamination sources are shown. The purple represents liquid tank waste at the time of the initial leak. The color shading from yellow to green depicts contaminant migration since the initial leak to its present location. Note that contamination exists around some groundwater monitoring wells outside the farm boundaries.

Gamma logging profiles near tank 241-BX-102 (Womack and Larkin 1971) suggest that most of the cesium-137 and some cobalt-60 remain in the upper part of the soil column. This is confirmed by a 1997 DOE report (DOE/GJ-Han-89 1997), which also showed that uranium was left behind in the soil column. Migration of the contamination by infiltrating surface water, however, could transport some of the mobile fraction of tank waste to groundwater, as illustrated in yellow to green in the central portion of the diagram. As shown near the holding tank, surface water leaks or spills that encounter residual vadose zone waste may cause this waste to move rapidly down in near vertical migration pathways, spreading the contamination to new regions. Alternatively, waste may have traveled by bulk transport through the vadose zone sediments, leaving a primarily vertical plume in the vadose zone. Waste liquid and mobile constituents from this scenario would tend to have some lateral movement by capillary forces or "wicking" into fine-grained sedimentary layers such as silt-rich zones. These layers are shown in green since they are contaminated. However, it is not expected that lateral migration is as important in the 200 East Area as it is in the 200 West Area.

2.1.1 Tank Farm Associated Sources

Tank Leaks

There are numerous sources of hazardous and radioactive contamination in the vicinity of the 241-B, 241-BX, and 241-BY Tank Farms. The most concentrated form is the waste currently stored in the SSTs. These tanks were used from the late 1940's through 1980 to store high-level waste streams from the chemical separation processing of spent fuel rods. Most of this waste was from the bismuth-phosphate process at B Plant, although records indicate that some REDOX, tributyl phosphate, and hot semi-works waste was also stored at these farms (Anderson 1990). Heel remnants of metal waste solids were left in some tanks following sluicing to remove metal wastes for the uranium recovery campaign in 1954.

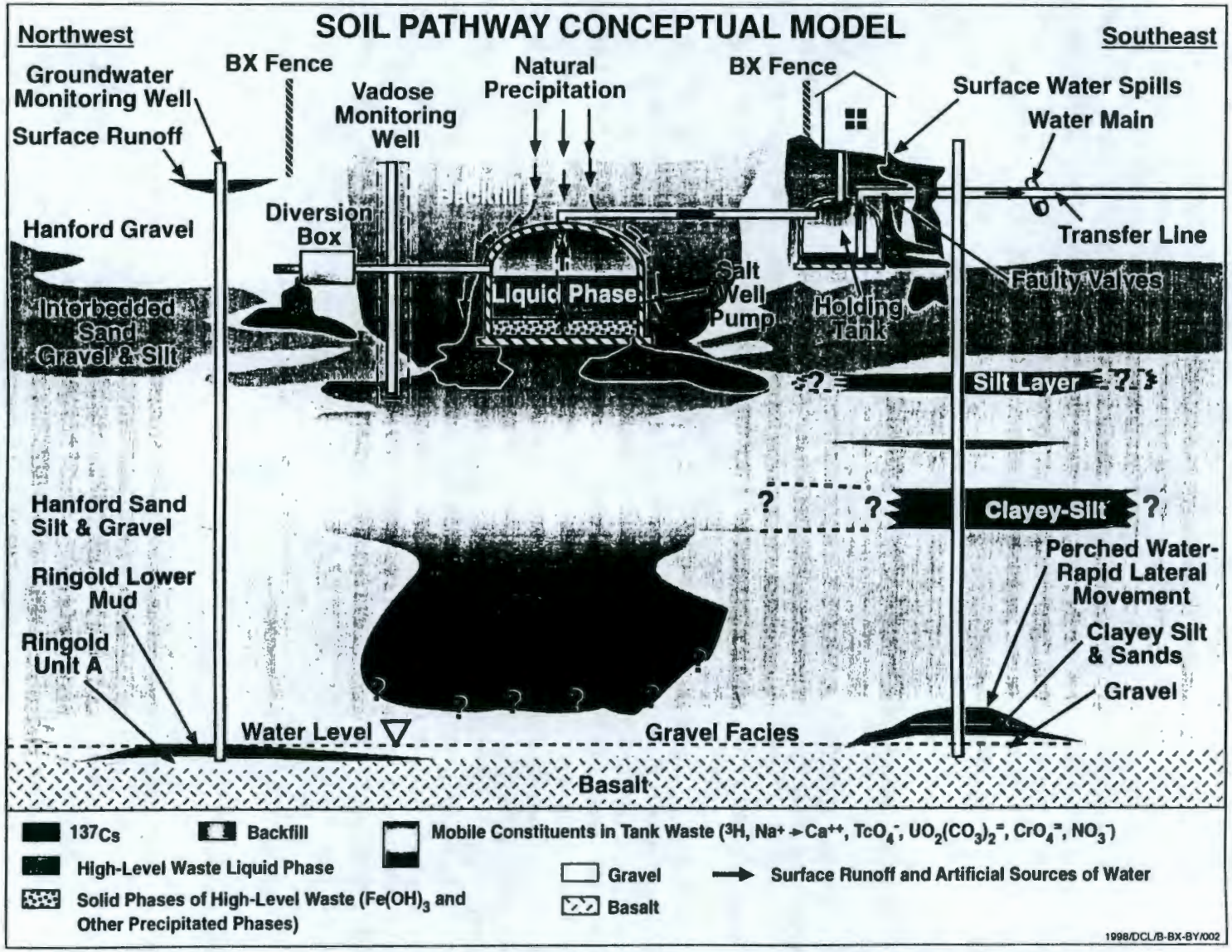

Figure 2.1. Soil Pathway Conceptual Model. This schematic depicts possible contamination sources in the vicinity of WMA B-BX-BY. Hypothetical pathways are illustrated that hazardous material could have taken from a source to a monitoring well. Driving forces are indicated that may have carried the waste constituents to the groundwater and thus, to a groundwater monitoring well.

After 1980, no further waste was added to these SSTs. Many of these tanks were decommissioned earlier because of known or suspected leakage. The waste was discharged to the tanks as alkaline slurries with a pH 9 or higher. Consequently the waste can be corrosive. Further information on the tank construction and history can be found in the assessment plan for WMA B-BX-BY (Caggiano 1996).

Of the 40 tanks located in the three farms, half are confirmed or assumed leakers (Hanlon 1997). A total leak volume of 119,500 gallons is reported for all the tanks with 70,000 gallons reported leaking from 241-BX-102 alone (Figure 1.2). This leak is the second largest known Hanford Site tank leak (Womack and Larkin 1971; Hanlon 1997). There are no leak volumes reported for nine tanks. Leak volumes address only tank leaks and not leaks from transfer lines or other ancillary equipment. Surface spills and overflow amounts are also excluded. Consequently, these reported leak volumes must be considered a minimum of the total liquid released within the tank farm boundaries.

Apparently, these tanks leaked from failed welding joints at the heel of the tank and from corrosion at the level of the waste residing in the tank. They were constructed to allow waste to cascade from one tank to the next when the first was full. The joints, where the cascade lines were attached to the tanks, were also known to leak. These types of leaks are illustrated in Figure 2.1.

Over time, various chemicals were added to the tanks to precipitate radioactive elements resulting in both solid and liquid factions. Much of the resulting supernatant was removed from the tanks and discharged to surrounding liquid effluent disposal facilities. Today the waste in the tanks exists as a stratified form of solid salt cake, sludge and liquid either as supernatants or interstitial liquids within the waste mass (Agnew 1997).

To reduce risk of further leaks from the tanks, an interim stabilization program has been instituted at the SST farms. The objective is to remove as much liquid from the tanks as possible. At the beginning of this groundwater quality assessment, all but four of the 40 tanks in WMA B-BX-BY had been placed on the interim stabilized lists. At that time, only tanks BY-103, BY-105, BY-106, and BY-109 remained to be pumped (Hanlon 1996). Tanks 241-BY-103, 241-BY-105, and 241-BY-106 are assumed leakers.

In July 1997, tank BY-109 was pumped and is on the stabilized list; however, during this time, tanks BX-103 and BX-101 were placed on the candidate intrusion list because of liquid increases in the tanks (Hanlon 1997). These increases are thought to be caused by water infiltrating from above the tanks, possibly due to precipitation or leaking water lines. It is possible that liquid intrusion has also recently occurred at BX-102. Also under the listings for interim stabilization status, it is noted that B-202 no longer meets the criteria for stabilization as a result of a steady increase in tank waste levels, indicating an ongoing intrusion. This was confirmed with in-tank videos (accomplished in March 1996).

Most tanks in WMA B-BX-BY contain only small amounts of liquids. However, past leaks, regardless of whether or not the material migrated to groundwater during the actual leaking event, have left residual contaminants in the unsaturated zone above the water table. These vadose zone plumes are potential sources of tank waste that could be remobilized and impact groundwater quality.

Recent data reported by DOE/GJ-HAN-89 (1997) describes a vadose zone plume mapped in the vicinity of tank BX-102. This plume extends to a depth of at least 150 feet (45.7 m). With the depth to groundwater at 254 feet (77.4 m), this leaves 104 feet (31.7 m) of vadose zone with little or no sampling.

This report concluded that the plume was residual contamination left from the 1970 leak at this tank. The main gamma-emitting contaminant identified was cesium-137. Furthermore, DOE/GJO-HAN-6 (1996) discusses the existence of gamma-emitting contaminants around all the tanks in the 241-BY Tank Farm that are known to have leaked.

Non-Tank Leaks

Surface spills of waste liquids have occurred in the SSTs at various times in the past. The existence concentrated gamma-emitting radionuclides close to the surface in 241-BY Tank Farm confirm the presence of shallow vadose zone plumes associated with spills (DOE/GJO-HAN-6 1996). Near-surface concentrations close to water pipe leaks could be another source of groundwater contamination.

An example important to this study is described in the DOE Management study of the B Plant Aggregate Area (1993). It is reported that contaminated soil between 241-BX-103 and 241-BX-102 was caused by a tank overflow. The statement is made that 30,000 to 90,000 gallons of waste were spilled to the ground between tanks 241-BX-102 and 241-BX-103 in 1951. Thus, contaminated soil from spills and overflows could be potential sources for contamination.

In addition to the spills and leaks from the tanks, waste was moved through transfer lines, diversion boxes, catch tanks, vaults, and receiving tanks. Leaks from some of these units have also likely contributed to vadose zone contamination. Given a sufficient driving force, any of these residual plumes could become a source for groundwater contamination.

2.1.2 Non-Tank Farm Related Sources

The 241 B-BX-BY Tank Farms were used during many processing campaigns over the years. Depending on which campaign was in progress, a series of liquid effluent disposal facilities were constructed around the farms (Figure 1.2). These cribs, tile fields and trenches were built to dispose of liquid waste to the soil column. The source of this liquid waste was primarily tank supernatants and scavenged waste from the uranium recovery campaign. Some facilities, however, received large amounts of tank condensate and some decontamination waste.

The volumes of this liquid effluent are large ranging, from 560,000 gallons to 22.3 million gallons (Figure 1.2). This practice of disposing tank-related wastes directly to the ground has resulted in extensive vadose zone and groundwater contamination surrounding the WMA B-BX-BY. These large vadose zone sources complicate the task of distinguishing tank farm sources from adjacent past-practice disposal facility sources. In this report, the term "tank waste" is used for waste that has mistakenly leaked from a tank or an associated unit. The terms "crib waste" or "trench waste" refers to waste purposely let to the soil column as a liquid discharge.

2.2 Source Constituents

At WMA B-BX-BY, large volumes of tank supernatants were discharged to the soil columns as opposed to WMA S-SX where only condensate was discharged to the soil column. Consequently at WMA B-BX-BY, differentiating tank waste from crib waste constituents in groundwater is complicated by the

chemical similarity of the two sources types. Consequently, constituents' chemical signatures must be evaluated with other considerations, such as trend characteristics.

Mobile constituents that are important to this conceptual model are technetium-99, nitrate, chloride, sulfate, uranium, cobalt-60, sodium, calcium, and chromate. Geophysical borehole logging results indicate that cesium-137 tends to remain in the upper part of the soil column (DOE/GJO-HAN-6 1996) because of its adsorption characteristics. Technetium-99 is a common fission product in all tank wastes. Nitrate comes from the nitric acid used in the dissolution of the spent fuel rods. Chloride is a co-contaminant with the sodium hydroxide used to neutralize the nitric acid. Uranium was in the metal waste heels left from past sluicing of the tanks during the uranium recovery campaign. Although chromate is expected as a result of the transfer of REDOX waste to B-BX-BY Tank Farms, it is not observed in the RCRA wells.

