Assessment of Chlorinated Solvent Contamination in the Crouch Branch Aquifer of the A/M Area (U)

September 30, 1997

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1 Executive Summary

As a result of historical releases of chlorinated solvents near the vicinity of the SRTC complex, a plume of dissolved contamination has migrated from the release area into the Crouch Branch Aquifer. This migration is a result of the transitional geology beneath the SRTC complex that has been identified with a facies change in the Crouch Branch Confining Unit. Chlorinated solvent contamination was first discovered in the Crouch Branch Aquifer from samples collected at the A/M Area production wells in 1981. Following this, numerous monitoring wells have been installed in the Crouch Branch Aquifer to determine hydrogeologic conditions and groundwater quality. The monitoring well data is supplemented with the collection and analysis of soil samples collected from soil cores throughout the A/M Area. Analysis of this combined data set indicates that a dissolved plume is migrating from the source area in the Northern Sector southwesterly towards the interior of the Savannah River Site. As indicated by the depth discrete soil data the plume is located within a distinct horizon in the Crouch Branch Aquifer and has a total thickness on the order of 50 feet. Based upon regional groundwater patterns the long-term outcrop should be southwest of the A/M Area in the vicinity of the Crackerneck swamp. Plume elevations in the A/M Area determined from the depth discrete soil data indicate that several of the monitoring wells in the Crouch Branch Aquifer are screened above the elevation of the plume, resulting in reporting of non-detect values at these locations. Current remediation strategies incorporate a pump & treat remediation system in the Northern Sector source zone complemented with mass removal aspects provided by active A/M Area production wells. The long-term effectiveness of this pump & treat system with respect to the Crouch Branch Aquifer will be determined from future concentrations at monitoring wells ASB 6AA and MSB 37TA and "bulk" samples collected at production wells 905-20A and 905-53A. One of the longest historical data sets available in the A/M Area is the collection and reporting of "bulk" production well samples. The collection and analysis of this data has been removed from the sampling schedule. The loss and impacts associated with the continuity of this long-term historical data set should be evaluated with the cost savings associated with removal. In addition to providing an indicator on the effectiveness of remediation in the Crouch Branch Aquifer, "bulk" samples also provide data necessary to estimate mass removal associated with production well operation. Since 1981 an estimated 6,200 pounds of organic solvents have been removed via operation of the A/M Area production wells. Based upon concentrations reported in 1994 and the current operating frequency of 905-20A and 905-53A, an additional 715 pounds of solvent will be removed every year. In addition to the reporting of "bulk" concentrations, a flow recorder should be considered for installation at production wells 905-20A and 905-53A.

Even though the production wells have had a dramatic effect on the distribution of chlorinated solvents in the Crouch Branch Aquifer, early well designs have combined with limited operations and a naturally occurring head difference between the Crouch Branch and McQueen Branch Aquifers resulting in a pathway for downward migration. These factors have resulted in the migration of a small amount of chlorinated solvent into the lower section of the Crouch Branch Aquifer and into the deeper McQueen Branch Aquifer in recent years. This downward migration is evident from a recent increase in concentrations observed at monitoring well MSB 34TB and concentrations reported in the McQueen Aquifer at soil boring MCB-12SB. Recent investigations have characterized the magnitude of solvent entering this aquifer using depth discrete water samples and velocity measurements in the wellbore of appropriate production wells. The results of this data indicates that less than 0.2 pounds per day of solvent entered the McQueen Branch Aquifer during idle periods prior to October 1996. During the summer of 1996 modifications were made to production wells 905-20A and 905-53A, two of the three wells contributing to the migration into the McQueen Branch Aquifer, to eliminate this migration path without effecting production capacity. The third well that could have contributed to contamination in the McQueen Branch Aquifer, 905-31A, was abandoned in FY97 with the integrity of the McQueen Branch Confining Unit restored during the process. In addition to these wells, production wells 905-15A and 905-82A and regional observation well LA-4 were included in this investigation. Production well 905-15A

is located entirely in the Crouch Branch Aquifer and does not contribute to downward migration. This well has been out of service since the late 1960's and was formally abandoned in FY96. Production well 905-82A is located in the McQueen Branch Aquifer and does not contribute to migration of solvents from the Crouch Branch Aquifer. Based upon the data collected during the investigation, regional observation well LA-4 is not contributing to migration of contaminants into the McQueen Branch Aquifer; and regional groundwater level instrumentation has been reinstalled at the wellhead. Of the three production wells contributing to the migration of solvent into the McQueen Branch Aquifer, well 905-53A was the most significant, followed by 905-20A and finally 905-31A. During operation the positioning and design aspects of wells 905-20A and 905-31A result in the capture of a significant portion of solvent that entered the McQueen Branch Aquifer via production well 905-53A.

Numerous data sources provide valuable insight on the extent and magnitude of the chlorinated solvent contamination in the Crouch Branch Aquifer. This data has been combined and used to map the extent of the contamination using fundamental principles of groundwater flow, the hydrostratigraphy of A/M Area, with mechanisms of contaminant transport. The distribution of chlorinated solvent contamination in the Crouch Branch Aquifer was determined using recent and historical data along with an analytical solution to the advective-dispersion equation. The results provide a reasonable estimate of the extent and distribution of chlorinated solvent (primarily trichloroethylene) contamination in the Crouch Branch Aquifer. Based upon this investigation maximum solvent contaminations in the Crouch Branch Aquifer are on the order of 1,000 $\mu g/l$ for trichloroethylene with tetrachloroethylene concentrations significantly less. The distribution of dissolved contaminants are controlled by local hydraulic conditions, transitional geology near the source zone, and the effects of the A/M Area production wells. Historical operation of the A/M Area production wells have managed to capture and contain a significant portion of the dissolved trichloroethylene plume that is located in the Crouch Branch Aquifer. Utilization of these wells as process water supply has resulted in the containment of the majority of the plume in the Crouch Branch Aquifer that is greater than 100 $\mu g/l$ trichloroethylene. As determined by capture zone analysis, production well 905-53A has had the greatest impact on plume containment with significant contributions also offered by production well 905-20A. As determined from depth discrete data at the Miscellaneous Chemical Basin a portion of the plume in the Crouch Branch Aquifer has passed south of the zone of capture offered by the production wells. The magnitude of this plume is less than 100 $\mu g/l$ trichloroethylene and reflects early releases at the SRTC complex and along the A-01 Outfall. The installation of additional characterization and monitoring at the elevation of the plume along this flowpath will allow for the long-term assessment of future migration in the Crouch Branch Aquifer. The continued operation of production wells 905-20A and 905-53A on an alternating frequency couples with source zone remediation in the Northern Sector to provide a cost-effectiveness remediation strategy for the Crouch Branch Aquifer. Any direct remediation within the Crouch Branch Aquifer should target the elevation of the plume and not the entire vertical extent of the aquifer.

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2 Objective

The purpose of this investigation is to document and describe the extent of chlorinated solvent contamination in the Crouch Branch Aquifer beneath the A/M Area of the Savannah River Site and to assess the performance of remediation activities on the contamination. This investigation includes an examination of the identified source zone with regards to current and historical groundwater concentrations, hydrostratigraphic environment, and groundwater migration patterns. This information is applied with an appropriate mathematical model to estimate the extent of contamination in the Crouch Branch Aquifer system. In order to assess the effectiveness of the remediation influencing the Crouch Branch Aquifer, the effects of the pump and treat program in the Northern Sector is coupled with plume containment and mass removal provided by operation of the A/M Area production wells.

3 Introduction and Background

In examining the extent of contamination and the effects of current remediation with regards to the Crouch Branch Aquifer, numerous parameters must be considered in the development and refinement of the conceptual model depicting contaminant migration. These parameters include the identification of known and potential source zones, the hydrostratigraphic environment which controls migration from the source zone, and the effects of the remediation activities. Once an accurate conceptual model is developed, appropriate modeling techniques can be applied to evaluate the extent of contamination and to assess the effects of remediation strategies. Each of these parameters have had a significant effect on the distribution of chlorinated solvent contamination in the Crouch Branch Aquifer and are discussed in subsequent sections of this report.

3.1 Purpose of the A/M Area

The A/M-Area is located in the northern section of the Savannah River Site (SRS) and consists of those facilities that fabricated reactor fuel and target assemblies for the SRS reactors (M-Area), laboratory facilities (SRTC, formally SRL), and administrative and support facilities (A-Area). Operations at these and other facilities within the A/M Area resulted in the release of chlorinated solvents, primarily trichloroethylene (TCE), tetrachloroethylene (PCE) and 1,1,1-trichloroethane (1,1,1-TCA) to the subsurface. These releases have resulted in the contamination of the soil and groundwater within the area. The first indication of solvent contamination in the Crouch Branch Aquifer occurred in July of 1981 when a water sample from production well 905-53A indicated trichloroethylene contamination at 10 $\mu g/l$, with contamination subsequently observed in production wells 905-20A and 905-31A (Horvath, 1988). Trace amounts, less than the current drinking water standards, have also been measured in production wells 905-68A and 905-82A. To aid in characterizing the extent of the contamination in the Crouch Branch Aquifer several monitoring wells have been installed and multiple bulk soil samples from the Crouch Branch Aquifer have been collected and analyzed (WSRC, 1993a) (WSRC, 1994) for volatile organics using a headspace analysis procedure developed at the Savannah River Site (Looney et al., 1993). The location of the production wells, monitoring wells, and soil borings in the Crouch Branch Aquifer are presented in Figure 1. The data and results from these investigations are combined to refine the conceptual model of contaminant transport and migration in the Crouch Branch Aquifer.

In order to efficiently manage the complete remediation program in the A/M Area, the region has been subdivided into five sectors. These sectors are the Central A/M Area, the Western Sector, the Southern Sector, the Northern Sector, and the Cretaceous. Although geographically and geologically identified, each of these sectors are defined based on the type of contaminants present and the remediation approach(s) employed. The delineation is primarily a management tool so that remediation strategies and goals for each sector can be appropriately developed. The type and extent of contamination in each of the sectors are summarized in Table 1 along with the current and/or proposed remediation strategies. The

Central A/M Area is formally defined by the capture zone of the original full-scale pump & treat system in the A/M Area. The effectiveness of this system in capturing the dissolved portion of the groundwater plume has been evaluated through extensive groundwater modeling activities (S.S. Papadopulos & Associates, 1987) (Haselow et al., 1991) (Jackson and Aleman, 1995).

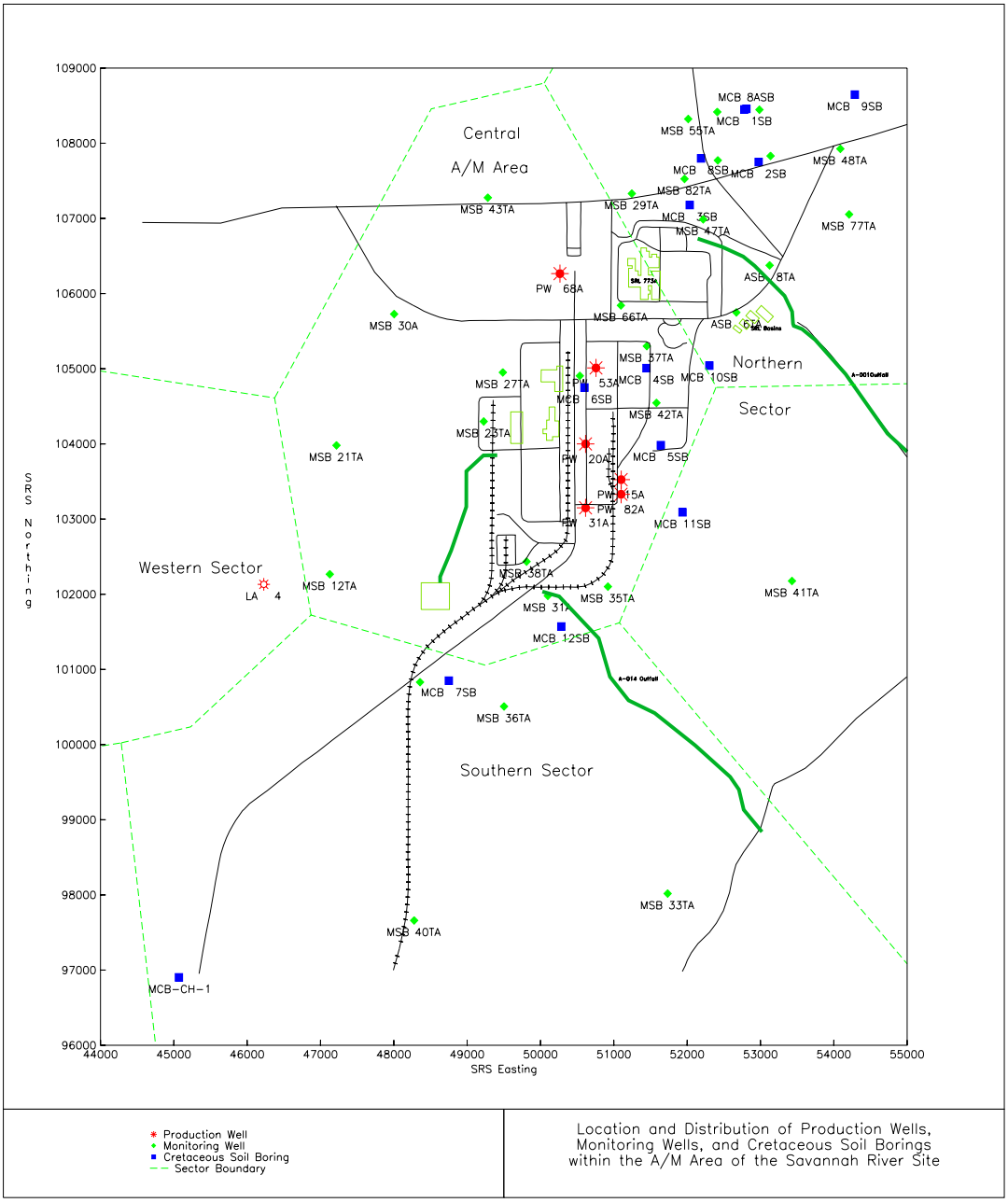
The Central A/M Area contains the two primary solvent release points, the M-Area Basin and the A-014 Outfall, along with the solvent storage facilities in the 300-Area and other miscellaneous solvent release areas. Historical references associated with the presence of chlorinated solvents in the A/M Area document releases in these areas (Gordon, 1982) (Christensen and Brendell, 1982) (Marine and Bledsoe, 1984). The source of the dissolved plume present in the Central A/M Area is attributed to the presence of DNAPL in both the unsaturated and saturated zones (Looney et al., 1992). Indirect assessment techniques have been applied to historical groundwater concentrations in the A/M Area and indicate that the distribution of DNAPL may be extensive (Jackson et al., 1996b). To address and remediate the NAPL in the unsaturated zone a series of soil vapor extraction (SVE) units have been installed in the source zone regions along the process sewer line and beneath the M-Area Basin (WSRC, 1997). These units have been very successful in the removal of contaminant mass in the vadose zone prior to entry into the saturated region. The current remediation approach for DNAPL focuses on the containment and removal of highly concentrated aqueous groundwater via conventional pump & treat complimented with SVE activities in the Vadose Zone. Successful long-term remediation will require development and deployment of DNAPL characterization techniques with appropriate removal or destruction technologies applied.