Normally, cobalt-60, as a divalent cationic "transition" metal, is not mobile and remains high in the soil column. Ferrocyanide, however, was added to the waste streams at the plant and to the tank wastes to precipitate strontium-90 and cesium-137 from the liquid waste. When cobalt-60 forms an anionic complex with cyanide, it can become mobile and has been found in groundwater downgradient from the WMA adjacent to a past-practice disposal site.

Calcium can be enriched in the groundwater because of an exchange reaction in the soil column between calcium and sodium as tank waste moved through the ground. For a more detailed discussion of this reaction, the reader is referred to Johnson and Chou (1998).

2.3 Driving Forces

In general, either the volume of leaked waste must be large enough to reach groundwater or an external source of water or other liquid must be available to pick up and remobilize a residual tank waste vadose zone plume. Most tanks in the WMA B-BX-BY, currently, do not contain large amounts of liquid waste. Thus, it is unlikely today that a tank could leak enough waste to reach groundwater unassisted. An exception could be a leaking waste transfer line during long-term waste removal operations; however, these lines are monitored for leaks. Therefore, driving forces for this conceptual model are primarily related to external water sources.

Sources of water in the vicinity of the tanks can be either artificial (man-made) or natural. Depending on whether the driving force is artificial or natural, there may be differences in the characteristics of the contaminant trend plots. Examples of man-made water sources include nearby leaking or ruptured water lines, leaking fire hydrants or broken valves. A complex system of water and waste transfer lines exist within the farms. Although some of the water lines to individual tanks have been closed, many are still pressurized. Another artificial water source may be related to the periodic flushing of waste transfer lines with water during routine maintenance.

Mobility of escaped waste can be increased as a result of natural recharge such as heavy rainfalls and sudden snowmelts. Johnson and Chou (1998) discuss the extent that rapid snowmelt from recent years has contributed to natural driving forces. The effect of these water sources can be enhanced by gravel surfaces, lack of plant uptake and transpiration, and surface depressions that tend to collect run-off (Figure 2.1).

2.4 Migration Pathways

The water table at WMA B-BX-BY is approximately 254 feet (77.4) below the surface. With such a deep aquifer, much of the migration pathway from the source to the groundwater monitoring well will be in the unsaturated or vadose zone. Liquid migration through this zone is not well understood, but is dependent, in part, on both lateral and vertical heterogeneities in permeability. Consequently, delineating migration pathways through a thick sequence of unconsolidated sediments is a challenging task.

In the 200 West Area, there are several stratigraphic units that allow for lateral spreading of liquids, in some cases for long distances. This lateral migration can allow contamination to impact the groundwater at some distance from the horizontal location of the source. In the 200 East area, however, unsaturated sediments are primarily coarse grained sands and sandy gravels with some thin, sandy silt units. Unlike 200 West Area, there are few horizons that would cause extensive lateral spreading at WMA B-BX-BY. An exception is the Ringold Lower Mud, which exists as discontinuous erosional remnants and, in places, extends above the water table (Narbutovskih et al. 1996). Extensive lateral, vadose zone migration has been attributed to this clay-rich unit where it is well developed at the 200 Area Treated Effluent Disposal Facility near B-Pond located approximately 2 miles to the east (Barnett et al. 1995). However, the lower mud, as erosional remnants, is thin and discontinuous under WMA B-BX-BY.

In several areas of the Hanford Site, clastic dikes exist that may provide vertical pathways for rapid liquid migration. At the 241-BY Farm and the 241-BX Farm, the presence of clastic dikes has been inferred (Narbutovskih et al. 1996). If clastic dikes do exist under the farms, these might allow rapid vertical movement of fluids through at least part of the vadose zone. Other migration pathways that would allow rapid vertical flow are the outer annulus of poorly sealed drywells within the farm boundaries. These wells are used for vadose zone monitoring with gamma ray logging tools and extend to depths of approximately 100 to 150 feet (30.4 to 45.7 m).

Studies of aqueous flow in sandboxes suggest that one common pattern of flow through unsaturated sediments is in relatively narrow, vertical fingers with some lateral spreading occurring at silty horizons. Once saturation is reached, vertical flow commences again. Furthermore, once these vertical pathways are established with an initial infiltration event, liquids from later infiltration events will prefer these established channels (Stephens 1996).

Evidence in support of this type of flow behavior in the 200 East Area comes from direct observation of infiltration tests performed at the 200E/105A Mock Tank Site (Narbutovskih et al. 1996). Electrical resistivity tomography was used to track leaking saline water from the surface to a depth of about 70 feet (21.3 m). Results indicate that this type of fingering might occur. Furthermore, analysis of the infiltration rate, the time to reach depth and the total volume of water leaked indicates that a point leak of 0.13 gallons per minute might reach groundwater in a few months (Hartman and Dresel 1997).

3.0 Observations

In this chapter, various observations are made that are pertinent to determining the source of contamination recently found in the groundwater at WMA B-BX-BY. For example, the stratigraphy is discussed to show that, for the most part, there are no major units that could cause extensive lateral migration of contaminants in the vadose zone as seen in the 200 West Area. Thus, the flow migration pathways for relatively small leaks should be primarily vertical.

The section on stratigraphy is followed by a brief discussion of the groundwater flow to illustrate the ambiguity in flow direction. With numerous surrounding potential contamination sources at this WMA, a comprehensive understanding of the flow direction is needed to properly interpret developing temporal and spatial patterns of groundwater contamination.

The regional groundwater contamination is briefly described to illustrate that the WMA is surrounded by contaminant plumes that existed prior to events observed recently at well 299-E33-41.

Those assessment groundwater monitoring results that are pertinent to source determination are presented in detail. Along with the results are observations of constituent patterns and co-varying trends, which assist in delineating the most likely source for the contamination found at well 299-E33-41.

Finally, information on several past Tank Farm occurrences is presented for two purposes. The first is to document that artificial water sources have occurred in the vicinity close to well 299-E33-41 just prior to the drilling in January 1991. These sources may have acted as a driving force to remobilize waste in old vadose zone plumes spreading the vadose contamination to well 299-E33-41 just prior to and during the drilling of this well. The second is to provide evidence that, in the recent past, water may have migrated through at least the upper vadose zone in the vicinity of the vadose zone plume and well 299-E33-41.

3.1 Stratigraphy

The 200 East Area consists of a sedimentary sequence that overlies the Columbia River Basalt Group on the north limb of the Cold Creek syncline. The basalt basement dips to the south increasing the thickness of the sedimentary package from north to south across the WMA. The sedimentary units consist of the Miocene to Pliocene Ringold Formation and the Pleistocene Hanford formation. In the 200 West Area, these two formations are separated locally by the Plio-Pleistocene unit. Close to the 200 East Area, they are separated by the pre-Missoula gravels. Under the 200 West Area, the Plio-Pleistocene consists of up to 40 feet (13 m) of massive, brown yellow, compact silt with minor fine-grained sand and clay (caliche). This unit is distinguished from fine-grained sediments in the overlying Hanford formation by carbonate cement content, massive structure in core, and high natural gamma response in gross gamma ray logs. Both of these unit are absent under WMA B-BX-BY (Figure 3.1).

Although the Ringold Formation can be up to 600 feet (185 m) thick at the Hanford Site, only the lowermost Unit A, a fluvial gravel and sand facies, and the lower mud unit, an overbank and lacustrine facies, are present under WMA B-BX-BY. In the 200 West Area, the lower mud unit can consist of a

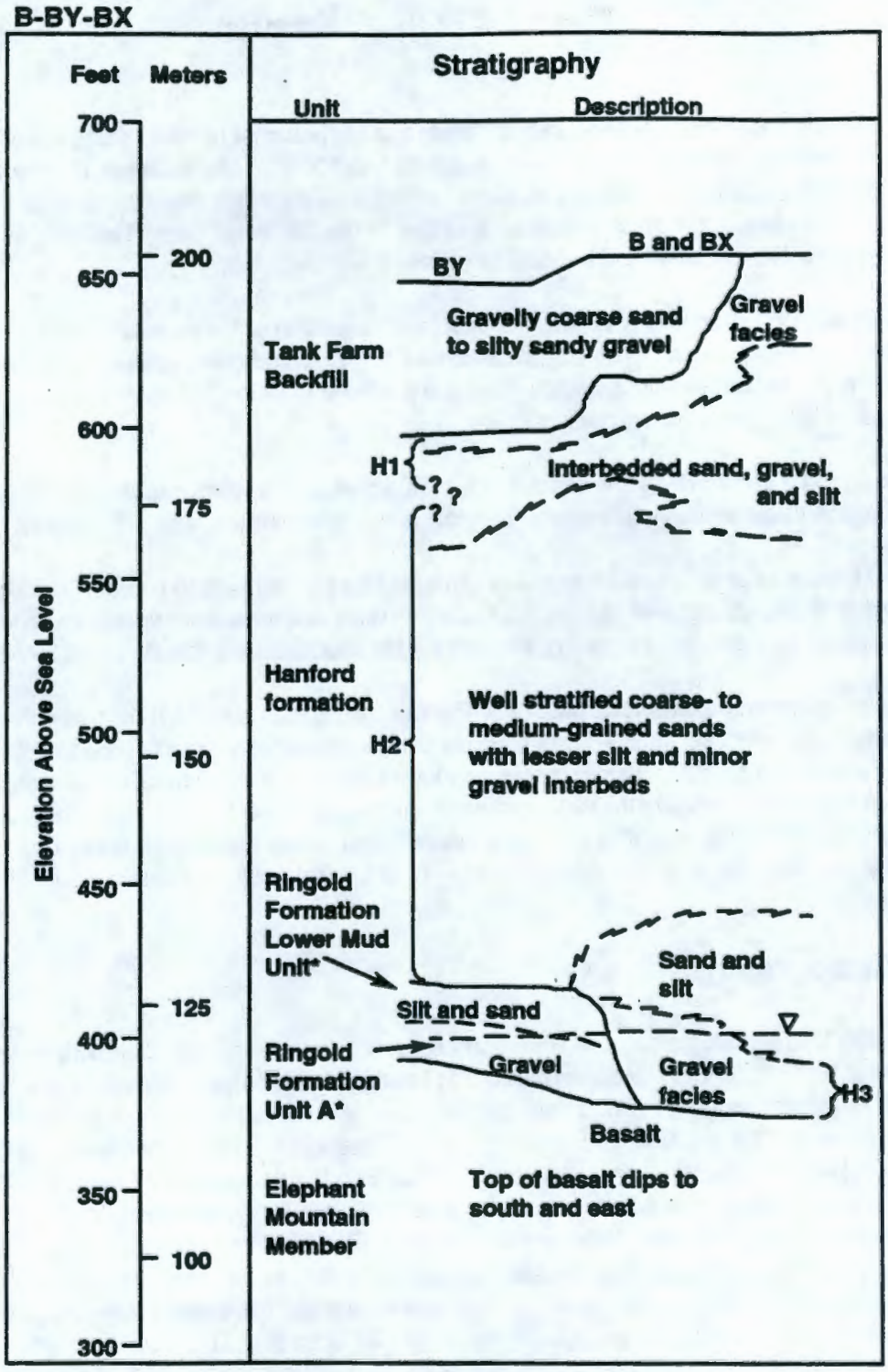

Figure 3.1. Stratigraphic Column of Sediments Beneath WMA B-BX-BY (after Narbutovskih et al. 1996)

semi-indurated, clay-rich overbank and lacustrine facies, which is laterally extensive across the area. However, under WMA B-BX-BY, this unit ranges from 10 to 15 feet (3 to 4.6 m) thick and is described as erosional remnants consisting of silts and sands (Narbutovskih et al. 1996).

The uppermost significant suprabasalt sedimentary unit at the 200 East Area is the Hanford formation deposited during the Pleistocene cataclysmic flood events. This formation is divided into three facies, silt dominated facies, H_1, the sand dominated facies, H_2, and the gravel dominated facies, H_3. Normally the silt dominated facies, referred to as the Touchet Beds, consists of interbedded silt and fine- to coarse-grained sands forming well stratified graded rythmites. The sand dominated facies consists of well stratified, laterally discontinuous planar beds of fine to coarse grained sand and granule gravels. The gravel dominated facies consists of cross stratified, coarse grained sand and granule to boulder gravels. These facies are gradational with each other.

Beneath WMA B-BX-BY, the H_1 unit consists of interbedded gravel facies and sand facies from 10 to 20 feet (3 to 6 m) thick (Figure 3.1). Lenticular downward thinning gravel beds dominate the H_1 unit. This facies is underlain by the sand-dominated unit H_2, consisting of 120 to 150 feet (37 to 46 m) of well stratified, coarse to fine grained sands containing laterally discontinuous silt facies interbeds. (Narbutovskih et al. 1996).