The migration of DNAPL downward into the saturated zone and laterally along lithologic strata serves to characterize the primary type of contamination associated with the Western Sector. Characterization and remediation efforts in the Western Sector requires identifying the location and thickness of DNAPL along these strata and the deployment of appropriate DNAPL removal/destruction technologies. Subsurface DNAPL serves as a long-term source for dissolved groundwater contamination within the A/M Area. This, along with the local groundwater flow pattern, has resulted in the migration of dissolved contaminants downward across the Green Clay confining zone and southward towards Upper Three Runs Creek. This migration pattern is the source of the relatively large plume associated with the Southern Sector. In the Southern Sector average groundwater concentrations are several orders of magnitude less than those found near the source zones. In addressing remediation programs within the Southern Sector, SRS investigators have examined alternative methods over conventional pump & treat technologies (Looney and Phifer, 1994). In order to cost effectively provide hydraulic control and treatment for groundwater contaminated with greater than 500 $\mu g/l$ trichloroethylene, a series of vertical recirculation wells are planned for installation within the Southern Sector (Jackson and Looney, 1996) with current field scale testing underway (White and Hiergesell, 1997).

Investigators have been unable to quantify the period and magnitude of releases near the SRTC complex to the extent that those at the M-Area Basin have been described (Marine and Bledsoe, 1984). The primary source is believed to be the operation of degreasers located in the Fabrication Laboratory in the basement of 773-A. Spent solvents from this facility were discharged to a "trade waste stream" which led to the present A-01 Outfall. Usage of chlorinated solvent in and around this facility varied from 1954 to 1979 when solvent usage ceased. The surface releases in this area have resulted in the contamination of the shallow Tertiary sediments in the vicinity of the SRTC complex. To address the presence of the dissolved solvent associated with these releases the original pilot scale air stripper used in the Central A/M Area was relocated to the northern portion of A/M Area and is designated as the A1 System. The A1 System along with the recently installed A2 System, provides groundwater remediation within the vicinity of the SRTC complex. This is referred to as the Northern Sector of the A/M Area. The performance and effectiveness of the A1 and A2 Systems has been evaluated through groundwater modeling activities (Haselow et al., 1991) (Jackson and Aleman, 1995). The approach SRS is taking in regards to Northern Sector remediation is to maximize mass removal in the Tertiary sediments using

conventional pump & treat technologies. This approach provides hydraulic control of contaminants in the source area and provides long-term protection for the deeper aquifer system. The presence of DNAPL in the Northern Sector has been suggested using indirect techniques (Jackson et al., 1996b) and would require long-term operation of the pump & treat system. The goal of the pump & treat system is to prevent the further downward migration of contaminants from the shallow Tertiary sediments to the deeper Cretaceous sediments.

The discontinuities of the confining zones associated with the transition of regional geology in the Northern Sector have resulted in the downward migration of a dissolved solvent plume into the upper portion of the Cretaceous age sediments, the Crouch Branch Aquifer. The SRTC releases are considered to be the major source for the deeper Cretaceous contamination present in the Central, Western, and Southern Sectors of the A/M Area. This aquifer is part of the regional hydrologic system that is used both on-site and off-site as a domestic and process water resource. The first indication of solvent contamination in the Crouch Branch Aquifer occurred in July of 1981 when a water sample from production well 905-53A indicated TCE contamination at 10 $\mu g/l$, with subsequent indications reported at production wells 905-20A and 905-31A. To aid in characterizing the extent of the contamination in the Crouch Branch Aquifer several monitoring wells have been installed and multiple bulk soil samples collected (WSRC, 1993a) (WSRC, 1994) and analyzed for volatile organics using a head-space analysis procedure developed at the Savannah River Site. The purpose of these characterization activities is to address specific items in current Part B Permit for the M-Area Hazardous Waste Management Facility. The present groundwater contamination in this aquifer is migrating towards the interior of the site with eventual long-term outcrop in the Crackerneck Swamp near the Savannah River southwest, of the A/M Area. As documented throughout the A/M Area corrective action program (United States Department of Energy, 1988) (WSRC, 1993b) the primary source of the Cretaceous contaminant plume is the past solvent discharges that occurred in the vicinity of the SRTC complex. SRS has pursued an aggressive characterization program to determine the extent of the contamination and the hydrostratigraphy that controls groundwater flow in the Cretaceous Aquifer system (Van Pelt et al., 1993) (Jackson et al., 1996a). The results and information from these investigations are incorporated in the development and evaluation of the remediation program for the Crouch Branch Aquifer. The successful remediation of this aquifer combines the effects of the pump & treat program in the Northern Sector with plume containment and mass removal aspects obtained by the operation of A/M Area production wells 905-20A and 905-53A.



Location and Distribution of Production Wells, Monitoring Wells, and Cretaceous Soil Borings within the A/M Area of the Savannah River Site

Figure 1: Location and Distribution of A/M Area Production Wells, Monitoring Wells, and Soil Borings within the Crouch Branch Aquifer.

Table 1: Source, Type, Distribution, and Remediation Strategy for Sectors in the A/M Area.

Source, Type, Distribution, and Remediation Strategy for Sectors in the A/M Area.				
Sector	**Source of Contamination**	**Type of Contamination**	**Distribution of Contamination**	**Remediation Strategy**
Central	Direct release to subsurface of large quantities of solvent with migration through the vadose zone and into the saturated zone.	DNAPL present in both saturated and unsaturated zone resulting in high aqueous concentrations.	DNAPL directly observed at the M-Area basin with indications that DNAPL is present in solvent use areas, the process sewer, and at disposal areas. Aqueous concentrations typically $\geq 1000\ \mu g/l$ TCE.	Identification and removal of DNAPL in subsurface. Mass removal from dissolved plume using M1 system. Remediation is complemented with SVE operations in the vadose zone. Limited use of cometabolic bioremediation.
Western	Subsurface Migration of DNAPL from M-Area Basin along lithologic strata.	High aqueous levels of concentrations due to subsurface DNAPL along migration path(s).	DNAPL path very thin leaving a "wake" of DNAPL that serves as long term source of contamination.	Identification and removal of DNAPL in subsurface. Recirculation wells proposed for groundwater $\geq 500\ \mu g/l$ TCE.
Southern	Advective Transport from Source Zones in Central A/M Area prior to installation of M1 pump & and treat system.	Aqueous concentrations associated with migration from M-Area Basin and A-14 release zones.	Plume is relatively large and has low concentration values typically on the order of 0-1000 $\mu g/l$ TCE.	Remediation of groundwater $\geq 500\ \mu g/l$ TCE via Vertical Recirculation Wells. Lower concentration portion (0-500 $\mu g/l$) addressed with phytoremediation.
Northern	Direct release to subsurface of small quantities of solvent with migration through the vadose zone and into the saturated zone.	Mostly aqueous with possible DNAPL identified using indirect methods. Residual vadose zone contamination near source is likely.	Localized plume due to downward gradient centered on source area and A1 outfall. Potential for small quantities of DNAPL near release area and A1 Outfall.	Pump & Treat from A1 and A2 systems. Possible deployment of Soil Vapor Extraction System.
Cretaceous	Advective Transport from Northern Sector due to transitional geology near SRTC release zone.	Dissolved Aqueous concentrations.	Large, thin, discrete plume with concentrations ranging from 0-1000 $\mu g/l$ TCE.	Source Zone Removal in Northern Sector with production wells removing significant portion of VOC's in Crouch Branch Aquifer.

3.2 Hydrostratigraphy

The hydrostratigraphy in A/M Area consists of three aquifers of the Floridan-Midville Aquifer System (Lewis and Aadland, 1994) (Aadland et al., 1995a) (Aadland et al., 1995b). Figure 2 presents the discussed hydrostratigraphy in a schematic representation. The aquifers and separating confining units of the Floridan-Midville Aquifer System are comprised of interbedded layers of sands, silts, and clays that are typical of a shallow marine, deltaic depositional environment. The aquifers, in descending order, are the Steed Pond Aquifer, the Crouch Branch Aquifer, and the McQueen Branch Aquifer. The Steed Pond Aquifer is comprised of the regionally defined "M-Area" aquifer zone, the "Green Clay" confining zone, and the "Lost Lake" aquifer zone. The majority of the solvent contamination present in the A/M Area is located within the Steed Pond Aquifer and is the primary target of the current remediation programs. Hydrostratigraphic information on these units is presented in the recent characterization documents (Aadland et al., 1995a) (Aadland et al., 1995b) and have been the focus of previous modeling studies (HydroGeologic Inc., 1996) (Jackson and Aleman, 1995) (Jackson and Looney, 1996). The Steed Pond Aquifer is separated from the Crouch Branch Aquifer by the Crouch Branch Confining Unit.

Within the A/M Area the Crouch Branch Confining Unit is defined by hydrostatigraphic information obtained from monitoring well MSB 42 (Aadland et al., 1995a). At this reference well the unit has an overall thickness of 78 feet and is comprised mainly of interbedded layers of clay and sand. At the reference well there are 5 distinct clay to sandy clay beds that comprise 46 feet of the total section. The presence of these beds have resulted in the division of the Crouch Branch Confining Unit into three hydrogeologic zones within the A/M Area. These three zones are well delineated in the north-central region of the A/M Area. In the western half of the region the individual zones are not delineated due to the absence of the sand beds referred to as the "Middle Sand" aquifer zone of the Crouch Branch Confining Unit. In the northeastern part of the A/M Area the clay beds of the "Upper Clay" and "Lower Clay" zones of the Crouch Branch Confining Unit are thin and or absent. It is in this region where groundwater flow occurs between the overlying Steed Pond Aquifer and the underlying Crouch Branch Aquifer.

The discontinuities and thinning of the Crouch Branch Confining Zone have been recently characterized using surface geophysical methods (Blackhawk Geometrics, 1996) (Eddy-Dilek et al., 1997). These studies were performed at the M-Area Basin, in the Western Sector, the Northern Sector, and at the Miscellaneous Chemical Basin. The purpose was to integrate surface time domain electromagnetic (TDEM) and shear wave reflection surveys with geophysical well log interpretations. These surveys concluded that TDEM conductance provides an accurate measure of the clay content for those sediments in the Crouch Branch Confining Unit. This investigation identified a difference of the facies in the sediments of the Crouch Branch Confining Unit near the vicinity of the SRTC complex compared to those in other parts of the A/M Area. These investigations attributed these changes with changes in stratigraphy and depositional environment. The change of facies from clay to sand in the northeast, as identified in the TDEM investigation, is in agreement with the reported thinning and disappearance of the "Upper Clay" and "Lower Clay" zones towards the northeast (Aadland et al., 1995a). The disappearance of the "Middle Sand" aquifer zone in the western portion of the A/M Area is also reflected by the increased conductance values reported in the TDEM survey.

Beneath the Crouch Branch Confining Unit lies the Crouch Branch Aquifer, formerly known as the *"Upper Tuscaloosa"*. This is the principal water-producing aquifer for the Savannah River Site and surrounding counties. Within the vicinity of the A/M Area the Crouch Branch Aquifer is approximately 300 feet thick having relatively high transmissivity values due to the coarse sand and low clay content of the aquifer. Although comprised mainly of course sand, the middle and lower portions of the aquifer are somewhat heterogeneous with layers of silt, clay, and sandy-clay present. Within the vicinity of the SRTC complex the clays of the Crouch Branch Confining Unit become thin and discontinuous, creating a strong

downward gradient between the Steed Pond Aquifer and the Crouch Branch Aquifer. As a result a thin, discrete plume of dissolved contaminants is present in the Crouch Branch Aquifer. The principle source for this plume is the numerous releases of unknown magnitude within the vicinity of the SRTC complex. SRS is currently assessing the extent of contamination in the Crouch Branch Aquifer with current remediation programs targeting the source of the contamination in the above Steed Pond Aquifer.