The basal Hanford unit H_3 consists of thin, laterally discontinuous intervals of gravels. The water table lies in unit H_3 in the northern part of the site. In the south, near 241-BX Tank Farm and 241-B Tank Farm, the water table lies in either the lower mud or unit A where present.

From the above descriptions, it can be seen that the sediments under WMA B-BX-BY are dominated by coarse sands and gravels. Units that could result in extensive lateral migration of fluids traveling through the vadose zone are lacking. For example, the Ringold lower mud unit is not sufficiently developed in either thickness, lateral continuity or mud content to provide significant lateral migration. The Plio-Pleistocene caliche unit is missing in the 200 East Area. Also the fine to coarse grained rhythmites appear to be absent from this sedimentary package. The absence of semi-indurated, cemented to partially cemented, laterally continuous units lead to the conclusion that significant lateral migration of fluids draining through the vadose zone is unlikely.

This conclusion is supported by the direct observation of migrating fluids using electrical resistivity tomography (ERT). Tomograms from infiltration studies conducted at the 200E/105A Mock Tank Site, located close to WMA B-BX-BY, displayed a dominant vertical flow path with no significant lateral spreading (Narbutovskih et al. 1996). These ERT studies tracked liquid migration to depths of 70 feet (21.3 m) in approximately 12 days with a modest leak rate of 0.13 gallons per minute. A simple extrapolation to the water table at 252 feet (76.8m) suggests that liquids released at the surface might reach groundwater in less than 2 months. Of course these data are valid only for the 200 East Area, and the results of this extrapolations give a minimum migration time.

Further discussion of site-specific stratigraphy can be found in Caggiano and Goodwin (1991), Caggiano (1996), and Lindsey et al. (1992).

3.2 Groundwater Flow

The regional water table map is shown in Figure 3.2. At WMA B-BX-BY, the water table is nearly flat with a maximum of 4 inches (10 cm) change in the water elevation across the site (Figure 3.3). This makes the local flow direction difficult to determine since it depends on the hydraulic gradient. In the recent past, the flow direction was to the northwest as evidenced in regional plumes (Hartman and Dresel 1997). Calculations indicate that a maximum flow rate would be about 135 feet (41.1 m) per year.

The flow should be turning back to the original pre-Hanford direction, which is to the east or southeast. Plume maps of contamination from the late 1940s indicate that the original flow direction was south southeast (Brown and Ruppert 1950). This anticipated flow direction change would be in response to the diminishing B-Pond mound located to the east. Recent borehole flowmeter tests indicate that flow is in the process of turning to a southwest direction in wells 299-E33-38 and 299-E33-31 (Kasza 1995). These directions would be consistent with a changing flow direction.

The hydrographs for RCRA wells indicate that some downgradient network wells may actually be higher in water elevation than the presumed upgradient wells (Figure 3.3). This relationship between wells has been similar for some time. The maximum data error for water level measurements is 1.4 inches (3.6 cm), with a typical error around 0.6 inches (1.5 cm). These errors are based on a maximum tape deviation of 1.2 inches (3 cm) with a measurement error of 0.24 inches (.6 cm). Thus the differences in water table elevations are greater than the measurement error.

One feature that can be seen in Figure 3.3 is the consistent, relatively high water table elevations of 299-E33-41 and 299-E33-42. The wells surrounding the farms were recently surveyed to eliminate any error associated with references to datum. Also, beginning in 1996, depth-to-water measurements are conducted on the same day to reduce barometric effects. Based on the consistency of the relative water elevation differences between wells over time, however, it is unlikely that barometric changes are causing elevation differences.

The aquifer is thin in this area with roughly 10 feet (3 m) of water remaining in the RCRA wells. Based on September, 1997 data, aquifer thickness is 11.8 feet (3.6 m) at 299-33-31 and 11.7 feet (3.6 m) at 299-E33-41. There are only 6.7 feet (2 m) left in 299-E33-42. The annual decrease in water elevation ranged from 0.61 to 0.73 feet (0.18 to 0.22 m) during 1997. If the present rate of decline remains stable, these wells should be capable of providing groundwater samples for 5 years or more. However, if the water table decline increases and the basalt subcrops, or there is not enough water left in a well to allow sample collection, a vadose zone monitoring method could be considered to replace or supplement unconfined groundwater monitoring.

Because there is high uncertainty in groundwater flow direction beneath the tank farms, analyses of the groundwater contamination data should consider possible alternative flow directions.

3.3 Regional Contamination

There are several radioactive and chemical contaminant plumes that exist in the groundwater in the northeastern section of the 200 East Area (Hartman and Dresel 1997). Figure 3.4 shows the mapped extent

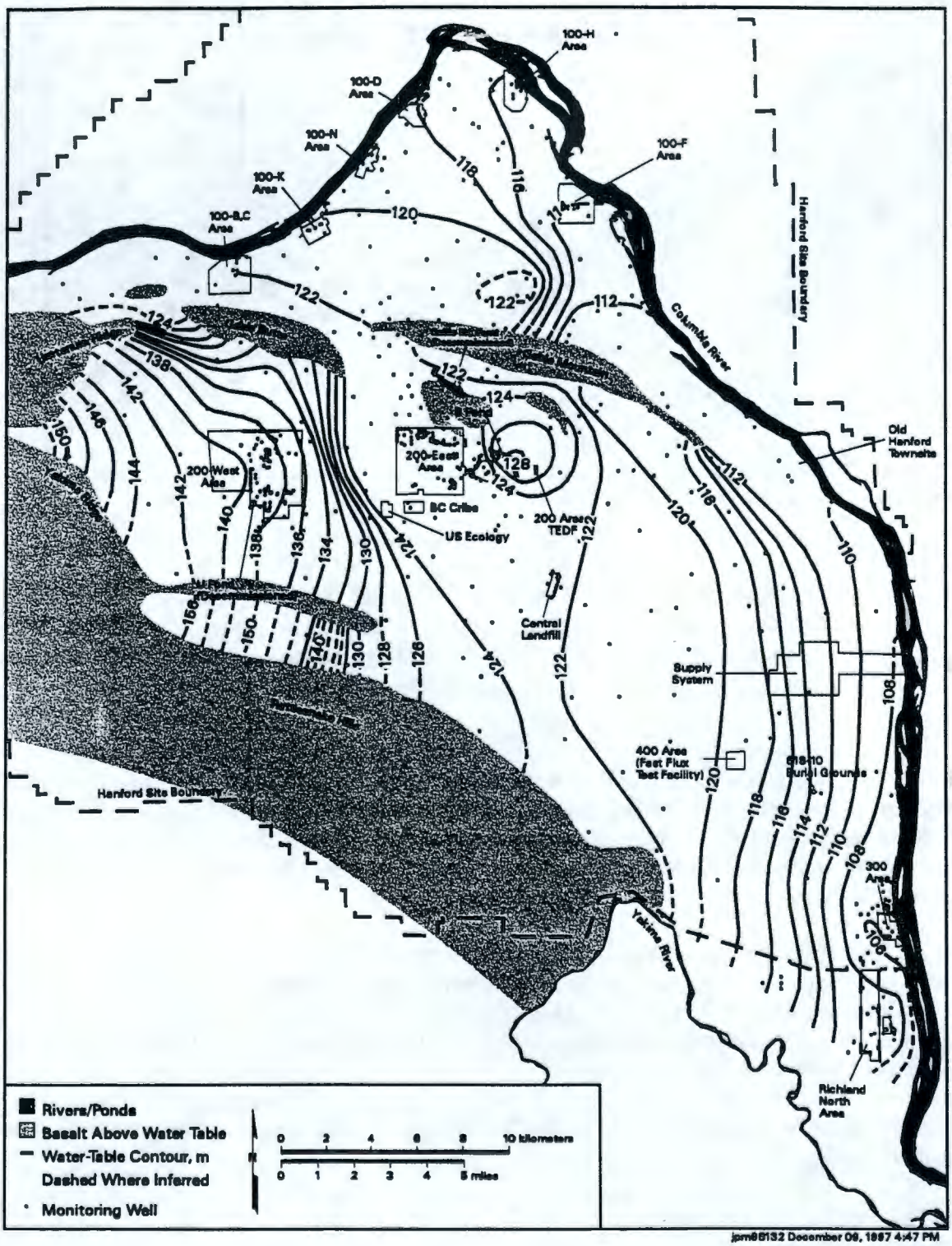

Figure 3.2. Water Table Elevation Map of the DOE Hanford Site (after Hartman and Dresel 1997).

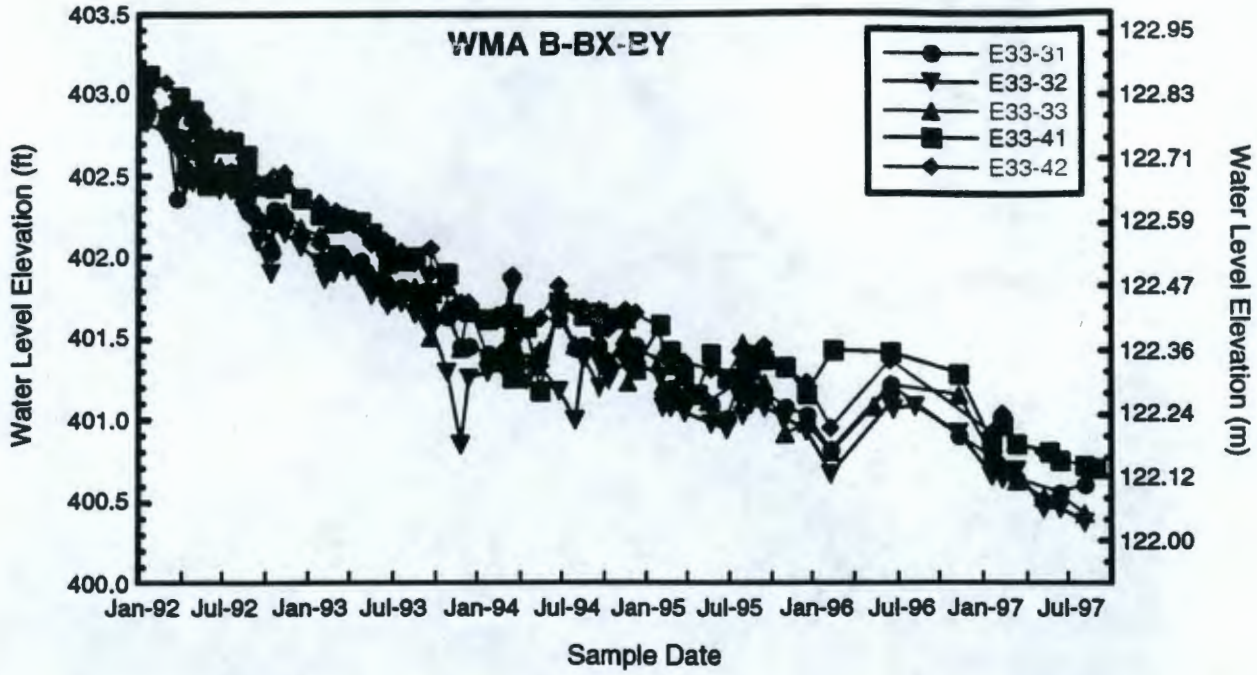

Figure 3.3. Hydrographs of the Wells Comprising the RCRA Network. Spurious data were removed. These data illustrate the flatness of the water table. Also shown is the consistent higher water levels of Wells 299-E33-41 and 299-E33-42. These wells were recently surveyed to eliminate survey error in the elevations.

of these contaminant plumes as of FY 1996. Regional plumes of tritium and iodine-129 stretch to the northwest and to southeast. The tritium is thought to be related primarily to B plant sources although waste condensate from the BY cribs also may have contributed. The iodine-129 sources are, at present, not known. The technetium-99 plume that extends to the northwest from the BY cribs is probably associated with discharges of supernatants and scavenged wastes.

A large nitrate plume also extends to the northwest from the BY cribs. This plume is most likely related to the supernatant wastes that were discharged the cribs. A small uranium plume is shown at well 299-E33-13, southeast of the BY cribs. Data collected in FY 1997 indicate that this plume may be more extensive. Although chromium might be expected from the REDOX waste that was stored in the tanks, very little is observed in the groundwater.

The contamination observed at well 299-E33-41 is localized with respect to these larger groundwater contamination plumes.