The McQueen Branch Confining Unit separates the Crouch Branch Aquifer from the deeper McQueen Branch Aquifer. Within the A/M Area the McQueen Branch Confining Zone is at a depth of 480-500 feet below the land surface and consists of silty sandy dark clays. In stratigraphic terms the McQueen Branch Confining Zone is considered to be in the middle portion of the Black Creek formation. In the A/M Area the McQueen Branch Confining Unit consists of an approximately 35-foot thick bed of clay and silty clay. Below the McQueen Branch Confining Unit is the McQueen Branch Aquifer, formerly known as the *"Lower Tuscaloosa"*. Within the A/M Area the McQueen Branch Aquifer is approximately 180-feet thick and consists of medium to very coarse-grained, very poorly to moderately sorted, slightly to moderately indurated pebbly sands. Within the A/M Area the hydraulic heads in the Crouch Branch Aquifer are on the order of 7-8 feet greater than those in the McQueen Branch Aquifer. This naturally occurring downward gradient between the Crouch Branch Aquifer and the McQueen Branch Aquifer serves as a potential driving force for migration in areas where the competency of the McQueen Branch Confining Unit has been compromised. Along with the Crouch Branch Aquifer, the McQueen Branch Aquifer is also used as a regional groundwater resource.

In April of 1983 a pumping test was performed to determine the hydraulic characteristics of the Crouch Branch and McQueen Branch Aquifers (Geraghty & Miller, 1983b). The objective of this test was to determine hydraulic properties of the *"Tuscaloosa"* Formation. As presented, the current hydrostratigraphic interpretation (Aadland et al., 1995a) formally delineates the *"Tuscaloosa"* formation into upper and lower sections known as the Crouch Branch and the McQueen Branch Aquifers. The *"Tuscaloosa"* formation is characterized by beds of fine to coarse grained quartz sand and gravel interbedded and intercalated with kaolinitic clays and silts. The pump test was conducted using production well 905-20A with water levels measured in the other production wells and in several surrounding monitoring wells. The data obtained from this test indicates that the average transmissivity value of the *"Tuscalossa Aquifer"* is 79,000 gpd/ft. The results from this test indicates that the aquifer system is generally confined with a small amount of leakance received from the overlying Tertiary Aquifer System (Geraghty & Miller, 1983b).

3.3 Groundwater Flow Patterns

Since the principle component of contaminant migration in the A/M Area is advective transport, understanding of local and regional groundwater flow patterns is vital in assessing the extent and distribution of contamination. Within the A/M Area, The flow of groundwater in the McQueen Branch and Crouch Branch Aquifers are controlled by numerous local and regional parameters. These parameters include the influence of the Savannah River to the west of the A/M Area, the identified facies change of the Crouch Branch Confining Zone in the northeast portion of the A/M Area, and the strong downward gradient in the Tertiary sediments that is characteristic of the entire A/M Area.

3.3.1 Tertiary (Steed Pond) Aquifer System

The majority of the groundwater contamination in the A/M Area is located in the Steed Pond Aquifer and is the target of current remediation activities. This aquifer contains the water-table unit. In the Central A/M Area the Steed Pond Aquifer is divided into the M-Area and the Lost Lake aquifer zones, which are separated by the Green Clay confining zone. Towards the north, in the vicinity of the SRTC complex, these units are not well distinguished and the unit is treated as one aquifer unit. The elevated

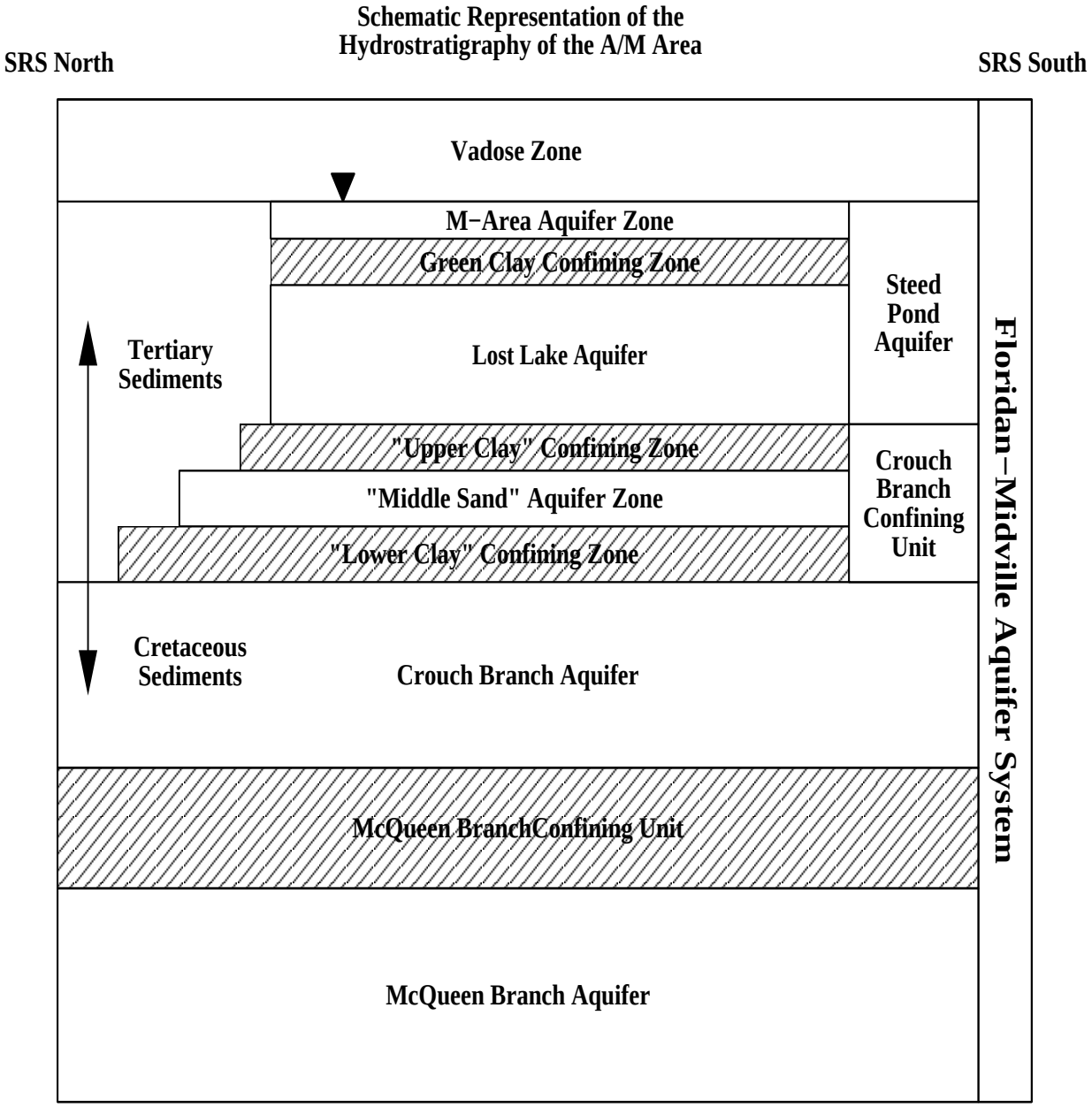


Figure 2: Hydrostratigraphy of the A/M Area

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topography, location of drainage features, and the numerous interbeded layers of sands, silts and clays combine to create a predominately downward flow direction within the aquifer. The potentiometric surface for this aquifer is presented in Figure 3 and represents water-table conditions prior to activation of the expanded A2 system near the SRTC complex. As shown in this figure the highest water levels are on the order of 240 feet with the effects of recovery wells in the Central A/M Area easily observed. Near the SRTC complex the water table is at an elevation of approximately 235 feet above mean sea level.

3.3.2 Crouch Branch Aquifer

As shown in Figure 1 numerous monitoring wells are screened within the Crouch Branch Aquifer within the A/M Area. These wells are fundamental in determining local values of hydraulic heads and subsequent principle directions of contaminant transport. As presented by previous investigators, the general groundwater direction in the Crouch Branch Aquifer is towards the interior of the site in a southwest direction (Aadland et al., 1995a) (Aadland et al., 1995b) (Jackson et al., 1996a). This flow direction is presented in Figure 4 which depicts the potentiometric surface for the Crouch Branch Aquifer as determined from monitoring wells within the A/M Area. This representation of groundwater conditions is accurate on a local scale and is in agreement with previous investigations. Due to the proximity of the site boundary with relation to the A/M Area, valid concerns are often raised as to the potential for off-site migration to the north and west of the A/M Area. The most likely pathway for this migration is in the Crouch Branch Aquifer. Offsite migration of contamination in this aquifer would be controlled by the regional hydraulic gradients and discharges. Unfortunately a limited amount of quantitative data is available north and west of the A/M Area and investigators must resort to qualitative information to cost-effectively resolve these concerns. With regards to the hydraulic heads in the Crouch Branch Aquifer, the outcrop of the Crouch Branch Confining Unit near the intersection of Hollow Creek and the Savannah River provides additional control on the potentiometric distribution in the Crouch Branch Aquifer. The outcrop locally elevates the heads in the Crouch Branch Aquifer higher than those previously presented near the outcrop zone (Aadland et al., 1995a, Plate 45). The effects of these elevated heads are presented in Figure 5 which combines the monitoring well data in A/M Area with a liberal estimate of heads in the outcrop region. This figure also incorporates hydraulic control in both the General Seperations and B-Area from observations at well clusters P-28 and P-29. The overall result is a westward gradient north of Site Road 1 that turns towards the west-southwest south of Road 1. Within the A/M Area there is no appreciable change in potentiometric surface as a result of the additional control at the outcrop zone. Monitoring wells MSB 55TA, MSB 29TA, MSB 43TA, and MSB 30A provide sufficient hydraulic control along the northwestern edge of the A/M Area to verify that the effects of the outcrop zone do not effect the historically presented flow direction in the A/M Area. Even though a potential westward migration path exists for contamination located north of Site Road 1, the possibility of offsite migration of contamination is extremely low. This is based upon historical groundwater concentrations from monitoring wells, depth-discrete soil sampling, and the proximity of the source zone with respect to the hydraulic gradient. These parameters are discussed in depth in subsequent sections of this report.

3.3.3 McQueen Branch Aquifer

Since the number of wells screened solely in the McQueen Branch Aquifer is extremely limited within the A/M Area, hydraulic conditions are derived and adopted from regional hydrogeologic investigations (Aadland et al., 1995a, Plate 46.). As presented in Figure 6 the general direction of groundwater flow in the McQueen Branch Aquifer is towards the southwest. The heads vary linearly towards the southwest from an estimated 204 feet near soil boring MCB 9SB at the extreme northeast to an estimated 188 feet in the extreme southwest. Within the A/M Area, the heads in the McQueen Branch Aquifer are on the order of 0-12 feet less than those in the above Crouch Branch Aquifer. The magnitude and distribution of the head difference between Crouch Branch Aquifer and the McQueen Branch Aquifer is presented in Figure 7. As presented in this figure, the head difference in the vicinity of the A/M Area production wells is on the order of 4-6 feet. This is the driving force responsible for the downward migration of

contamination from the Crouch Branch Aquifer into the McQueen Branch Aquifer during idle periods for those production wells screened in both aquifer zones.

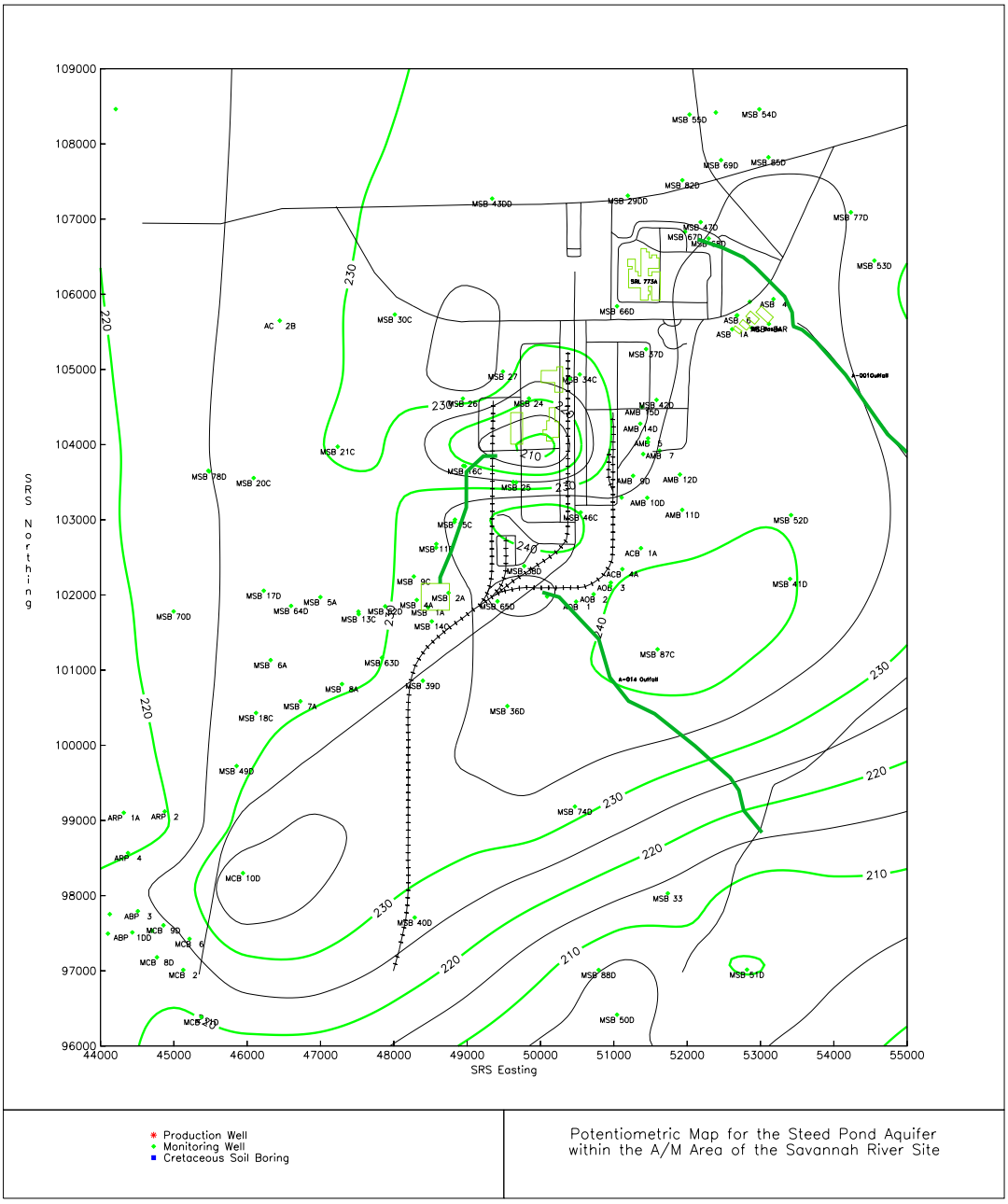


Figure 3: Potentiometric Map for the Tertiary (Steed Pond) Aquifer within the A/M Area.

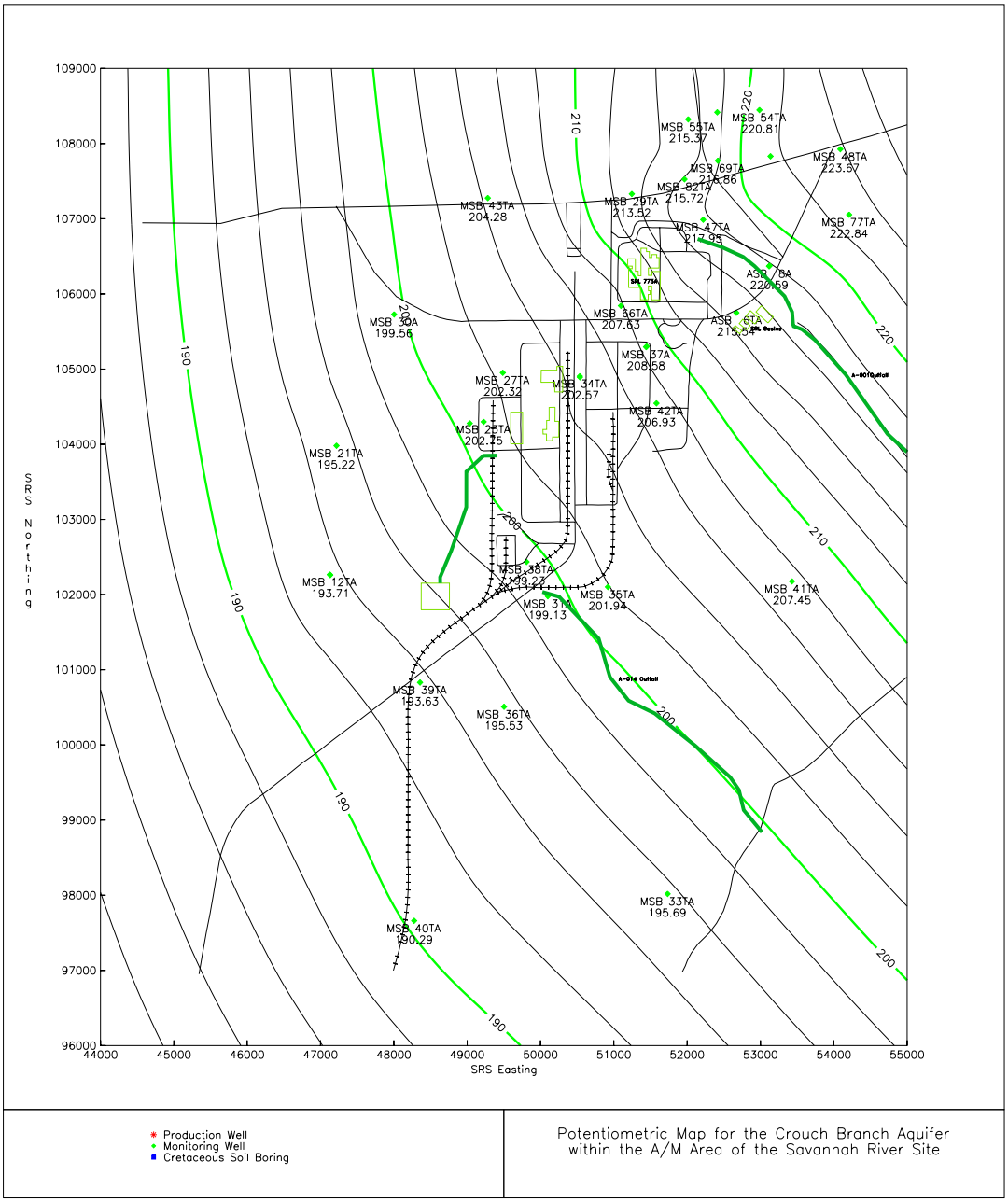


Figure 4: Historical Potentiometric Map for the Crouch Branch Aquifer within the A/M Area derived without additional control offered at the outcrop region near Hollow Creek (Data derived from Average 1996 Heads).

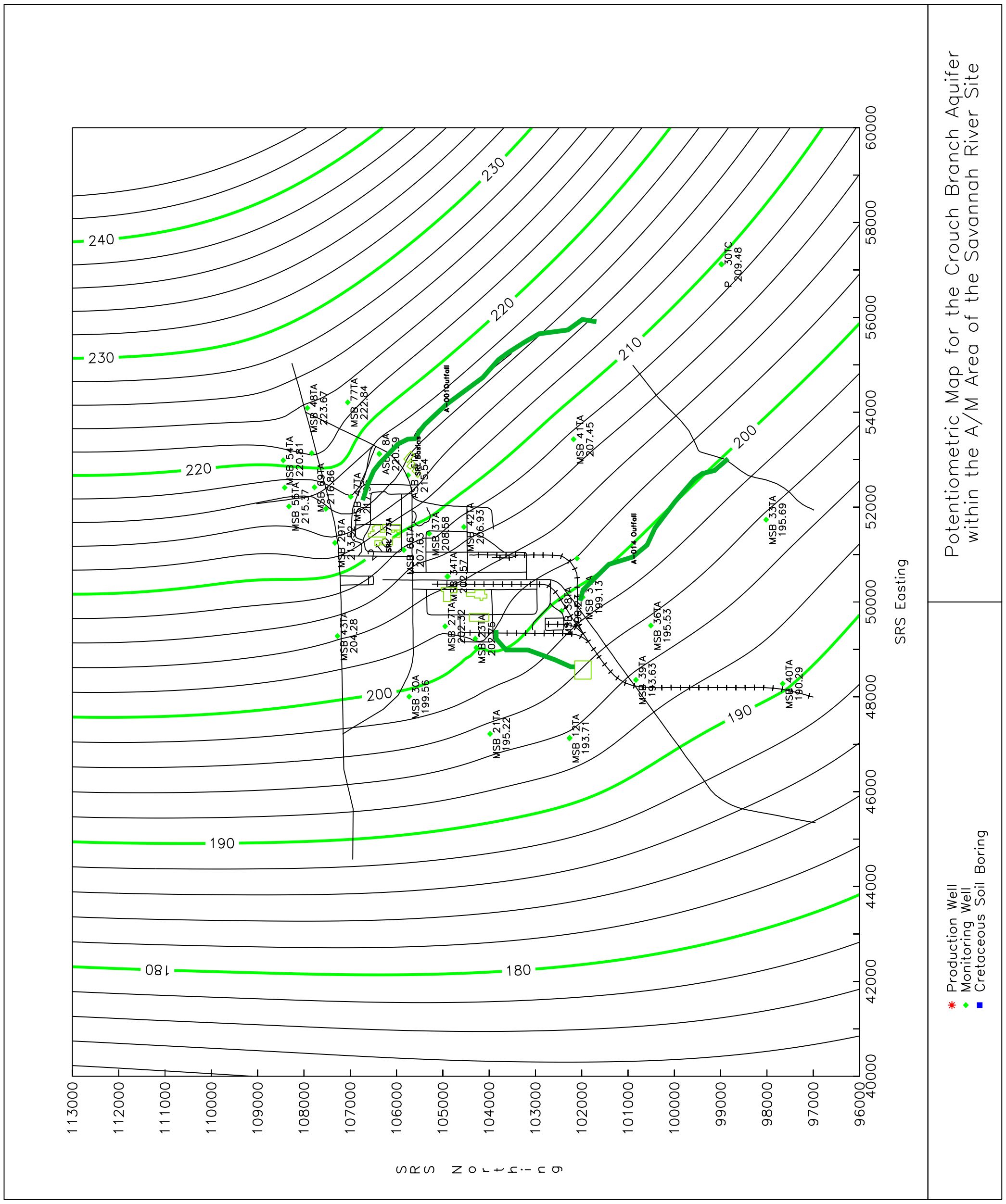


Figure 5: Potentiometric Map for the Crouch Branch Aquifer within the A/M Area incorporating additional control to the northwest at the outcrop region near Hollow Creek (Data derived from Average 1996 Heads).

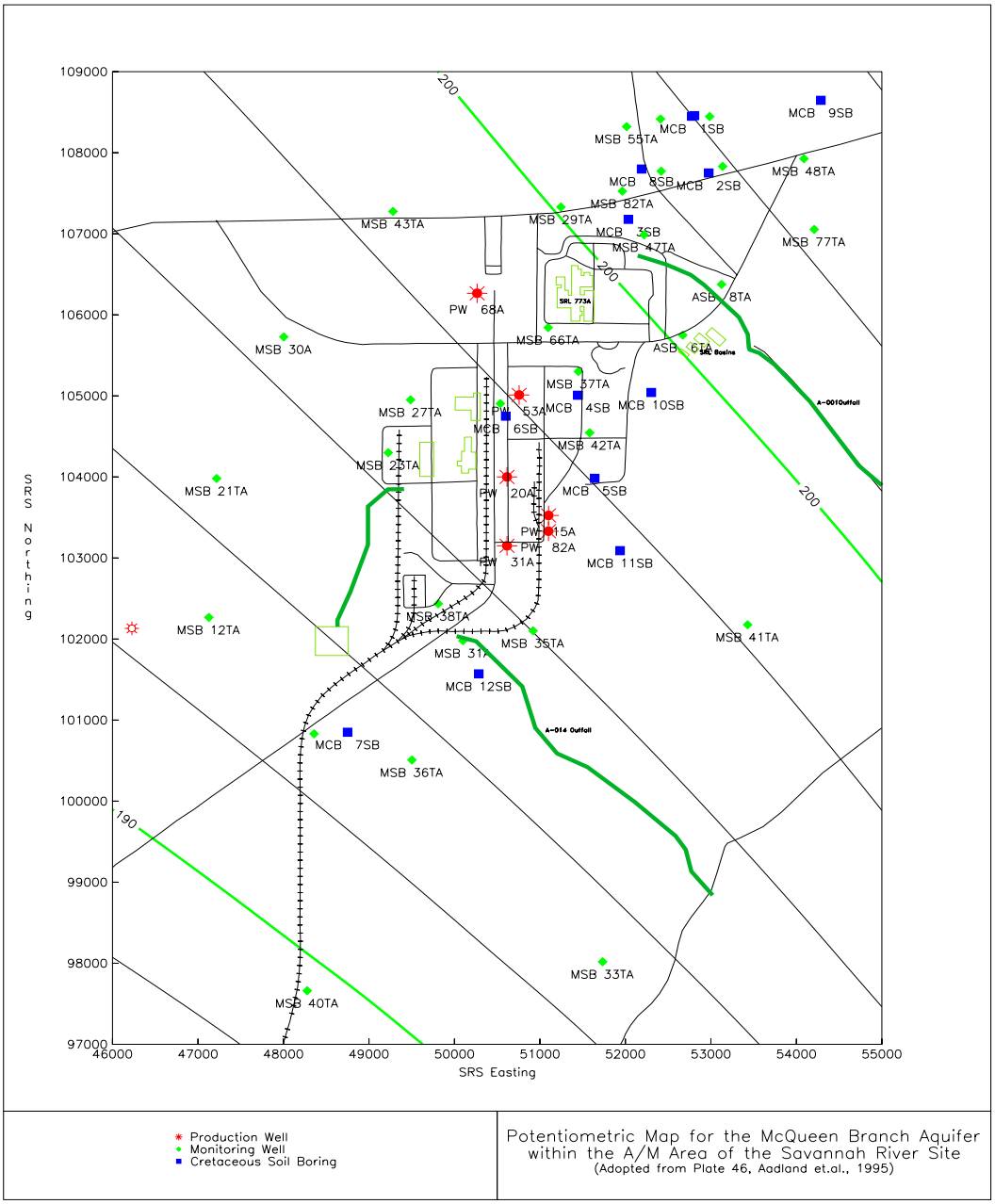


Figure 6: Potentiometric Map for the McQueen Branch Aquifer within the A/M Area.