3.4 Local Contamination

This section contains data and associated observations on the immediate region around the three tank farms. The first section provides a description of the vadose zone contamination found in the borehole

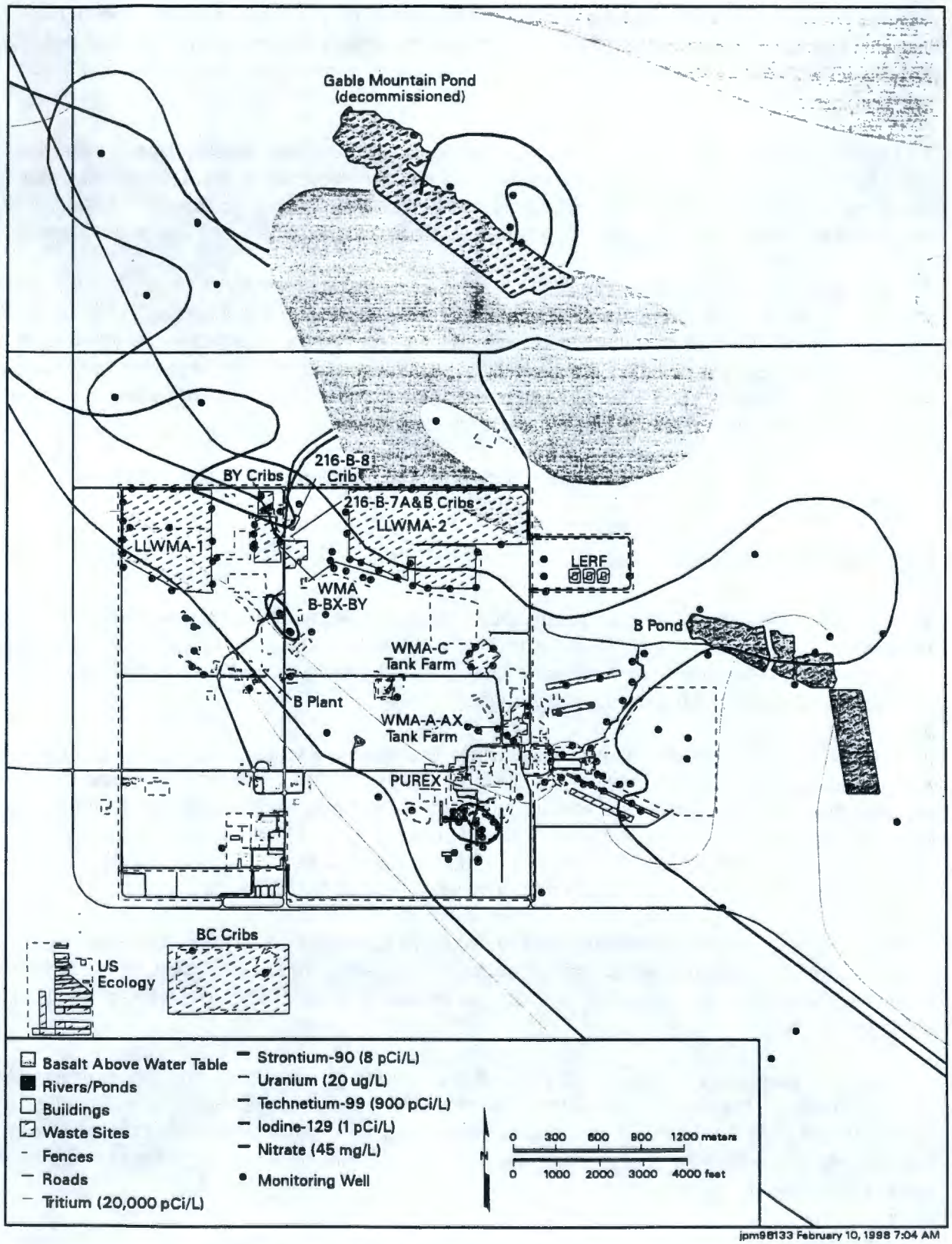

Figure 3.4. Regional Plume Map of Contaminants in the Vicinity of WMA B-BX-BY (after Hartman and Dresel 1997).

cuttings from well 299-E33-41. It also provides information on the nature of the sediments during the drilling of this well. The purpose is to associate the time that drilling commenced with the time that major artificial water releases occurred in the same vicinity and the proximity of the 241-BX-102 tank leak vadose zone plume to the well location.

The second section provides the results of groundwater monitoring data collected during the assessment. Comparisons are made between the groundwater chemistry observed at well 299-E33-41 and that seen at various wells associated with surrounding cribs and tile fields. These are non-RCRA wells, and have not been sampled on regular intervals in the past. Consequently the data for these wells is sparse.

There are seven wells in the interim RCRA groundwater monitoring network. These wells can be seen in Figure 1.2. In addition there are two RCRA compliant wells that were drilled for the 200-BP-1 operable unit investigations. Prior to assessment, they were used for supplemental sampling and water level information. Well 299-E33-38 is in the BY cribs and thus, is helpful to differentiate contamination associated with these units. Well 299-E33-39 lies to the northeast of the area and is neither upgradient nor downgradient from the farms. Both are sampled for the assessment investigation.

In addition to these wells, eight others are sampled for the continuing assessment. These wells are also shown in Figure 1.2.

3.4.1 Vadose Zone Contamination

The most immediate groundwater quality issue addressed in this study centers around sudden increases in a variety of constituents in well 299-E33-41. This well was drilled from January to April 1991 as part of the original RCRA groundwater monitoring network. It is located between 241-B and 241-BX Tank Farms close to the 241-BX fence (Figure 1.2).

While drilling this well, radioactive contamination was found in a series of silt lenses in the upper sand-dominated section at 73 feet (22.3m), 78 feet (23.8 m), 137 feet (41.8 m), 164 feet (50 m), and 218 to 240 feet (66.4 to 73.2 m). Radiation was detected up to 4,000 disintegrations per minute (dpm) at these intervals. Analyses of soil samples identified potassium-40, uranium-235, uranium-238, and lead-214. Gross alpha content from 218 to 240 feet (66.4 to 73.2 m) ranged from 13.2 pCi/g to 5.0 pCi/g. Beta/gamma radiation for the same depth interval ranged from 384.2 pCi/g to 164.5 pCi/g.

The gross alpha concentrations can be accounted for by the natural abundances of uranium and thorium decay series radionuclides in Hanford sediments. However, the observed gross beta concentrations are approximately 10 times higher than the mean gross beta concentration of 20 pCi/g for the Hanford Site (DOE 1996).

A spectral gamma ray tool was run in this well prior to setting permanent casing. The log data was recently reanalyzed, but provides results that conflict with the laboratory analyses for samples collect from 218 to 240 feet (66.4 to 73.2 m). The discrepancy was noted in the borehole package produced shortly after the well was drilled (Caggiano, 1992). These data are currently under investigation to determine the cause of the discrepancy.

Since the laboratory analysis did not identify any artificial gamma emitters in the interval from 218 to 240 feet (66.4 to 73.2 m), the excess gross beta may be due to the long-lived beta emitter, technetium-99. Unfortunately analysis of the soil samples for technetium-99 to confirm this tentative conclusion is not possible since the contaminated samples were not archived. However, the July 1991 groundwater sample from this well showed that technetium-99 was at 333 pCi/L while the upgradient well 299-E33-33 had a value of 5.2 pCi/L. This elevated technetium-99 in the groundwater supports the above conclusion.

Perched water was encountered at 224 feet (68.3 m). Sediments are described as moist-to-wet for the rest of the section. The first water table measurement was on 3/25/91at 245.8 feet (74.9 m) from surface. A second measurement on 3/27/91 recorded the water level at 247 feet (75.3 m) from the surface. The well construction and completion summary sheet gives an April 1991 measurement as 252.4 feet (76.9 m) from ground surface. These numbers indicate a rapid draining of 6.6 feet (2 m) of water during this single month.

In the months just prior to drilling well 299-E33-41, several flooding events occurred just south of this well's location at the 244-BX double contained receiving tank (DCRT). The migration through the vadose zone of water from these flooding events during the time well 299-E33-41 was being drilled would explain the perched water, unusually moist soils reported during drilling, and the temporary elevated water table.

Well 299-E33-41 is also located close to the 241-BX-102 vadose zone plume mapped by Womack and Larkin (1971). In fact, drywell 299-E33-141 (Figure 1.2), located 37 feet (11.3 m) from well 299-E33-41 but inside 241-BX Tank Farm, was recently surveyed with a borehole spectral gamma log tool (DOE/GJ-HAN-89, 1997). Although most of the contamination is near the surface, 20 to 30 pCi/g of uranium-238 were detected at 75 and 98 feet (22.9 and 29.9 m). Lesser amounts of cesium-137 and antimony-125 were also detected at these depths. Total depth in well 299-E33-141 is 100 feet (30.5m). Well 299-E33-41 is also close to the site of the 30,000 to 90,000 gallons overflow/spill between 241-BX-103 and 241-BX-102 in 1951 (DOE/RL-92-05 1993).

The crib nearest well 299-E33-41 is 216 B-7b. The distance from 216 B-7b crib to well 299-E33-41 is 300 feet (91.4 m). Compared to the relatively close distance (37 feet) (11.3 m) that well 299-E33-141 is to well 299-E33-41, it more likely that the vadose zone contamination at well 299-E33-41 is from remobilized residual vadose zone waste from the 241-BX-102 tank leak. Further mapping of the vadose zone contamination in this area during Phase II of the assessment will help delineate this source.

3.4.2 Groundwater Contamination

Mobile groundwater constituents associated with tank farm wastes are expected to display similar trends over time for samples from a particular well. For example, conductivity would be expected to co-vary with nitrate, chloride, and possibly sulfate. Technetium-99 would be expected to co-vary with all of these. Although tritium is also present in tank waste, the large pre-existing plume in the region masks any present tank farm sources.

Observations of contamination, based on RCRA groundwater monitoring data, are presented in this section. Comparisons of these data are made with data from selected wells associated with crib-waste.

Any data received after August 1997 will be evaluated in the next stage of the assessment with exception of cyanide data. Information was used from the November 1997 sampling event. If data are missing from a trend plot, it is because those data had not been received at the time this report was prepared.

Conductivity Trends

Background field conductivity for groundwater under the 200 Areas plateau is 344 umhos/cm (Johnson et al. 1993). The statistical critical mean for the WMA is 365.7 umhos/cm. A trend plot of conductivity data collected for the RCRA groundwater monitoring program is shown in Figure 1.3. The following observations are pertinent to this study.

- When conductivity values exceeded the critical mean in February 1996 and verification sampling confirmed the high levels in June 1996, the groundwater monitoring program was changed from detection-level monitoring to a groundwater quality assessment program. In August 1996, the level dropped to 334 umhos/cm. At this point in time, a false positive claim was considered.

- In well 299-E33-41, conductivity rose to 394 umhos/cm in February 1997, dropped in May 1997, then rose again in early August 1997, to 542 umhos/cm. Three weeks later, it dropped to 316 umhos/cm. This site was kept in assessment because of exceedances of conductivity and technetium-99 in this well. These changes were so transient that if the WMA had been monitored semiannually, neither of these high conductivity values would have been observed. This well has been semiannually sampled since November 1992.

- Conductivity has risen steadily in 299-E33-31 and rose to 377 umhos/cm above the critical mean in May 1997. During 1997, conductivity rose again in well 299-E33-32 to 385 umhos/cm in August 1997.

- The high amplitude, high frequency, repeating character of the conductivity trend in Figure 1.3 for well 299-E33-41 should be particularly noted.

The gradual rise in local background conductivity in the downgradient wells is unlikely to be related to the declining water table intersecting vertical stratification of the groundwater contamination. For example, measurements of conductivity versus depth taken in well 299-E33-32, (Figure 3.5), show little variation with depth. These data indicate that there is no appreciable chemical stratification of the aquifer in this area.

The gradual rise above background values may, however, be related to natural recharge moving through the highly contaminated soils under the SST farms. Johnson and Chou (1998) have discussed the significant increase in annual snowmelts in the last few years and the possible consequences to remobilizing waste in vadose zone plumes. Alternatively, the gradual increase may be caused by a return to ambient background conductivity.

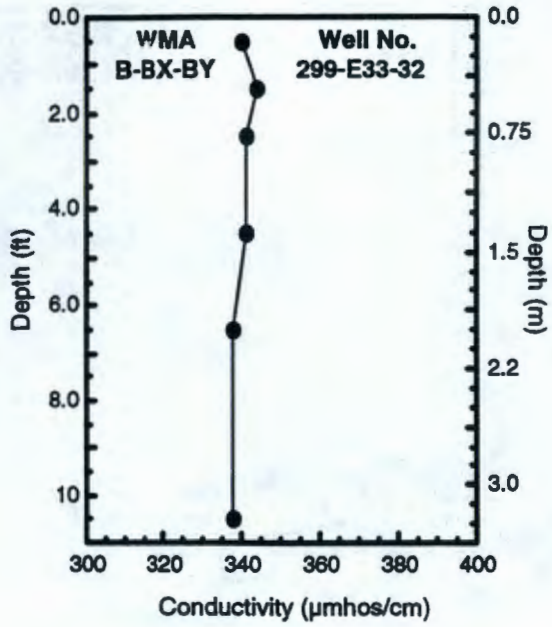

Figure 3.5. Measurements of Conductivity Versus Depth for RCRA Well 299-E33-32.

Technetium-99

Comparisons of technetium-99 trends for well 299-E33-41 with selected non-RCRA wells are made in Figure 3.6. Comparison of technetium-99 trends between RCRA wells is shown on Figure 1.5. The upgradient well is included to allow a comparison with upgradient background values. In well 299-E33-33, the upgradient well, technetium-99 has been less than 10 pCi/L since the earliest sample in March 1991. This value is quite low compared to data from downgradient wells. The most important observation is that none of these non-RCRA wells that are close to cribs and crib vadose zone plumes display the high amplitude, high frequency character of technetium-99 in well 299-E33-41. Clearly, the signature is distinct for well 299-E33-41, indicating a different source than that for the plume associated with the BY cribs. The drinking water standard is 900 pCi/L.

Co-varying Trends

Trend plots of technetium-99 versus conductivity, nitrate, chloride, and sulfate are shown in Figure 3.7. The important observations are made below.

- Conductivity and technetium-99 show a strong correlation in well 299-E33-41, confirming the high amplitude, high frequency character of the technetium-99 data (Figure 3.7a).

- Nitrate, chloride, and sulfate are the primary cause of the changes in conductivity in well 299-E33-41 and correlate with the technetium-99 trend (Figure 3.7b,c, and d). Of these constituents, nitrate especially displays the repeating, high frequency character of the technetium-99 data.

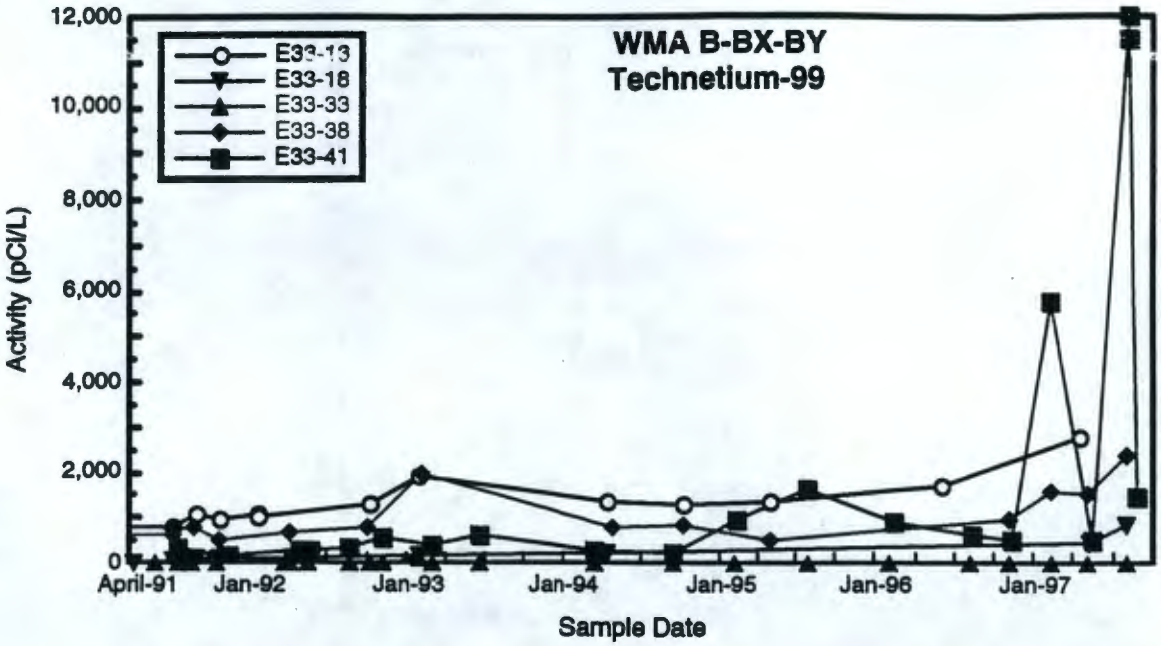

Figure 3.6. Trend Plot of Technetium-99 for Wells 299-E33-13, 299-E33-18, 299-E33-33, 299-E33-38, and 299-E33-41.

Sodium/Calcium

Tank waste is high in sodium because sodium hydroxide was added to the process stream to neutralize the nitric acid. Consequently, a tank waste signature in the groundwater chemistry should be higher in sodium than background values. At some SSTs, however, the calcium concentration was elevated above background instead of the sodium. These occurrences may be a result of the sodium cation preferentially replacing the calcium in the soil column during waste migration (Johnson and Chou 1998).

At WMA B-BX-BY, the calcium concentration was, in the recent past, below the Hanford Site background values of 40,000 to 60,000 µg/L (Figure 3.8). Presently, calcium appears to be rising across the WMA (Figure 3.8) although the data are not clear in well 299-E33-33. This may be a result of significant decreases in cooling water or treated water discharges to upgradient disposal facilities (e.g., the B Pond system) that tend to "dilute" ambient groundwater. There should be a general increasing trend back to the site wide background values as the aquifer adjusts to the reduced discharge volumes. However, is the groundwater flow direction has changed, the elevated calcium may be coming from a northerly direction. As yet, the cause of the increasing calcium is unknown.

Sodium concentrations, however, are close to background values for all wells in the area except well 299-E33-41 (Figure 3.9). When sodium concentrations are compared to wells associated with crib contamination, it is clear that a unique chemical signature exists for the groundwater at well 299-E33-41. Sodium increased from 20,100 µg/L in November 1996 to 29,600 µg/L in May 1997 while little or no change occurred in the other wells. The sudden increase in the sodium corresponds to the February 1997 increase in technetium-99 for this well, indicating a tank waste source for this contamination.

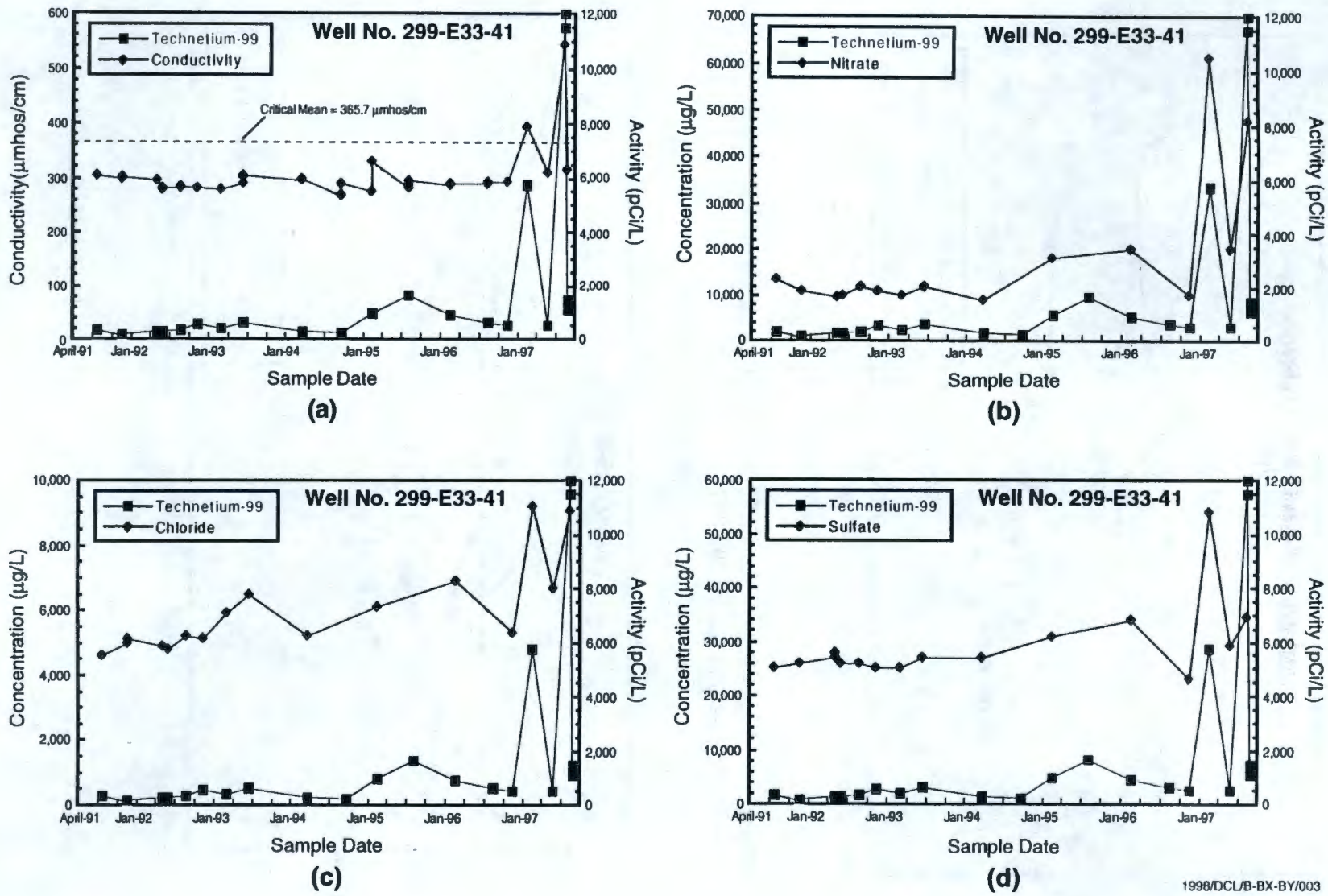

Figure 3.7. Trend Plots for Well 299-E33-41 Showing Comparisons Between Technetium-99 and Conductivity (a), Nitrate (b), Chloride (c), and Sulfate (d). The late August 1997 sample was not analyzed for anions.

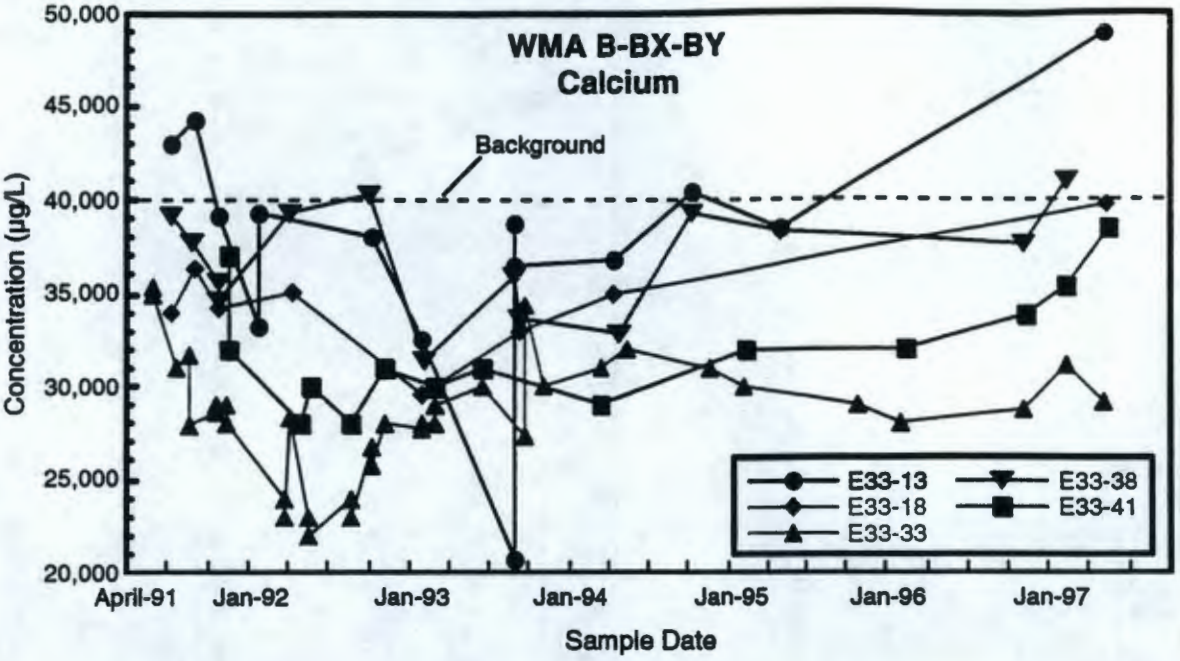

Figure 3.8. Trends Plot of Calcium for Wells 299-E33-13, 299-E33-18, 299-E33-33, 299-E33-38, and 299-E33-41.