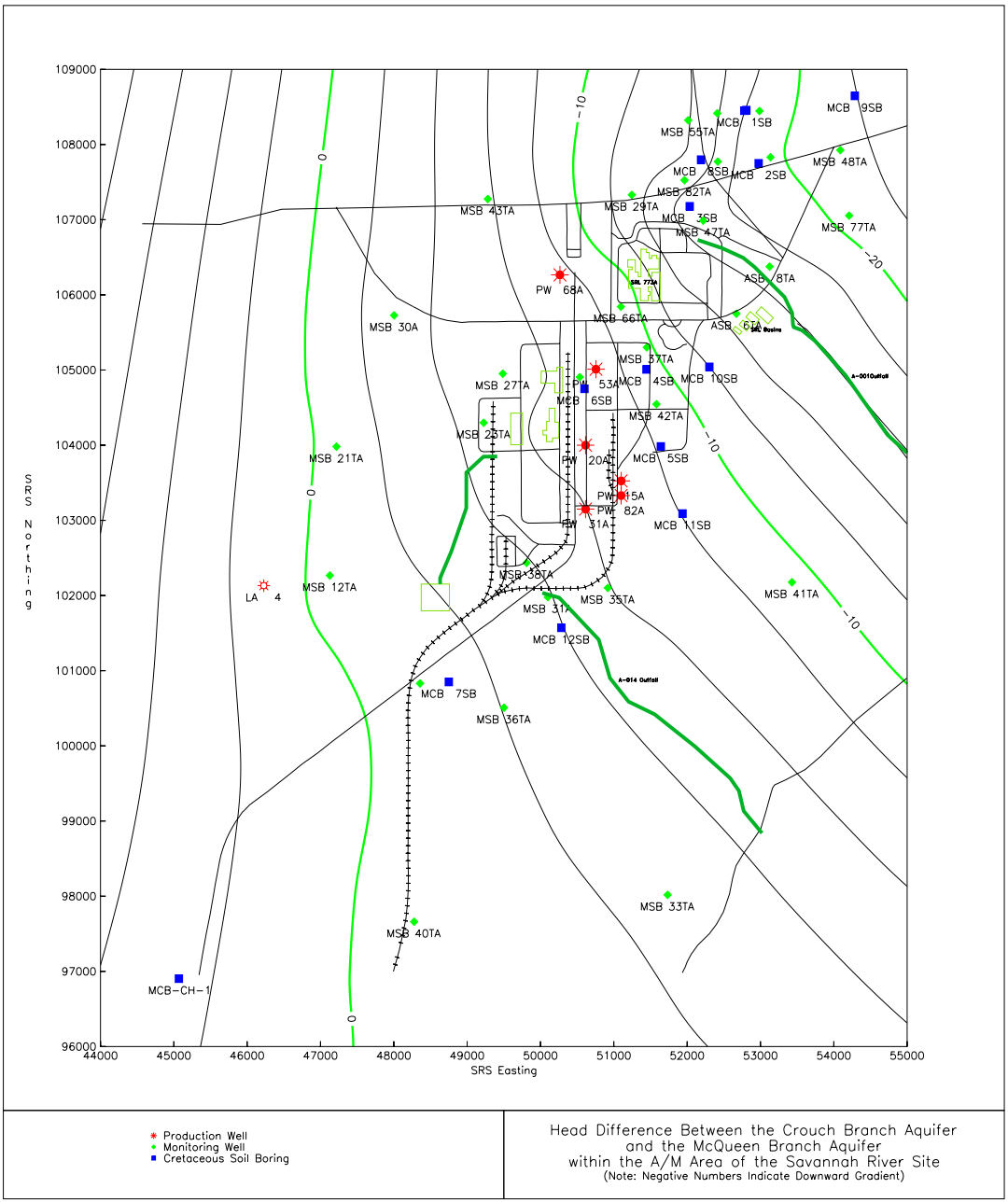


Figure 7: Difference Between the Potentiometric Head in the Crouch Branch Aquifer and the McQueen Branch Aquifer within the A/M Area (Negative Numbers indicate Downward Hydraulic Potential).

3.4 A/M Area Production Well System

The production well system in the A/M Area consists of a series of wells that are used to provide domestic and process water for operations in the A/M Area of the Savannah River Site. As presented in Figure 1, the production wells are located in the central portion of the A/M Area. The production well system was installed in the early 1950's during the initial construction phases of the plant. The system originally consisted of wells 905-15A, 905-20A, 905-31A, and 905-53A. With the exception of 905-15A, which is located entirely in the Crouch Branch Aquifer [*Upper Tuscaloosa*], the original wells were installed with screen zones in both the Crouch Branch and the McQueen Branch Aquifers [*Upper* and *Lower Tuscaloosa*]. The downward gradient between the Crouch Branch Aquifer and the McQueen Branch Aquifer creates a conduit for flow between these two zones during idle periods. Wells incorporating this type of screen design are no longer constructed in the water supply industry. The original production well system was expanded in the mid-1960's when well 905-68A was installed in the Crouch Branch Aquifer [*Upper Tuscaloosa*] to serve as a backup source of water for the Site's Emergency Response Center. During this same period, production well 905-15A was removed from service and placed in a standby status. In July of 1977 production well 905-82A was installed with screen zones located entirely in the McQueen Branch Aquifer [*Lower Tuscaloosa*]. In November of 1988 production well 905-31A was removed from service and placed in a standby status. Currently production wells 905-20A, 905-53A, 905-68A, and 905-82A are operated. Production well 905-15A was formally abandoned in FY96 and well 905-31A was abandoned in FY97. Production well 905-82A is used as a source of domestic water and has been incorporated into a recently installed domestic water loop. Production wells 905-20A and 905-53A provide process water on an as needed basis with one well typically in operation.

In addition to the six production wells in the Central A/M Area, an additional production well exists. This well is designated as LA-4 and, as shown in Figure 1, is located west of the M-Area Basin near monitoring well MSB 12TA. Available records describing this well are limited, with the best resource being the United States Geological Survey, Water Resource Division, South Carolina District office in Columbia, South Carolina. The well is owned by the Department of Energy, Savannah River Site. Based upon records on file with the USGS, the well was installed in February 1951 as an early production well for the Savannah River Plant. There is no information indicating that the well was ever used for process operations at the Savannah River Plant. The well is constructed in a manner similar to other production wells in the A/M Area, only with less screen zones. According to the USGS records, LA-4 is a drilled observation well with 18 inch casing from the surface to 318 feet. The well has an 8 inch lower casing from 279 to 605 feet. The well has screens located at 390-400, 455-465, and 590-600 feet below the land surface. Since May of 1952 the USGS has maintained continuous water level data with summaries published as part of the annual hydrologic conditions in South Carolina. In it's history the well has been identified as SRP-4M and AK-2. Currently the well is recognized by the USGS as AK-430 and by the identification number 331940081443501.

3.4.1 Production Well Design

The early production wells in the A/M Area were installed with multiple screen zones in the Crouch Branch and McQueen Branch Aquifers, formally referred to as the *"Upper Tuscaloosa"* and *"Lower Tuscaloosa"* respectively. By examining available records that document the as-built conditions of the production wells, several general comments regarding the method of construction can be formed. The production wells are constructed in two sections, a large diameter upper section that is grouted into the Tertiary sediments and a smaller diameter lower section that penetrates the deeper Crouch Branch and McQueen Branch Aquifers. The as-built records indicate that the upper sections were generally installed to and firmly grouted into the "Lower Clay" zone of the Crouch Branch Confining Unit, formally referred to as the *"Ellenton Clays"*. Once below this clay zone, the bore for the lower section was under-reamed and a series of screens and casing installed. After installation of the lower section, a continuous gravel pack was installed along the length of the lower section from the maximum depth to the upper most

screen zone. The screen zones are connected by this continuous gravel pack. The continuous gravel pack installed at production wells 905-20A, 905-31A, and 905-53A connects the Crouch Branch Aquifer and the McQueen Branch Aquifer at these locations. It is unknown whether well LA-4 has this continuous gravel pack feature. During periods of well operation these effects are insignificant, however during idle periods the head difference between the two aquifers serves as a driving force for the movement of groundwater via the wellbore. Table 2 presents the specific design features of each of the production wells. As shown in Table 2, each of the production wells has a 5 foot screen section that is typically located at the lap-joint between the upper and lower casings. The exact purpose of this screen is unknown and it is very unlikely that this "weep screen" contributes to the production capacity of the wells. Modern wells no longer incorporate this feature.

3.4.2 Video Surveys, Packer Testing, & Vertical Velocity Profiles

The presence of downward flow in the idle production wells was initially documented in 1983 with the data obtained from a vertical velocity survey performed in well 905-53A (Geraghty & Miller, 1983a). The data from this survey revealed that between 430 feet to 640 feet below grade, the average downward velocity was 7 feet per minute, or approximately 28 gallons per minute in the 10-inch wellbore. In December of 1983, Geraghty and Miller performed a series of tests to determine the condition of production well 905-53A. These tests included a TV camera survey, packer testing, and a variety of geophysical logging including a fluid velocity log (Geraghty & Miller, 1983a). This data supports the hypothesis that during idle periods downward flow exists from the Crouch Branch Aquifer into the deeper McQueen Branch Aquifer via the wellbore of production well 905-53A. To confirm this theory, the series of tests performed by Geraghty and Miller in 1983 at production well 905-53A were repeated at each of the A/M Area production wells during 1996 (Jackson et al., 1996a). The purpose of these tests were to identify those production wells that contained VOC contamination and to facilitate modifications necessary to prevent downward flow during idle periods. The nature, purpose, and results of these tests are summarized below.

Downhole Video Surveys The purpose of this survey was to allow a visual inspection of the internal condition of each wellbore. Since several of the wells involved with this program were installed in the early to mid 1950's the possibility exists for some form of internal wellbore damage. The down-hole video surveys provided rapid assessment of the internal condition of the wellbore, condition of telescoping joints, and provided a confirmation on the elevation and type of screen zones for later sampling. During this test a video camera was lowered into the wellbore, recording and documenting these parameters. Video surveys were performed on both the surface and lower casings at production wells 905-15A, 905-20A, 905-53A, and 905-82A and the regional observation well LA-4. Due to well deviations associated with installation and drilling, the lower casing of production well 905-31A was not initially inspected. The surveys confirmed the documented as-built conditions with regards to screen elevations with no significant damage identified. The video surveys were performed by Deep Venture of Perry, Florida and Graves Environmental of Jackson, South Carolina to verify and validate the conditions of each well.

Production Well 905-15A During the video survey the screen zones at 265 feet and 380 feet were not identified. The shutter screen zone beginning at 422 feet was identified. During the video survey it was observed that this screen zone was fouled with debris and appeared to be completely plugged. It is very likely that similar fouling has occured in the first and second screen zones which would make visual detection extremely difficult. The well bore was filled in with sediment at a depth of 445 feet preventing surveying below this depth. There was no damaged or defective casing observed in either the upper or lower casing during the video survey.

Production Well 905-20A As a result of the video survey at production well 905-20A, a brass pump strainer was discovered and removed in the bottom of the well. The screen zones in this well were readily

observed. The screens in the upper section were clean with no evidence of plugging or fouling. The screens zones located in the deeper section were slightly plugged, possibly due to the presence of the pump strainer that was removed. Based upon the observed screen conditions the upper screen zones probably contribute more to well production than the lower screens. During the course of the investigation a small amount of sediment was air lifted out of the bottom of the well and the lower screen sections were cleaned with a wire-brush.

Production Well 905-31A Initially video surveying at production well 905-31A were not completed due to deviations in the wellbore. Several attempts were made to transgress the lap-joint between the 18 inch upper casing and the 8 inch lower casing. A spool-piece was installed at the lap-joint and the video survey was performed prior to well abandonment. During this survey the screen zones were recognizable; however, there was evidence of plugging and fouling similar to that observed at 905-15A.

Production Well 905-53A The video survey performed at 905-53A identified screen zones as presented, with no evidence of plugging or fouling in any of the screen zones. This is associated with well maintenance and cleaning activities that occured in April of 1994.

Production Well 905-82A During the course of the current investigation production well 905-82A was removed from service for maintenance. As a result a video survey was performed and screen conditions were found to be as reported with no evidence of plugging or fouling.

Observation Well LA-4 During the video survey of LA-4 it was discovered that the 8 inch lower casing begins at a depth of 234 feet instead of 279 feet as reported by the USGS. The lower casing was positioned off-center which made access to the lower section difficult. Graves Environmental installed a centering piece at the lap-joint to aid access to the lower casing. During the video survey of the lower casing no screen zones were observed. However, turbid water conditions and the amount of casing fouling are factors that severely prohibited the identification of screen zones. At a depth of 548 feet camera blackout occured indicating that sediment had filled the bottom 57 feet of the well, including the 590-600 foot screen section.

Packer Testing of Upper Casing The purpose of this test was to identify any possible leaks in the surface casing that is grouted into the Tertiary sediments of the A/M Area. During this test a large packer was installed and inflated inside the surface casing immediately above the top of the lower casing. The surface casing was then filled with water to an elevation slightly above the standing water level in the Tertiary zone(Steed Pond Aquifer). The water level in the wellbore was then observed and monitored for leaks. This test was performed on production well 905-20A and 905-53A and regional observation well LA-4 with no noticeable decline in the observed water level. This test was previously performed on production well 905-53A (Geraghty & Miller, 1983a) and as reported the water level dropped to 90 ft. below the land surface before stabilizing. This drop was previously identified as a possible leak in the upper casing at this depth. This drop in water level was not observed in the testing performed in 1996 and is believed to be a result of improper packer setting during the 1983 test. As a result of these tests there is no evidence that the surface casing in the Steed Pond Aquifer is leaking, and thus contributing to the contamination in the Crouch Branch Aquifer.

Profile of Vertical Flowrates The purpose of this activity was to measure the magnitude of the vertical flowrate in the wellbore of idle production wells between the Crouch Branch and the McQueen Branch Aquifers. This data, coupled with water sample analysis, allows researchers to develop both a qualitative understanding of the dynamics of the system as well as providing invaluable data for estimating the amount of contaminant that has moved into the McQueen Branch Aquifer. This bulk estimate regarding the amount of contaminant is necessary to develop any future actions regarding the

McQueen Branch Aquifer. The profile of vertical flowrate was obtained by lowering a flowmeter inside the wellbore from the bottom of the well to the lap joint between the upper and lower casing. Measurements of the vertical velocity were made across the entire screen interval and have been combined with well construction data and discrete wellbore samples to assist researchers in understanding the dynamics of contaminant migration in the McQueen Branch Aquifer.

The vertical velocity profiles were performed using a 9710 Logging Tool available from Century Geophysical Corporation (See Appendix A). This tool uses a 256-pulse-per-revolution optical encoder to measure flows in the range of 2 to 200 feet per minute. The tool incorporates an impeller such that a linear relationship between flow in the wellbore and counts per revolution is readily maintained. The average vertical velocity in the wellbore was determined by traversing the tool a number of times from the bottom of the well to the lap joint at various, constant speeds. The corresponding results from each run were used with linear regression techniques (Holman and Gajda, 1989) to obtain the average vertical velocity profile across the screen section and then normalized with the logging speed to obtain the distribution of vertical velocity in each wellbore. Table 3 presents a summary of the regression coefficients for the vertical velocity data collected.