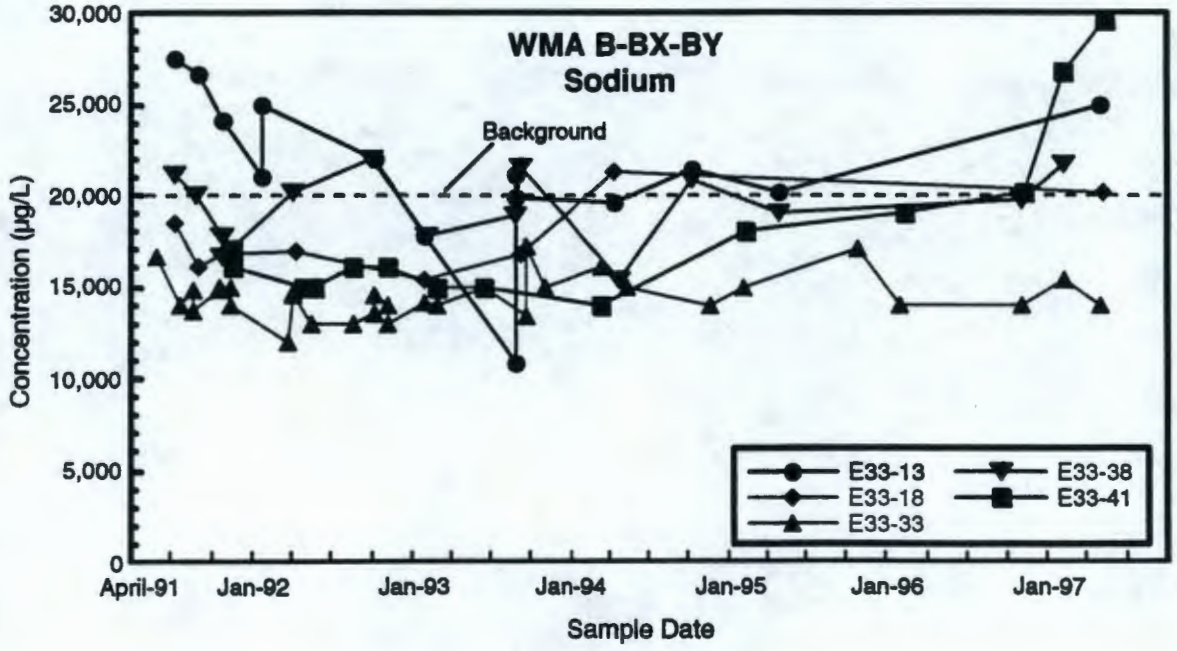

Figure 3.9. Trend Plot of Sodium for Wells 299-E33-13, 299-E33-18, 299-E33-33, 299-E33-38, and 299-E33-41.

Uranium

The drinking water standard for uranium is 20 µg/L. At WMA B-BX-BY, the natural background levels in the groundwater are about 2.5 µg/L. This low value is observed for all the RCRA wells except well 299-E33-41. As of August 1997, uranium is slightly elevated between 8 to 12 µg/L in this well. As seen in Figure 3.4, a small uranium groundwater plume at well 299-E33-13 was reported by Hartman and Dresel (1997) for FY 1996. This well was sampled annually by the Groundwater Surveillance Project and the elevated uranium in this well was reported by the Project in annual reports for FY1994 and FY1995 (Dresel et al., 1995; Dresel et al., 1996).

Prior to 1995, uranium was sampled for the WMA RCRA network wells and select wells in the BY cribs managed under the 200-BP-1 CERCLA project. With the exception of well 299-E33-13, the uranium level in most wells was below 10 µg/L. Analyses for uranium were discontinued after early 1995 since the data indicated that, in general, uranium was not an issue in the area. With the appearance of high technetium-99 levels in well 299-E33-41, not only were uranium analyses resumed for the RCRA wells, but data are now being collected for the expanded assessment network. For example, well 299-E33-18 had not been sampled for uranium since 1994 and well 299-E33-38 was last sampled for uranium in 1995. Both these wells are associated with cribs.

In Figure 3.10, a comparison is made between data for well 299-E33-41 and data for wells located close to the surrounding cribs. Values for samples collected in August 1997 range from 197 µg/L in well 299-E33-13 to 58.1 µg/L in well 299-E33-38. Although the occurrence of uranium (12 µg/L) in well

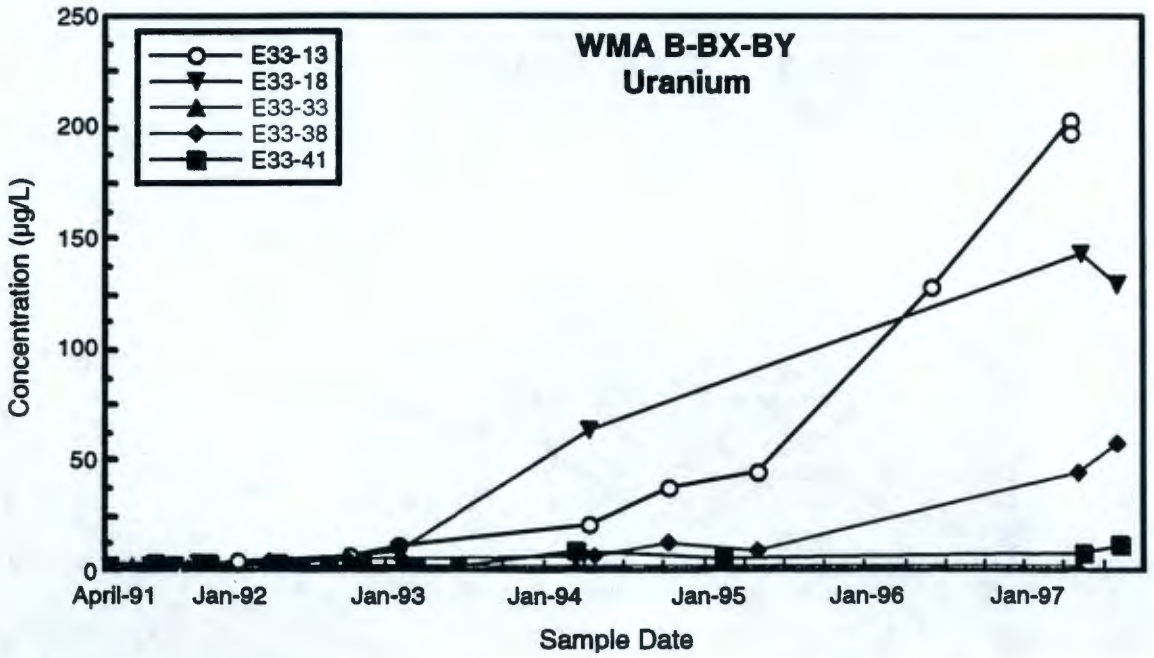

Figure 3.10. Trend Plot of Uranium for Wells 299-E33-13, 299-E33-18, 299-E33-33, 299-E33-38, and 299-E33-41. The drinking water standard for uranium is 20 µg/L.

299-E33-41 is not completely understood, a large discrepancy exists between uranium concentrations in this well with respect to wells associated with cribs. Since uranium levels have increased significantly above the DWS of 20 µg/L, monitoring has increased and possible causes are being investigated.

Other Constituents

The last important chemical constituent is cyanide. The maximum contaminant level allowed is 200 µg/L. As of November 1997, cyanide has been found only in wells associated with cribs (Figure 3.11). There is no detectable cyanide in well 299-E33-41 or the other RCRA wells at present. It might be expected that remobilized waste from a primary crib source would contain some cyanide. Ferrocyanide was added to tank waste to precipitate selected radionuclides. The solid precipitate settled binding the cyanide in the tanks in an immobile solid phase. On the other hand, the supernatant enriched with excess cyanide was discharged to the cribs. The cyanide complexed at the cribs with cobalt-60 forming a mobile constituent. The lack of cyanide at well 299-E33-41 further distinguishes the contaminant source for this well as being tank waste.

Cobalt-60 has been found in the groundwater at well 299-E33-5 at 25.7 pCi/L. Well 299-E33-13 may be showing low levels of cobalt-60, but the data quality has not been sufficient to be certain. The interim DWS is 100 pCi/L for cobalt-60.

Although the assessment wells are monitored for cesium-137, the only known occurrence in the groundwater was the 7900 pCi/L reported in April 1972 in well 299-E33-27. This well was plugged to a depth of 240 feet (73.2 m) in 1976 because it was thought that the cesium-137 was migrating down the outside of

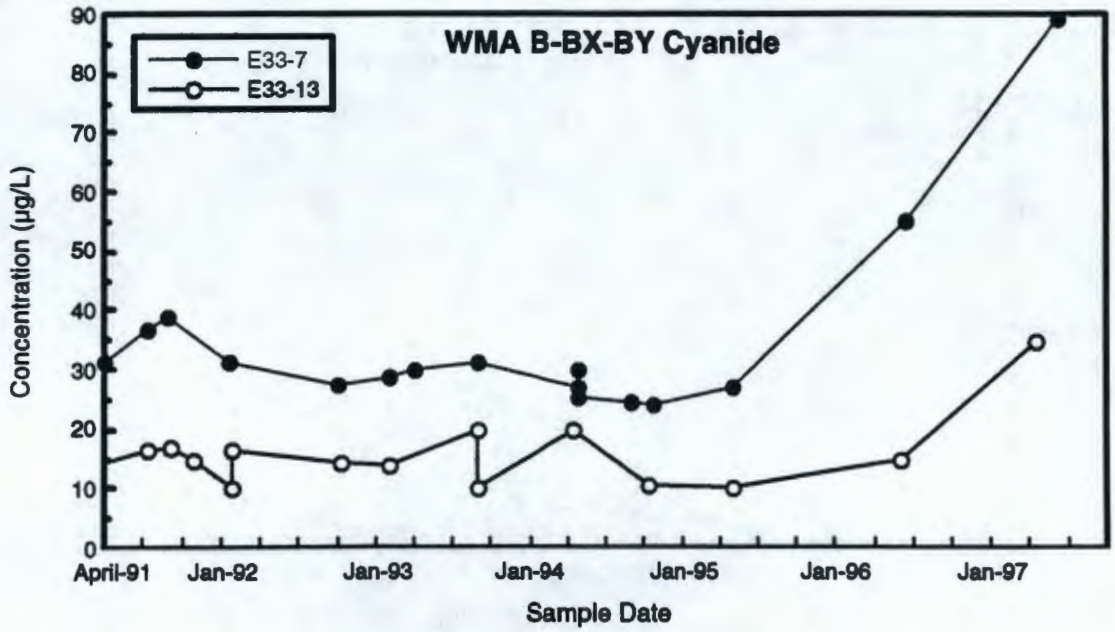

Figure 3.11. Trend Plot of Cyanide for Wells 299-E33-13 and 299-E33-7. This constituent was not detected in well 299-E33-41.

the casing. The lack of cesium-137 might be expected since field observations and experimental data indicate that cesium-137 is usually held in the upper part of the soil column close to the tanks. There are, also, no known occurrences of strontium-90 in the groundwater under 241-B-BX-BY Tank Farm.

3.5 Tank Farm Occurrences

A series of occurrence reports and farm operations information are listed and briefly described below for use in the next section. These reports document that artificial water sources have existed in the past that could have remobilized waste in the vadose zone associated with the 241-BX-102 tank leak. Furthermore, flooding events occurred that might have caused the nearby vadose zone contamination observed during drilling, to spread to the present location of well 299-E33-41. Several of the occurrences below describe water line leaks and valve ruptures at the 244-BX receiving tank, located approximately 150 feet 45.7 m) south of well 299-E33-41 (Figure 1.2). It is quite likely that this water was remobilizing tank waste while well 299-E33-41 was being drilled.

- WHC-TANK FARM-1990-0054 September 1990, raw water was found discharging out of a ½ inch line onto the ground from the exterior wall of the 244-BX double contained receiving tank (DCRT), located just south of well 299-E33-41 (Figure 1.2). Although a leak detection alarm sounded, and the area was checked, the open line was not discovered. Approximately 4 ½ hours later, an open valve was found in the DCRT building. It is not reported how long the water flowed onto the ground prior to the alarm activation. Although information is provided in the report that a 1500 gallon increase was observed in the DCRT, no estimate is given on the total volume of liquid released to the soils. It is, however, stated that the open valve was finally noticed because a pool of water adjacent to the 244-BX DCRT pump pit was discovered.