Production Well 905-15A The average vertical velocity in production well 905-15A was determined using velocity measurements at average line speeds of 15, 30, and 45 feet per minute. The results of these tests are presented in Figure 8. As shown in the log presented on the left, the raw velocity data increases uniformly in magnitude with increasing log speed, providing an intuitive confirmation on the linear aspect of the tool. As presented in Table 3 the correlation coefficient for the linear least squares regression for this data is 0.9962 and provides quantitative information on the linearity of the tool. With the exception of noise, most likely associated with water quality issues, the constant signal associated with the raw data indicates that there is not a significant change of velocity across the length of the well. The suite of logs presented in the middle of Figure 8 presents the normalized velocity for each of the three logging speeds with the average velocity presented in the strip log on the right hand side of Figure 8. Regions of downward flow are identified in the log of average velocity by those regions having a positive value. These regions are shown as filled regions in Figure 8. As presented in Figure 8 a slight downward velocity exists between the uppermost screen, at the lap-joint, and the top of the screen section beginning at a depth of 380 feet. The magnitude of this velocity is less than 4 feet per minute and may be associated with the slight downward gradient present within the Crouch Branch Aquifer.

Production Well 905-20A The average vertical velocity in production well 905-20A was determined using velocity measurements at average line speeds of 15, 30, and 45 feet per minute. The results of these tests are presented in Figure 9. Unlike the results presented for 905-15A, the results from production well 905-20A show a dramatic and reproducible increase in velocity beginning at a depth of 430 feet and reaching a maximum at a depth of 470 feet. As shown in Figure 9 and as presented in Table 2 this interval corresponds to the screened interval in the Crouch Branch Aquifer. The velocity magnitude is constant between the interval from 470 feet to 510 feet. The magnitude of this velocity is in the 6-8 feet per minute range and is associated with the head difference between the Crouch Branch Aquifer and the McQueen Branch Aquifer. With an 8 inch wellbore this corresponds to a flowrate of 23,000 gallons per day during idle periods. Between 510 feet and 550 feet the magnitude of the velocity decreases. The decrease in velocity in this interval corresponds to the first section of screen in the McQueen Branch Aquifer. Below this region no significant velocities are measured. The rapid decrease in velocity in the upper screen section may be associated with fouling of the lower most screen zones as observed during video surveys.

Production Well 905-53A The average vertical velocity in production well 905-53A was determined using velocity measurements at average line speeds of 15, 30, 45, and 60 feet per minute. The results of these tests are presented in Figure 10. As presented in this figure the downward velocity steadily

increased between depths of 410 feet and 470 feet and corresponds with those screens located in the Crouch Branch Aquifer. Between depths of 470 feet and 520 feet the velocity is uniform and begins decreasing at the elevation of the first screen in the McQueen Branch Aquifer. Unlike the rapid decrease in velocity observed at production well 905-20A, the velocity at 905-53A slowly decreases across the entire screened interval in the McQueen Branch Aquifer. This decrease is attributed to screen conditions at 905-53A, which were cleaned in April of 1994. At the elevation of the McQueen Branch Confining Unit the downward velocity in the wellbore is on the order of 16-18 feet per minute. With a 10 inch wellbore this corresponds to a flowrate of 95,000 gallons per day during idle periods.

Production Well 905-82A The average vertical velocity in production well 905-82A was determined using velocity measurements at average line speeds of 15 and 30 feet per minute. The results of these tests are presented in Figure 11. This production well is screened entirely in the McQueen Branch Aquifer. As presented in Figure 11, no appreciable amount of downward flow exists in the wellbore of this well during idle periods. The velocity indications between 670 and 680 feet are associated with end effects and are not considered valid.

Production Well 905-31A Due to deviations in the well-bore the lower screen section of production well 905-31A could not be accessed with the logging tool. As a result velocity profiles are not available. Using the velocity results obtained at production well 905-20A and 905-53A and the results of the video surveys, it is possible to develop some general conclusions on what the velocity profile would be. As presented in Table 2 production well 905-31A only has 10 feet of active screen in the Crouch Branch Aquifer. Downward velocities in the well-bore should increase rapidly in this section, not quite reaching the magnitude observed at 905-20A. The suspected decrease in velocity is a result of the shorter screen section and the lower head difference between the aquifers as presented in Figure 7. Once in the McQueen Branch Aquifer the velocities should decrease uniformly across the entire screen length, however as observed at 905-20A, screen conditions may have a significant impact on the rate at which the velocity decreases.

Observation Well LA-4 Numerous unsuccessful attempts were made to log the velocity profile in observation well LA-4. The results of these tests were variable and could not be duplicated. The extent of biological fouling in the wellbore has a direct effect on the impeller used to measure flow. Numerous runs were made only to discover that the impeller had been blocked by debris. As a result no vertical velocity logs are available for observation well LA-4. Based upon depth discrete concentrations collected from the well-bore and visual observations during the video surveys, regional observation well LA-4 does not have strong communication with the Crouch Branch Aquifer. Supplementing this is the location of the observation well with respect to the region of downward gradient between the Crouch Branch and the McQueen Branch Aquifers. As shown in Figure 7, this well is located in a region were the heads in the lower McQueen Branch Aquifer are on the order of 1 foot higher than those in the upper Crouch branch Aquifer.

3.5 Modifications to the A/M Area Production Wells

As a result of the data collected during this investigation, the Site's Environmental Restoration Department sponsored the installation of commercial packers and check valve assemblies in the two production wells identified as the primary source of contamination to the deeper McQueen Branch Aquifer zone. Modifications were made to production wells 905-20A and 905-53A. These modifications prevent the future downward migration of contaminants via the well-bore while satisfying A/M Area water production demands. The installed configuration allows for the continued removal of contamination already present in the Crouch Branch Aquifer, while preventing downward migration to the McQueen Branch Aquifer during idle periods. In addition to these modifications, production well 905-31A, which may have contributed to contaminant migration, was abandoned in FY97. During the investigation,

production well 905-15A, which is not contributing to the migration of VOC contamination to the McQueen Branch Aquifer, was abandoned during FY96. Wells 905-15A and 905-31A were no longer required to satisfy the water demands of A/M Area and were identified as production wells that *may* be contributing to the migration of contaminants. The possibility of contributing to contamination of the McQueen Branch Aquifer led the Environmental Restoration Department to sponsor the abandonment of 905-15A in FY96 and the abandonment of 905-31A in FY97. The primary reason for abandonment of these wells was the reduction of production needs in the A/M area.

Production Well 905-15A and 905-31A Production well 905-15A was abandoned in FY96 under the direction of WSRC EMS personnel. The well has been out of service since the late-1960's. The surface casing is firmly grouted into the Tertiary sediments and the video survey does not indicate any damaged surface casing. The well has screen zones entirely in the Crouch Branch Aquifer and was abandoned and sealed using cement grout installed from the bottom upward. There are several reasons that a well should be carefully sealed when abandoned. These include the elimination of physical hazards, conservation of aquifer yield, maintenance of confined head conditions, or the prevention of cross-communication between two aquifers. In regards to well abandonment in the A/M Area, prevention of cross-communication between two aquifers is of greatest importance due to the presence of VOC contamination in certain aquifer zones. Consideration for cross communication between aquifer zones was necessary for the abandonment of production well 905-31A. As a result, the integrity of the McQueen Branch Confining Unit needed to be considered during the abandonment process. Abandonment of this well was sponsored by the Environmental Restoration Department and was performed by the Site Utility Department under Method 4 of Scope of Work AID-SUD-965048. This abandonment procedure calls for the perforation of the casing at the elevation of critical confining zones and the injection of grout into these regions. During the abandonment of production well 905-31A, strip perforations were made in the 8 inch casing from 470 feet to 490 feet below the land surface. The wellbore was then filled with grout to this depth and temporary packers were used above this region to inject grout through the perforations and into the formation, effectively restoring the integrity of the confining zone. Once injection of the grout at this depth was completed the wellbore was grouted to the surface.

Production Well 905-20A and 905-53A As a result of the identified pathway via the well-bore of the idle production well and the confirmed presence of VOC contamination in the Crouch Branch Aquifer, the Site's Environmental Restoration Department sponsored the installation of commercial packers and check valve assemblies in 905-20A and 905-53A. These two wells are to be the main source of service water once the new consolidated domestic water system is completed. The installed equipment prevents the future downward migration of contaminants via the well-bore while satisfying A/M Area service water demands. The assembly consists of a commercial check valve that is installed with a packer at the elevation of the McQueen Branch Confining Zone. During well operation the check valve is open and water is extracted from both the Crouch Branch and the McQueen Branch Aquifers. Performance tests performed after installation did not show significant reductions as a result of assembly installation. During periods when the wells are not pumped the check valve closes due to the naturally occurring gradient between the Crouch Branch and the McQueen Branch Aquifer. This action prevents the downward vertical migration via the well-bore during idle periods.

Observation Well LA-4 Based upon depth discrete concentrations collected from the well-bore, visual observations during the video surveys, and likelihood of an upward gradient at this location, regional observation well LA-4 does not have strong communication with the Crouch Branch Aquifer. As a result the well is not contributing to migration of contaminants into the McQueen Branch Aquifer and the USGS has reinstalled groundwater level instrumentation at the wellhead.

Table 2: Summary of A/M Area Production Well Construction Design Information.

	905-15A	**905-20A**	**905-31A**	**905-53A**	**905-82A**
SRS Drawing #	W165134	W165132	W165133	S5-7-501	S5-7-2158
Design Capacity	450 gpm	1000 gpm	1000 gpm	1500 gpm	1000 gpm
Date of Installation	4/16/51	8/9/51	12/4/51	5/17/57	7/11/77
Surface Elevation	376.5 ft msl	371.8 ft msl	374.6 ft msl	381.8 ft msl	375.5 ft msl
Total Depth	467 ft	674 ft	687 ft	667 ft	710 ft
Surface Casing Depth	280 ft	411 ft	427 ft	400 ft	460 ft
Surface Casing Diameter	18 in	18 in	18 in	20 in	18 in
Surface Casing Bore	24 in	24 in	24 in	26 in	22 in
Inner Casing Depth	241 - 467 ft	350 - 667 ft	377 - 687 ft	350 - 665 ft	410 - 695 ft
Inner Casing Diameter	8 in	8 in	8 in	10 in	10 in
Inner Casing Bore	17 in	30 in	17 in	30 in	30 in
Zone of Gravel Pack	264 - 467 ft	365 - 667 ft	397 - 687 ft	400 - 665 ft	420 - 710 ft
Screen Zones	277 - 282 ft	387 - 392 ft	412 - 417 ft	385 - 390 ft	445 - 450 ft
	392 - 422 ft	411 - 441 ft	442 - 452 ft	423 - 428 ft	496 - 506 ft
	422 - 462 ft	441 - 461 ft	497 - 537 ft	440 - 455 ft	511 - 521 ft
		509 - 539 ft	562 - 582 ft	460 - 470 ft	534 - 544 ft
		539 - 584 ft	602 - 682 ft	520 - 535 ft	560 - 570 ft
		604 - 614 ft		540 - 545 ft	585 - 600 ft
		629 - 669 ft		565 - 575 ft	610 - 615 ft
				590 - 595 ft	620 - 630 ft
				608 - 628 ft	638 - 648 ft
				645 - 660 ft	655 - 665 ft
					680 - 690 ft
Length of Weep Screen	5 ft	5 ft	5 ft	5 ft	5 ft
Length in Crouch Branch	70 ft	50 ft	10 ft	30 ft	0 ft
Length in McQueen Branch	0 ft	125 ft	140 ft	70 ft	100 ft
Total Screen Length	75 ft	180 ft	155 ft	105 ft	105 ft

Note: All Distances are Referenced to Land Surface.

Table 3: Summary of Regression Coefficients for the Vertical Velocity Data Collected at the A/M Area Production Wells.

Well ID	Run	Line Speed	RPS	A	B	R
905-15A	15 fpm	15.060 fpm	14.186			
	30 fpm	28.314 fpm	130.808			
	45 fpm	43.246 fpm	236.869			
				0.1264	12.7899	0.9962
905-20A	15 fpm	15.032 fpm	13.881			
	30 fpm	29.643 fpm	152.493			
	45 fpm	44.393 fpm	274.187			
				0.1126	13.1506	0.9984
905-53A	15 fpm	14.816 fpm	0.03111			
	30 fpm	29.228 fpm	0.35898			
	45 fpm	44.281 fpm	0.84972			
	60 fpm	58.910 fpm	1.21202			
				36.3463	14.5304	0.9966
905-82A	15 fpm	14.836 fpm	17.438			
	30 fpm	29.868 fpm	112.937			
				0.1574	12.0916	N/A

$S_l = A\ CPS + B$
where: S_l is Line Speed in Feet per Minute and CPS is the Counts Per second from Logging Tool.

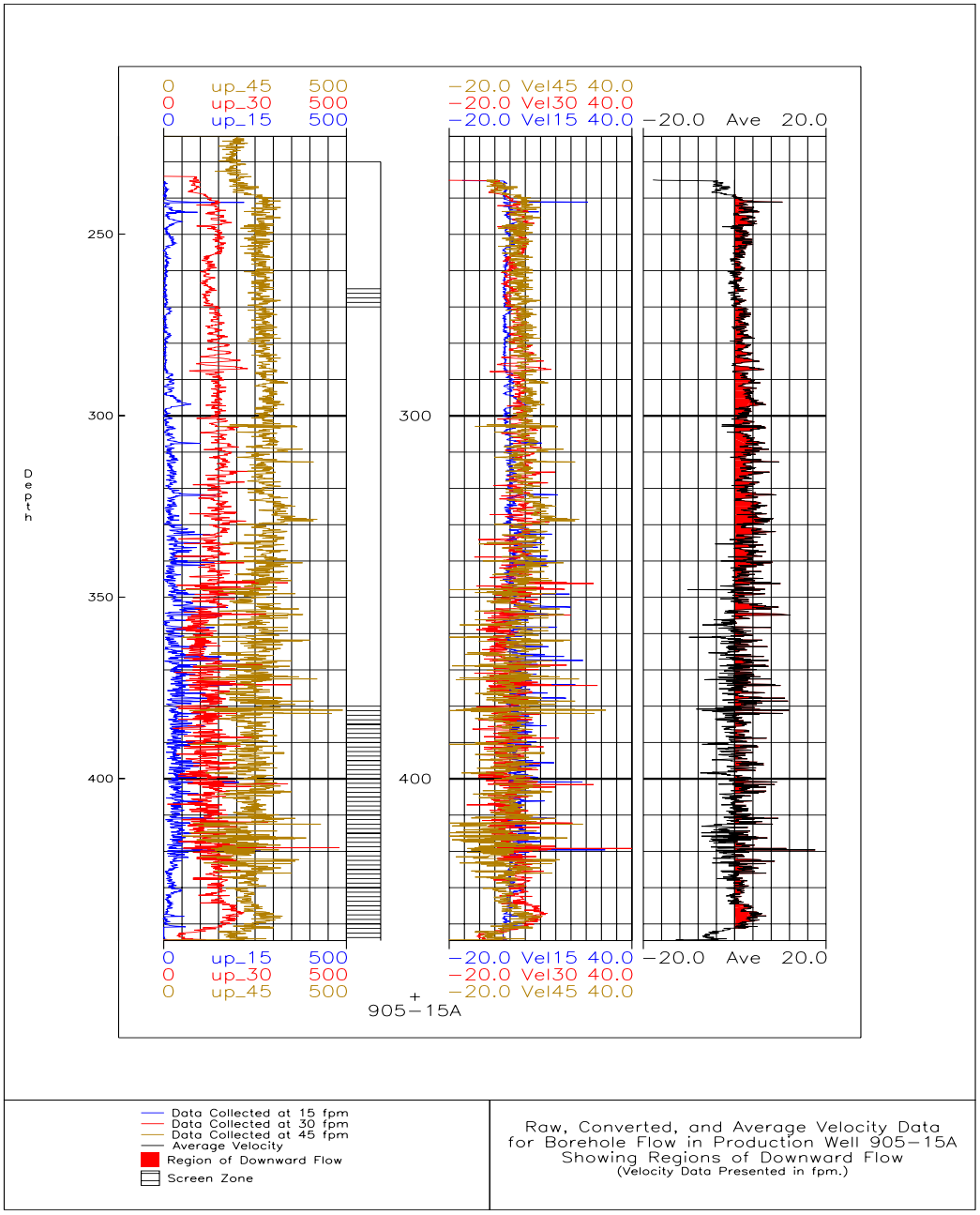


Figure 8: Velocity Data Collected from Production Well 905-15A.

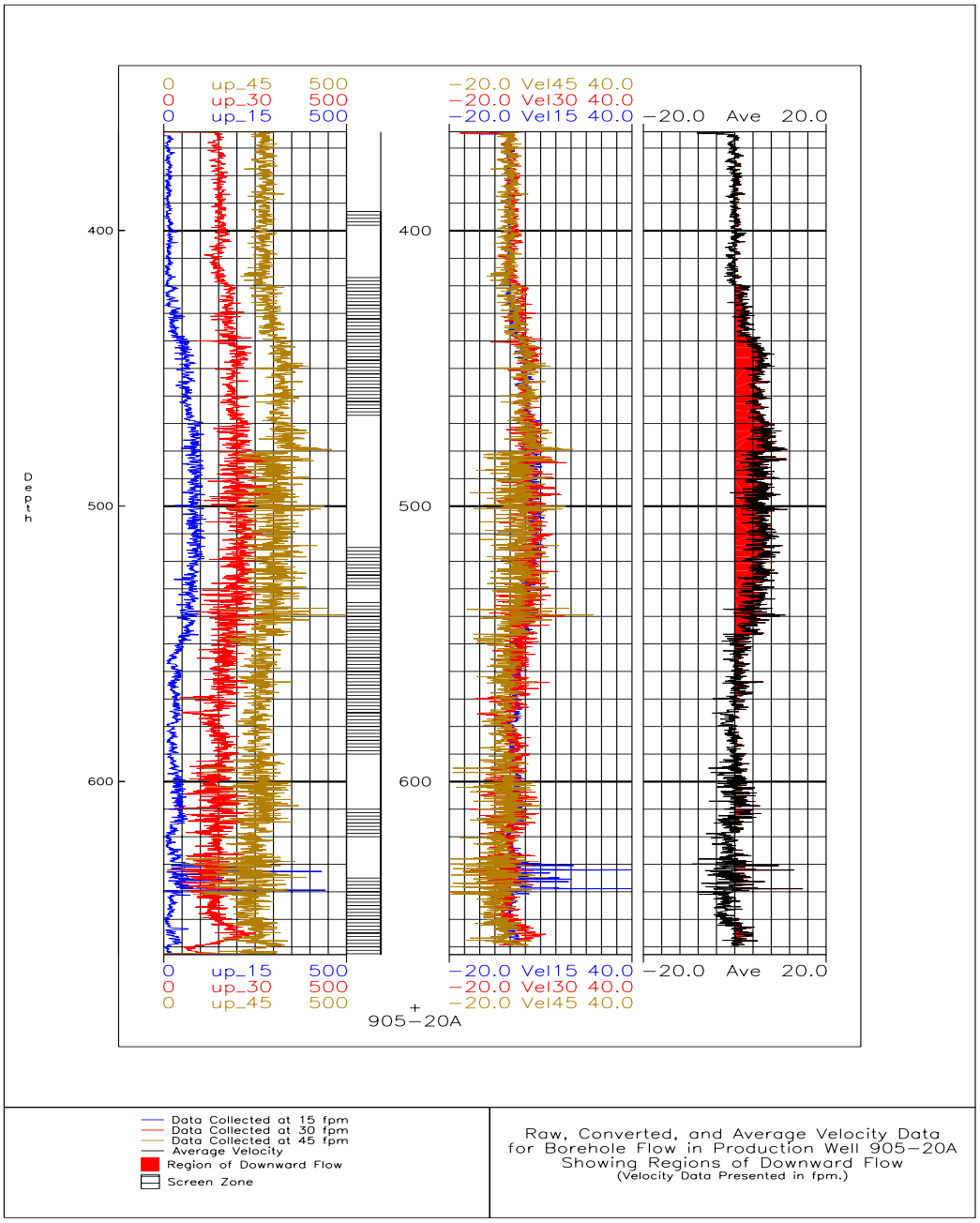


Figure 9: Velocity Data Collected from Production Well 905-20A.

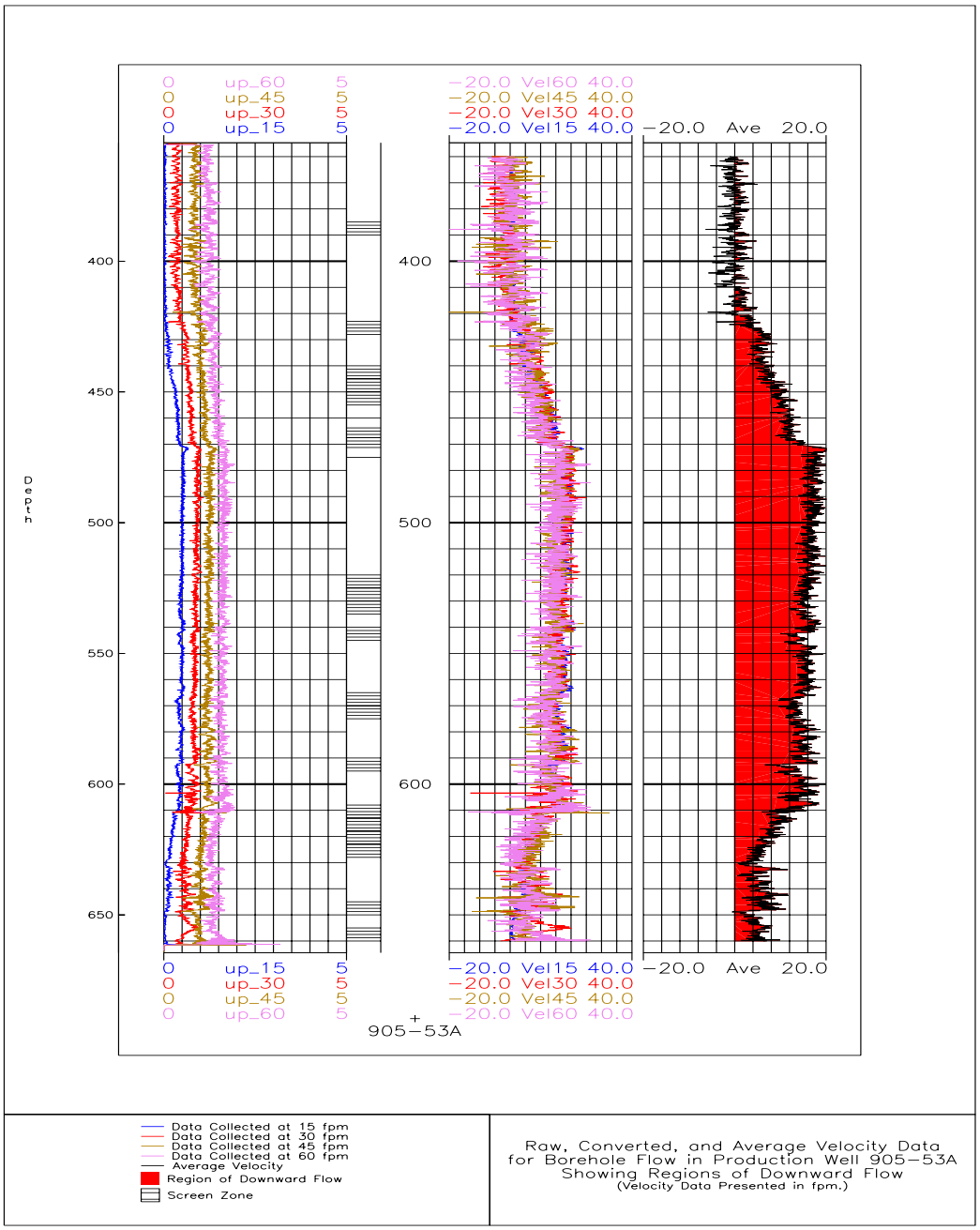


Figure 10: Velocity Data Collected from Production Well 905-53A.

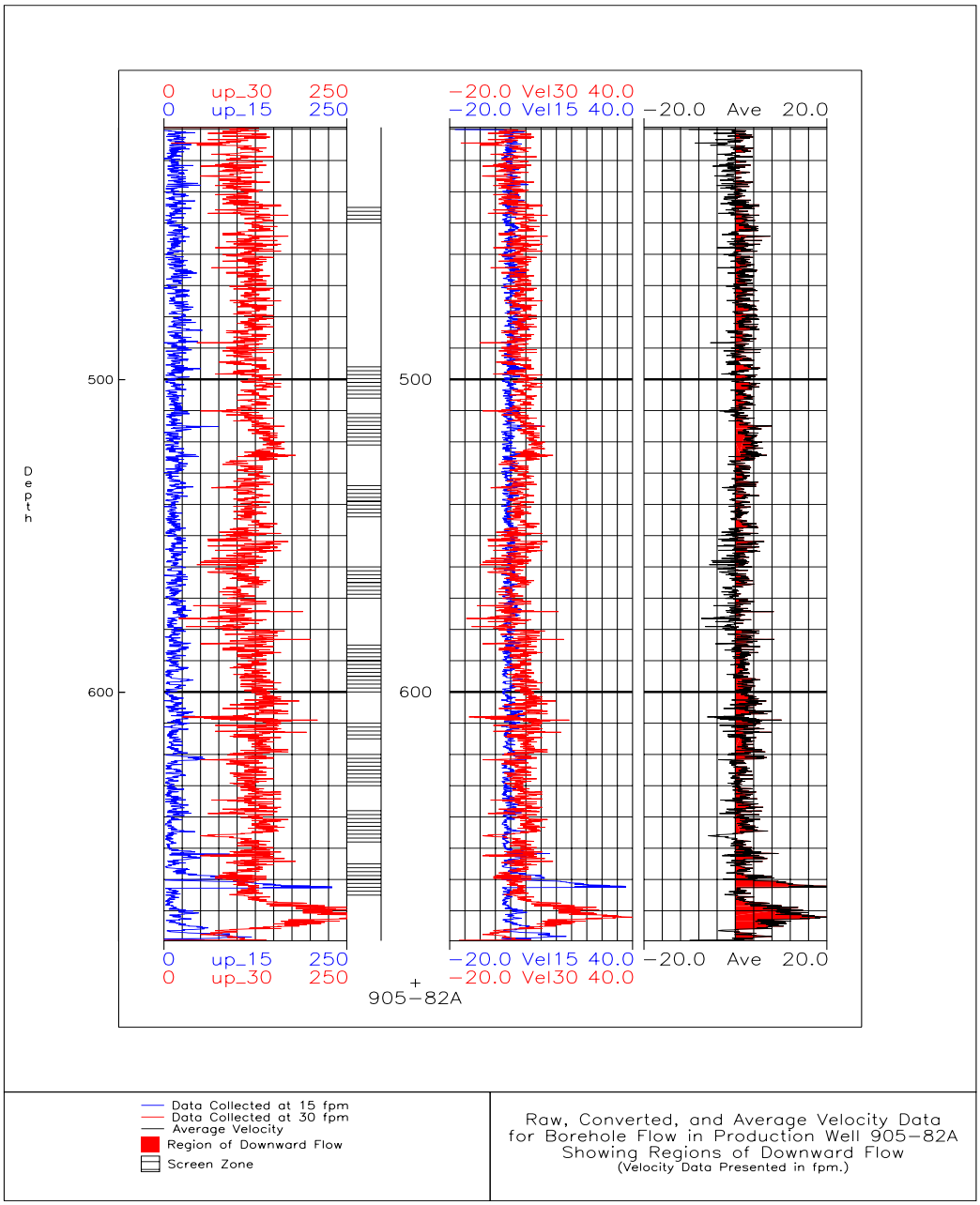


Figure 11: Velocity Data Collected from Production Well 905-82A.