- WHC-TANK FARM-1990-0373 December 1990, sub-zero weather conditions caused raw water piping in the 244-BX DCRT building to rupture several valves. No estimate is made of the amount of water discharged to surrounding soil. It is stated that approximately 550 gallons of water drained into 244-BX DCRT via the 244-BX flush pit floor drain. It was also necessary to remove the excess water from the flooded instrument building. It is important to note that drilling commenced in January 1991 for well 299-E33-41, located approximately 160 feet (48.8 m) north of 244-BX DCRT. There is a slight downward slope towards the north at this location.

- Two single-shell tanks, close to well 299-E33-41, have been placed on the candidate intrusion list indicating possible liquid intrusion into the tanks (Hanlon, 1997). Both 241-BX-101 and 241-BX-103 have been interim stabilized. Tank 241-BX-101 is an assumed leaker. These tanks are placed on this intrusion list because surveillance data show that the surface levels in the tanks have met or exceeded the increase criteria. Both tanks are on the east side of 241-BX Tank Farm, near well 299-E33-41. The source of the liquid that may be intruding into these tanks is currently unknown.

- As built diagrams show 6-inch and 4-inch raw water lines and 1.5-inch sanitary water lines running north-south along Baltimore Avenue and along the farm fence lines. These lines run past 244-BX DCRT and next to well 299-E33-41. Also, 241-BY Tank Farm has some pressurized water lines inside the tank farm fence lines.

The above observations of vadose zone contamination in well 299-E33-41, groundwater chemistry and tank farms occurrences are compared in the next chapter to a series of specific conceptual models. The degree of agreement or disagreement identified a best-fit model to determine the source of contamination at well 299-E33-41.

4.0 Discussion

The following discussion focuses primarily on the contamination recently observed in well 299-E33-41, located between the B and BX Tank Farms. While upward trends are also emerging in wells along the west side of BX and BY Tank Farms, they are not developed sufficiently to determine sources and contaminant pathways. These data will be addressed in Phase II of the assessment.

The following, qualitative approach provides a framework to facilitate interpretation of the data. Although some aspects of the approach can be quantified by modeling end members and isolated elements, quantification exceeds the scope of this initial assessment. Conceptual models, specific to different scenarios, are developed that consider simple combinations of contaminant source, well location and driving force location. Each specific model is then evaluated with respect to the observations of vadose zone contamination, groundwater chemistry and artificial tank-related water sources for well 299-E33-41. After the approach is explained, the best-fit scenario is presented first followed by less favorable possibilities.

4.1 Approach

Normally, to determine a groundwater contaminant source, the spatial and temporal contaminant chemistry patterns are evaluated. Then, with the help of simplifying assumptions, attempts are made to determine possible migration pathways and driving forces. The objective is to use these variables to backtrack to the source. This amounts to using observations to piece together one specific "picture" or conceptual model that might identify the unknown source.

The following approach, however, begins with a generic model, identifies the important elements comprising this model and then, builds specific scenarios by combining these elements. These specific scenarios are constrained by assumptions appropriate to the contamination observed at well 299-E33-41. Although this is a qualitative approach, the final scenarios can be considered essentially end member situations tailored for well 299-E33-41. This approach allows an unbiased process to determine the contaminant source and assure that all reasonable possibilities are considered.

Some appropriate limitations/assumptions are placed on these conceptualized pictures for the situation at WMA B-BX-BY. They are:

- Specific models are for single-well occurrences. As shown in the previous section, the groundwater chemistry signature at well 299-E33-41 appears to be unique to this well.

- Sources are vadose zone plumes. Because there is little liquid waste left in most of the tanks and the liquid discharge facilities are no longer used, the most likely source is a residual vadose zone plume associated with either a crib or a tank-related leak.

- The driving force for contaminant transport to groundwater is surface or near surface water. Although this water source may be natural precipitation, it is unlikely in the case of well 299-E33-41 because the chemistry and the trend plots give a unique signature not observed in other wells. If the water source

were natural precipitation, the fluctuating character seen in the chemical trend plots should be seen in other wells.

- Vadose zone pathways within the Hanford Formation at the 200 East Area are dominated by downward vertical flow through the formation. This assumption is made only for saturated or near-saturated gravity flow of a discrete water leak. It is supported by the ERT infiltration studies for at least the upper section of the sediment package.

- Contaminants that reach groundwater flow towards and intersect a monitoring well. Without a better understanding of the local groundwater flow direction, it is difficult to assign a specific flow direction for the scenarios. So the scenarios only consider the situation when flow is from the point of entry of the contamination into the groundwater to the well.

There are several elements or variables that can be variously combined to construct a general model. Some elements are observable and thus, are part of the database. Other elements are difficult to measure or observe and thus, are poorly known. They are, however, still key parameters controlling contaminant migration and characteristics of trend plots.

For example, if groundwater contamination travels through the aquifer for a "long" time, the degree of dispersion will be greater than that for a "short" time. A dispersed groundwater plume could be expected to display a well-developed breakthrough curve with a characteristic exponential rise over time. On the other hand, if the contamination is entering the aquifer "close" to the well, the breakthrough would be difficult to define unless the sampling interval is short enough to allow data points to be collected very close together. If groundwater samples were not collected often enough to define the breakthrough curve, a trend plot would show a sudden, sharp increase in contamination with no visible breakthrough curve or exponential rise. Terms such as "far" and "close" are used in a loose qualitative sense to set end member situation. Of course, the amplitude of this contaminant increase would be related to the concentration of the source.

These elements are listed below along with choices particular to contamination observed at well 299-E33-41.

1. Source plume
   - Vadose zone contamination from tanks
   - Vadose zone contamination from cribs/trenches/reverse wells

2. Distance from the well to the water source
   - Close
   - Far

3. Location of the well with respect to vadose zone contamination
   - Well resides in vadose zone contamination
   - Well is located out of contamination is pristine soils

4. Nature of the water source
   - Localized

- Distributed

5. Travel time of contaminant in the groundwater
   - Long time
   - Short time

6. Degree of dispersion in the front of the plume
   - Highly dispersed
   - No dispersion

7. Characteristics of the chemical trend plots
   - Well-developed breakthrough curve
   - No breakthrough curve

8. Chemical correlations
   - Correlations exist
   - No correlations exist

Several possible conceptual model or scenarios for the observed contamination at well 299-E33-41 are set forth in Figure 4.1. These scenarios illustrate different combinations of Elements 1 through 5 above.

Figures 4.1a and 4.1b show similar scenes with a tank-related vadose zone source for the contamination. The vadose zone plume may have existed when the well was installed or it may have migrated to the well at a later time. For Figure 4.1a, the water source is localized and the travel time of contamination in the groundwater is short. For Figure 4.1b, the groundwater travel time is long.

Note that no scenario is shown in which the well is located within the vadose zone source and the travel time is long. The documented volumes for tank leaks, overflows, and spills are at most 115,000 gallons (tank 241 T-106). But crib/trench discharges were as great as 14.2 million gallons for a single crib (Figure 1.2). The ratio of width-to-depth (aspect ratio) for a tank-source vadose plume is less than one while crib plumes are close to one. This is based on large volume differences between tank leaks and crib discharges. Thus, it is unlikely that a well located in a tank-source vadose plume could have a long travel time for groundwater contamination.

Figure 4.1c depicts a residual vadose zone source caused by past-practice effluent discharges. The monitoring well is located within the contaminant boundaries. The water source is localized, and the travel time of contamination in the groundwater is short.

Figure 4.1d is similar. However, in Figure 4.1d the well is outside of the vadose zone plume with a long travel time for the contamination. The water source is localized, and the travel time of contamination in the groundwater is long.

In Figure 4.1e the well is located within the contaminant source. The crib-associated vadose zone plume may have existed when the well was put in or it may have migrated to the well at a later time. With respect to Figure 4.1c, the travel time is long.

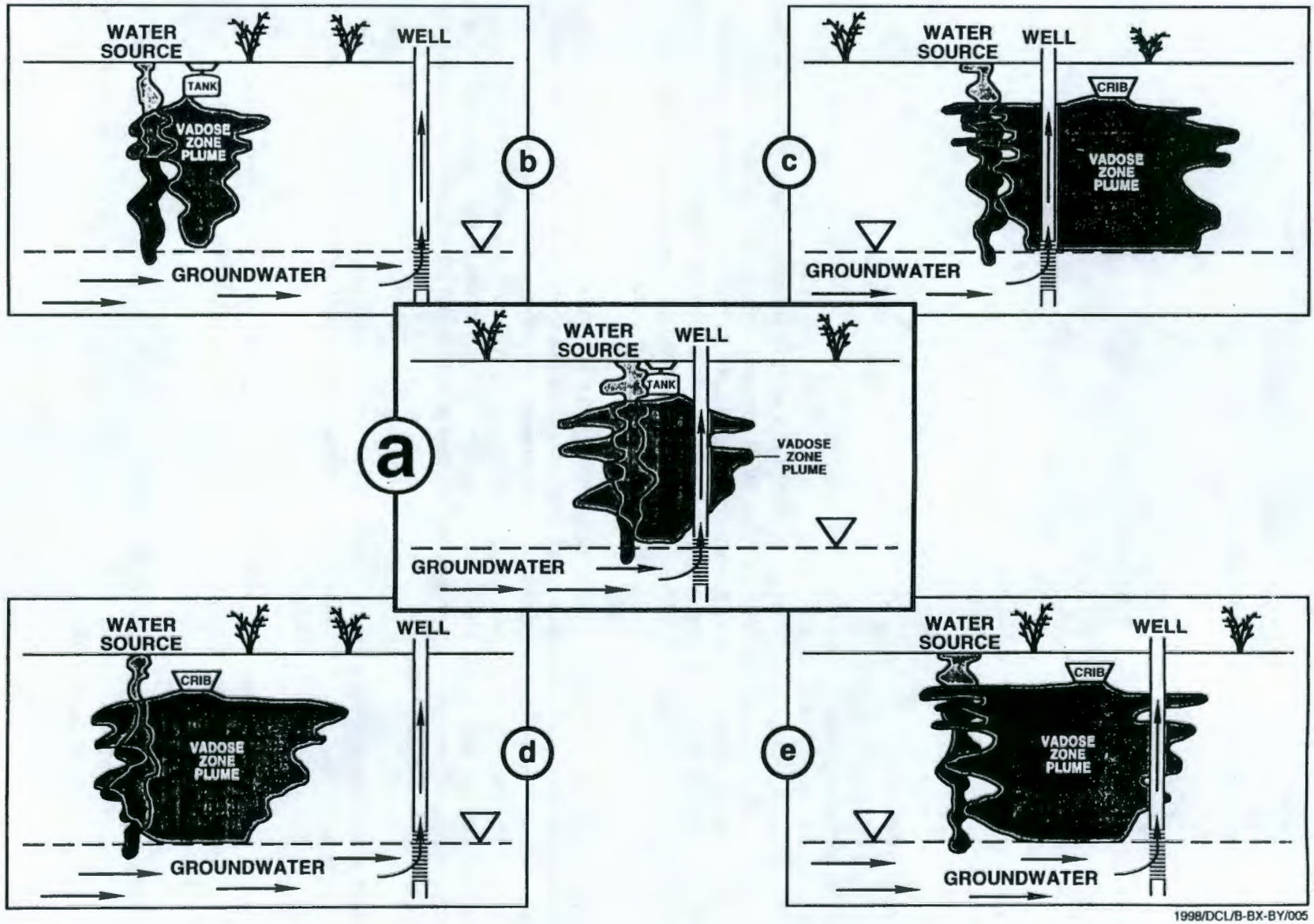

Figure 4.1. The combination of elements of vadose zone sources, water-based driving forces, and monitoring well locations that are possible at WMA B-BX-BY. Direct knowledge of the spatial relationship between any two of these three parameters, gives important insight on contamination source.

4.2 Data Analysis

The observations, of the groundwater chemistry and tank farm occurrences, are analyzed with respect to the five scenarios generalized in Figure 4.1. Each scenario is discussed with respect to data presented for well 299-E33-41. Discussions on data from other wells are secondary. In each scenario, the agreement with the observations are evaluated to determine which best fits the observations.

Although all five scenarios depicted in Figure 4.1 are discussed in the remainder of this section, one scenario emerges as being the most likely, or best fit. It is set forth first and followed by the discussions of the other four scenarios.

Preferred Scenario

In this scenario, considered to be the best fit and illustrated in Figure 4.1a, the contaminant source is a vadose plume from tank operations, either new or old. The well intersects the source plume and the driving force is water lost during routine tank farm operations or from nearby raw or sanitary water lines. The travel time of contamination in the groundwater is short and the driving force is localized. This scenario suggests that the water source is located close to the original leaking tank since the vadose plume is not extensive.

Supporting Issues

- This scenario explains the lack of exponential character seen in the chemistry trend plots for well 299-E33-41. If the travel time of the contamination in the groundwater were long, then there would be enough time for the migrating plume to have some degree of dispersion and exhibit a rising exponential breakthrough curve. On the other hand, if the contamination enters the groundwater close to the well, as it does in Figure 4.1a, then closely spaced sampling intervals would be required in order to detect the exponential character of the breakthrough curve.

- The high amplitude characteristic of the trend plots can be explained because the plume source is either leaked or spilled tank waste that has left concentrated vadose zone plumes. When these high concentrations of tank waste are mobilized and there is a very short travel time in the groundwater, then there would be little dispersion or diluting effect. Sudden, high concentrations of tank waste constituents should be observed.

- The high frequency in the observed chemistry trend plots can be understood because the driving source is related to current farm operations or nearby events. This allows for water to be turned on, then off, which explains the high frequency, pulsing character in the trend plots.

- The uniqueness of the contaminant chemistry observed in the data for well 299-E33-41 can also be explained with this scenario. Since the contamination enters the groundwater close to well 299-E33-41 and the driving force operates for a limited time (as seen by the frequency of three weeks to a month),

there is a limited mass of waste entering the ground. The closest groundwater monitoring well to 299-E33-41 is at least 300 feet (91.4 m) away. With the degree of dispersion that might occur with increasing travel time and the small areal extent that would be expected of these waste pulses, this event may not be observed in any other wells. This is especially true if the actual flow direction is to the south.

- This scenario is further strengthened by the proximity of tanks 241-BX-101 and 241-BX-103 to well 299-E33-41. These are the tanks noted under observations to have suspected water intrusion, supposedly causing liquid level rises. There is, at least, the implication that substantial amounts of water are or were migrating through the subsurface near the location of the well.

Non-Supporting Issues

- As yet, a specific driving force has not been identified; however, several examples of actual farm-related incidents creating water-sourced driving forces were presented in Chapter 3. Further identification of specific driving forces is pursued under Phase II of the assessment.

- Although unlikely that the residual vadose plume at well 299-E33-41 is not from a tank leak or spill, there is a possibility that contamination found during drilling involves crib waste. A more adequate understanding of both crib and tank vadose zone plumes is needed.

- Well 299-E33-41 is a RCRA compliant well. It was required that the borehole annulus be sealed to prevent vertical communication. There is no evidence that this well is improperly sealed. There are, however, numerous drywells located close to 299-E33-41. If one of these is poorly sealed, the outside of the annulus could provide a partial migration conduit through the upper vadose zone. Rapid migration of liquids through the 200 East Area sediments has, however, been demonstrated with ERT studies several times in recent years (Ramirez et al. 1995; Narbutovskih et al. 1996). These field infiltration studies show that with a modest leak rate of 0.10 gallons per minute for a point source, liquids migrate to depths of 70 feet (21.3 m) in less than 2 weeks. With such rapid infiltration rates, it is unnecessary to invoke the potential of unsealed boreholes to explain migration of tank liquids to groundwater (Hartman and Dresel 1997).

Following are the discussions of the remaining, albeit less likely, four scenarios illustrated in Figure 4.1.

Scenario 1

This scenario (Figure 4.1b) considers a vadose zone source from a leaking tank. Although the plume is depicted as leaking from a tank, it could just as easily originated from a diversion box or a waste transfer line as shown in the conceptual model (Figure 2.1). Also this source of tank waste can be from previous or current leaks. The driving force could be related to tank farm operations or to a non-related leaking raw or sanitary water line. The well is located outside the plume, the distance is far and the travel time is long.

Supporting Issues

- The scenario fits the observed high amplitude or high concentrations seen in the contaminant trend plots.

- The pulsing character seen in the contaminant trend plots can be partially explained by this scenario. An artificial water-source, driving force can be turned on and off such that the leak is periodically activated.

Nonsupporting Issues

- This does not agree with the observation that well 299-E33-41 is located in a residual vadose zone plume.

- An exponential breakthrough curve would be expected for this scenario, in contrast to the pulsing character observed in well 299-E33-41. For example, the effect of the longer groundwater migration route is such that each leak event should be spread out over time and should result in a more gradual or exponential increases in groundwater contaminant concentrations followed by a similar decline. There is no agreement to the lack of an exponential breakthrough curve observed for data from well 299-E33-41.

- Although there is some agreement to the high frequency character of the contamination observed in well 299-E33-41, the fit is not complete. Given a long travel distance, the groundwater plume should have spread areally to some extent, as previously indicated, resulting in a similar time-concentration pattern in other nearby wells.

Although Scenario 1 does not provide a good explanation for the data from well 299-E33-41, it may be the correct conceptual model for contamination seen in wells 299-E33-42 and 299-E33-31, located on the west side of the BY tank farm. These wells are showing increases in contamination with the same constituents as well 299-E33-41. There is some "pulsing" of the contamination. With the longer travel time, there are distinct breakthrough curves, the amplitudes (or concentrations) are not as great, and the signature is seen in more than one well. Groundwater contamination is, however, still dynamic and requires additional time for the time-concentration pattern to develop.

Scenario 2

In Figure 4.1c, the well is located not only within the crib-source vadose zone plume, but close to the localized driving source as well. The travel time for contamination through the groundwater is therefore short.

Supporting Issues

- The well location fits with the observed vadose zone plume around 299-E33-41.

- As in Scenarios 1 and 2, there is potential that the same chemical constituents would be seen in groundwater contamination from some of the crib sources as from the tank vadose sources. The case is not as weak for this scenario because the groundwater migration pathway is short and there would be little dilution effects from normal dispersion.

- The observation of no breakthrough curve is satisfied in this scenario. The short travel time would mitigate dispersion effects in the groundwater data.

Nonsupporting Issues

- Because well 299-E33-41 is close (approximately 37 feet) (11.3 m) to the mapped edge of the vadose plume from the leak of 241-BX Tank, and is 300 feet (91.4 m) from the mapped edge of the nearest crib vadose plume, it is most likely that contamination observed while drilling well 299-E33-41 is from the tank leak.

- There are no documented artificial driving force for areas near the cribs, however, a natural, distributed driving forces, such as natural recharge, could be considered for this scenario. Still, there is no mechanism for explaining the high frequency, pulsing character of the observed trend plots without using an artificial, localized water source that can be turned off and on over short periods of time.

- Although there is a better match with the chemistry, there is still the level of concentrations to consider. If the activity of waste discharged to the cribs was lower that residual tank waste, groundwater contamination from crib vadose sources could be expected to have lower concentrations. The high concentrations seen in the data from well 299-E33-41 are more easily explained with a tank source.

Scenario 3

In Figure 4.1d, the hypothesized source is the residual vadose plume left from effluent discharges to the soil column. The well is located outside of the source plume in uncontaminated soils. The distance from the well to the water source is far, the water source is localized, and the travel time for the contamination is long.

Supporting Issues

- This scenario may fit the observations of chemical constituents if the concentrations of the residual waste in the soils is great enough to allow for the dilution effects of the water-source driving force and the dispersion effects caused by a long travel time through the groundwater. Tank effluent discharged to the cribs should have had lower activities.

Nonsupporting Issues

- This does not fit the observation that well 299-E33-41 resides in a residual vadose zone plume.

- With the long travel time of the contamination in the groundwater required by this scenario, it is difficult to explain the observation that increases in contamination at well 299-E33-41 displays no breakthrough curve. With a long travel time, the groundwater plume should have had some degree of dispersion that is reflected in the trend plot as an exponential rise.

- There is a questionable agreement with the high amplitude character, or high concentrations, of the observed data trend plots as discussed above.

- There is no agreement with the high frequency, pulsing character of the contamination observed in well 299-E33-41. The sudden changes seen in the chemical concentrations over periods as short as 3 weeks do not fit a picture with a long travel time for groundwater migration.

- For a surface water driven source to reach the groundwater and travel a significant distance, the plume should have obtained some degree of areal extent. Although similar chemical co-variances to well 299-E33-41 may exist for wells 299-E33-31 and 299-E33-42, these data lack the high amplitude, high frequency, pulsing character of data from well 299-E33-41. Data from wells 299-E33-31 and 299-E33-42 display an exponential character in the chemical increases. As yet, the unique chemical signature of well 299-E33-41 has not been observed in another well.

Scenario 4

This scenario is depicted in Figure 4.1e. Although similar to Scenario 3, the well is located within the crib-sourced vadose zone plume. The distance remains far between the driving force and the well location, the water source is localized and the travel time for groundwater contamination is long.

Supporting Issues

- There is a match with the observation that well 299-E33-41 is located in a residual vadose zone plume.

- Although ambiguous as explained above, there is potential that the chemical constituents observed could be consistent with a residual crib vadose zone plume.

Nonsupporting Issues

- This scenario is subject to the same weakness as Scenario 3, except for the well's location within a crib-source vadose zone plume.

The preceding analysis of the data and observations has shown that models with sources other than those related to WMA B-BX-BY cannot explain the contamination observed in well 299-E33-41.

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5.0 Conclusions

According to 40 CFR 265.93(d) (6) and (7), the first determination of an interim assessment investigation (Phase I) may result in one of two decisions. The first is that no hazardous waste or hazardous waste constituents from the facility have entered the groundwater and the results support this conclusion. The other decision is that hazardous wastes from the facility have entered the groundwater. The results of this assessment investigation have presented evidence that strongly favor the latter decision that current/past operational practices at WMA B-BX-BY have resulted in observed groundwater contamination.

Observations of the groundwater contamination and tank farm occurrences combined with a qualitative analysis of possible solutions, leads to the following conclusions.

- Recent elevated technetium-99, nitrate, chloride, sulfate and sodium in well 299-E33-41 appear to be related to remobilized tank waste from the WMA. The trend plot characteristics of high amplitude, high frequency events combined with the well's proximity to a known tank-leak vadose plume and with documentation of local water driving forces indicate that this WMA contributed to the observed contamination. Data reported in February 1997 showed that technetium-99 was 6 times the DWS of 900 pCi/L. Early August 1997 data reported technetium-99 as 13 times the DWS.

- Based on 1) the vadose zone contamination found in 1991 during drilling of well 299-E33-41, 2) the existence of perched water and saturated sediments, 3) the rapid drop in water level shortly after well completion and 4) the documented events of nearby artificial water releases at the surface, it is likely that this contamination is remobilized vadose waste from a leak in tank 241-BX-102 (70,000 gallons). The overflow/spill that occurred in 1951 of 30,000 to 90,000 gallons between tanks 241-BX-102 and 241-BX-103 may have contributed.

- The rising trends of technetium-99 and nitrate seen on the west side of the WMA in wells 299-E33-42, 299-E33-31, and 299-E33-32 may be related to the WMA. As evidenced with the August 1997 data, however, the situation is still dynamic. Contamination concentrations are still increasing and have not yet peaked. Determination of the contamination source for these wells will continue as part of the Phase II assessment.

The contamination observed at well 299-E33-41 appears to have recently entered the groundwater as evidenced by the sudden sharp rise in anions, sodium and technetium-99. Furthermore, the contamination events are localized and the concentrations are low when compared directly to waste stored in the single-shell tanks. Consequently, the overall impact on the groundwater quality may be small, especially when compared to the large regional contaminant plumes that currently exist in this region.

The open issues noted above, and assessment of the nature and extent of the groundwater contamination attributable to WMA B-BX-BY will be addressed in development of the Phase II assessment.

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6.0 Proposed Phase II Investigative Approach

The Phase I assessment of WMA B-BX-BY concluded that the WMA has impacted groundwater quality and a more detailed Phase II assessment is necessary. The following tasks will be included in the Phase II assessment.

1. Quarterly monitoring will continue including selected non-RCRA assessment wells a) to further differentiate crib sources from tank sources and b) to construct local contaminant plume maps to determine temporal and spatial trends of contaminant movement. More frequent monitoring may be considered for specific constituents/wells if data warrant it.

2. Evaluate vadose zone contamination of crib waste and correlate with recent in-farm vadose characterization studies. For example, structure maps may be constructed for prominent horizons in the Hanford Formation to map possible migration routes through the vadose zone to groundwater.

3. Conduct further evaluations of groundwater flow directions.

4. Investigate possible causes for rising conductivity seen across the area. Evaluate groundwater chemistry and elevation data for evidence of natural recharge.

A Phase II assessment plan will be proposed with implementation in FY98, after regulator and stakeholder remarks have been addressed. Meanwhile, sampling will continue quarterly with monthly sampling as necessary until the Phase II plan can be prepared and implemented.

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