4 Contamination in the Cretaceous Aquifer System

The first indication of solvent contamination in the Crouch Branch Aquifer system occurred in July of 1981 when a water sample from production well 905-53A indicated trichloroethylene contamination at 10 $\mu g/l$ (Horvath, 1988). This event, combined with the discovery of solvent contamination at the M-Area Basin, prompted SRS investigators to voluntarily pursue an extensive characterization and remediation program. The objective of this program was to determine the extent, magnitude, and distribution of the organic constituents necessary to facilitate remediation. As a result of these efforts a plume consisting of dissolved chlorinated solvents, primarily trichloroethylene and with lesser amounts of tetrachloroethylene, has been identified in the Crouch Branch Aquifer beneath the A/M Area of the Savannah River Site (Geraghty & Miller, 1983a) (Horvath, 1988) (Van Pelt et al., 1993) (WSRC, 1993a) (WSRC, 1994). This aquifer is part of the regional hydrologic system that is used both on-site and off-site as a domestic and process water resource. Currently the groundwater contamination in this aquifer is flowing in a direction towards the interior of the site. The long-term outcrop of the plume is expected to be in the Crackerneck Swamp near the Savannah River southwest of the A/M Area. As documented throughout the A/M Area corrective action program (United States Department of Energy, 1988) the primary source of this contaminant plume is the past solvent discharges that occurred in the vicinity of the SRTC complex.

4.1 Conceptual Model of Contaminant Migration

Within the SRTC complex two 200 gallon degreasers were operated in Building 773-A. Solvents from these degreasers were released along a trade waste stream within the SRTC complex that leads to the A-01 Outfall. These degreasers reached peak operation in the 1950's when solvent consumption was an estimated 30-40 drums per year (Marine and Bledsoe, 1984). During the 1960's this consumption was reduced by approximately 30%. Solvent usage continued to decline and one of the degreasers was removed in 1964. According to the historical records the majority of the solvent used in the 773-A degreasers was trichloroethylene, with tetrachloroethylene only being used after 1973 (Marine and Bledsoe, 1984). In 1979, the solvent was changed to 1,1,1-trichloroethane, but usage had so declined that the old solvent was removed from the degreaser and never loaded with new solvent. The solvent releases to the trade waste stream in the vicinity of the SRTC complex serves as a primary source of chlorinated solvent contamination within the SRTC complex and within the deeper Crouch Branch Aquifer.

Once released at the surface, solvent wastes moved vertically through the M-Area and Lost Lake aquifers zones of the Steed Pond Aquifer and into the Crouch Branch Aquifer. Historical monitoring well concentrations indicate the possible presence of DNAPL along the horizon of the Green Clay confining zone beneath the SRTC complex (Jackson et al., 1996b). The indication of DNAPL at the elevation of the Green Clay confining zone is an indirect inference based upon the magnitude of historical groundwater concentrations within the vicinity. To date there is no characterization data to suggest that DNAPL has migrated to the elevation of the Crouch Branch Aquifer. As depicted conceptually in Figure 2, the Green Clay confining zone and the clays of the Crouch Branch Confining Zone become thin and discontinuous within the vicinity of the SRTC complex. Near the SRTC complex the groundwater moves downward through the Steed Pond Aquifer (M-Area and Lost Lake) and upon reaching the elevation of the Crouch Branch Aquifer turns and flows horizontal beneath the A/M Area towards the interior of the site. The lateral migration within the Crouch Branch Aquifer is controlled by the influences of the Savannah River to the northwest of the A/M Area and by the geology associated with marine depositional environments. In this vicinity the Savannah River acts as a groundwater discharge point for the Crouch Branch Aquifer.

From the SRTC complex the general direction of groundwater flow is downward across the Steed Pond Aquifer and into the Crouch Branch Aquifer. The downward flow is a result of the discontinuities of the local confining zones associated with a facies change in the Crouch Branch Confining Unit. Upon entering the Crouch Branch Aquifer, lateral gradients control the flow and the groundwater moves towards the

interior of the site with projected long-term outcrop southwest of the A/M Area in the Crackerneck Swamp. These effects combine to create a dissolved plume on a slightly downward trajectory within the Crouch Branch Aquifer. As the flow continues to the southwest, the downward trajectory continues to decrease. This flow path is depicted conceptually within Figure 12.

Due to the relatively high groundwater velocities present in the Crouch Branch Aquifer, advection transport mechanisms dominant the lateral migration of contamination. Dispersion and, to an even lesser extent, diffusion effects control the transverse migration. Lateral gradients near the SRTC complex are greatest and slowly relax along the flowpath creating a fairly constant lateral gradient in the Central A/M Area. For the purpose of describing the areal extent and shape of the plume in the Crouch Branch Aquifer, the flow direction can be approximated as linear one-dimensional flow towards the southwest. Since the magnitude of the horizontal gradient in the Crouch Branch Aquifer controls the length of the plume and mechanical dispersion controls the width, it is possible to make several general comments regarding the shape of the plume. The first is that the principle axis of the plume will lie along a line from the source area towards the southwest, the principle direction of groundwater flow in the Crouch Branch Aquifer. The source area for the Crouch Branch Aquifer can be conceptualized as either a point source or a small region located at or near the SRTC complex and possibly extended towards the southeast along the A-01 Outfall. Based upon the magnitude of the plume and the groundwater velocity in the Crouch Branch Aquifer, the aspect ratio (ratio of length to width) of the plume should be fairly high. Pumping and associated capture effects caused by the A/M Area production wells make the examination of historical concentrations downgradient of these wells subjective. As identified previously (Haselow, 1989) and in subsequent sections, the operation of these wells have had a dramatic effect on controlling the plume in the Crouch Branch Aquifer.

In addition to the dissolved plume in the Crouch Branch Aquifer, it is likely that a small amount of dissolved contamination may have entered the deeper McQueen Branch Aquifer as a result of recent idle periods associated with the A/M Area production wells. This is presented conceptually in Figure 12. The downward migration from the Crouch Branch Aquifer into the McQueen Branch Aquifer via the wellbore of inactive production wells would have occured in the early 1990's when changing Site missions resulted in a decrease in water demand. Modifications and abandonment activities in FY96 and FY97 have eliminated the potential for any future migration via these pathways (Jackson et al., 1996a). Subsequent sections of this document provide a conservative estimate on the amount of aqueous solvents that may have entered the McQueen Branch Aquifer via the wellbore of the production wells during these idle periods.

4.2 Historical Production Well Concentration

In July of 1981 a water sample from production well 905-53A indicated trichloroethylene contamination at 10 $\mu g/l$ (Horvath, 1988). After this discovery, dissolved solvents were also identified in water samples from production wells 905-20A and 905-31A. Trace non-reproduced amounts, less than the current drinking water standards, were also measured in wells 905-68A and 905-82A. A summary of the average amount of chlorocarbon in the A/M Area Production Wells has been compiled from SRP/SRS Annual Environmental Reports and is presented in Table 4. As indicated from this data, the chlorinated solvent concentrations in production wells 905-20A and 905-53A have steadily increased since 1982. The historical data presented in Table 4 is presented graphically in Figure 13. As presented the historical concentrations of trichloroethylene at production wells 905-20A and 905-53A have steadily increased between 1982 and 1989. As a result of the increased levels of chlorocarbon, primarily trichloroethylene, in these two wells there historical application has been exclusively limited to that of a process water resource. The decrease and variability in concentrations reported after 1989 at production well 905-20A are associated with reductions and changes in production demands and well utility. The collection and reporting of "bulk" samples from the production wells was not included in the 1995 or 1996

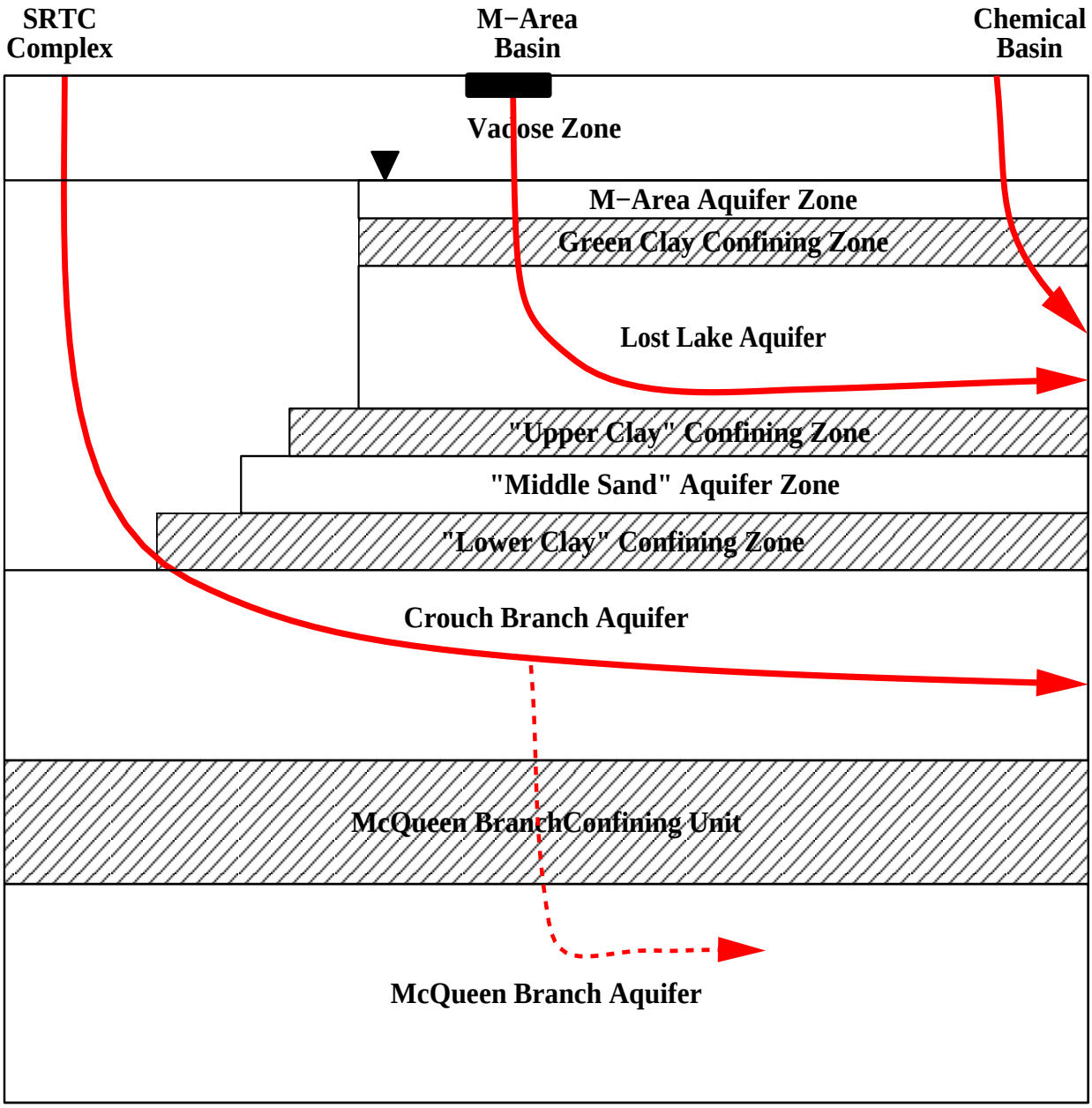


Figure 12: Conceptual Model of the Migration of Dissolved Contamination from the SRTC Complex into the Crouch Branch Aquifer Zone.

environmental reports. The historical data provides valuable information on the contamination in the Crouch Branch Aquifer. Continuation of this sampling program is one viable method for the long-term assessment of the remediation strategies associated with the Crouch Branch Aquifer.

Other than during 1990, measurable quantities of chlorinated solvents have not been detected in samples from the domestic water wells 905-68A and 905-82A. Production well 905-68A is not located in the plume trajectory and production well 905-82A is screened entirely within the McQueen Branch Aquifer. Even though a small amount of chlorinated solvent has entered the McQueen Branch Aquifer via the idle production wells, the location of production well 905-82A, the relatively low quantities involved, and the pumping volume of the well make detection practically impossible.

It noted that the data presented in Table 4 is representative of the level of contamination that occurs as a result of pumping from the entire screen section of an individual production well. As presented in Table 2 this distance ranges from 75 to 180 feet of total screen length with over 200 feet of continuous gravel pack. It is erroneous to conclude from the data presented in Table 4 that the Crouch Branch and McQueen Branch Aquifers are uniformly contaminated across the entire vertical extent of the production well screens. Data from numerous sources (WSRC, 1993a) (WSRC, 1994) (Van Pelt et al., 1993) indicate that the dissolved contaminant plume in the Crouch Branch Aquifer is localized along a thin, distinct horizon within the Crouch Branch Aquifer. During well operation, the groundwater plume containing high contaminant concentrations is mixed with the water from the uncontaminated sections of the aquifer to produce a “bulk” contaminant level. This “bulk” contaminant level represents the average concentration as a result of mixing across the entire screened interval and is the data presented in Table 4. This conclusion is developed from examination of historical groundwater concentration data, aqueous concentrations of groundwater derived from depth discrete headspace data, and vertical profiles of concentration along the wellbore of select production wells. Each of these items are discussed in depth in the following sections of this report.

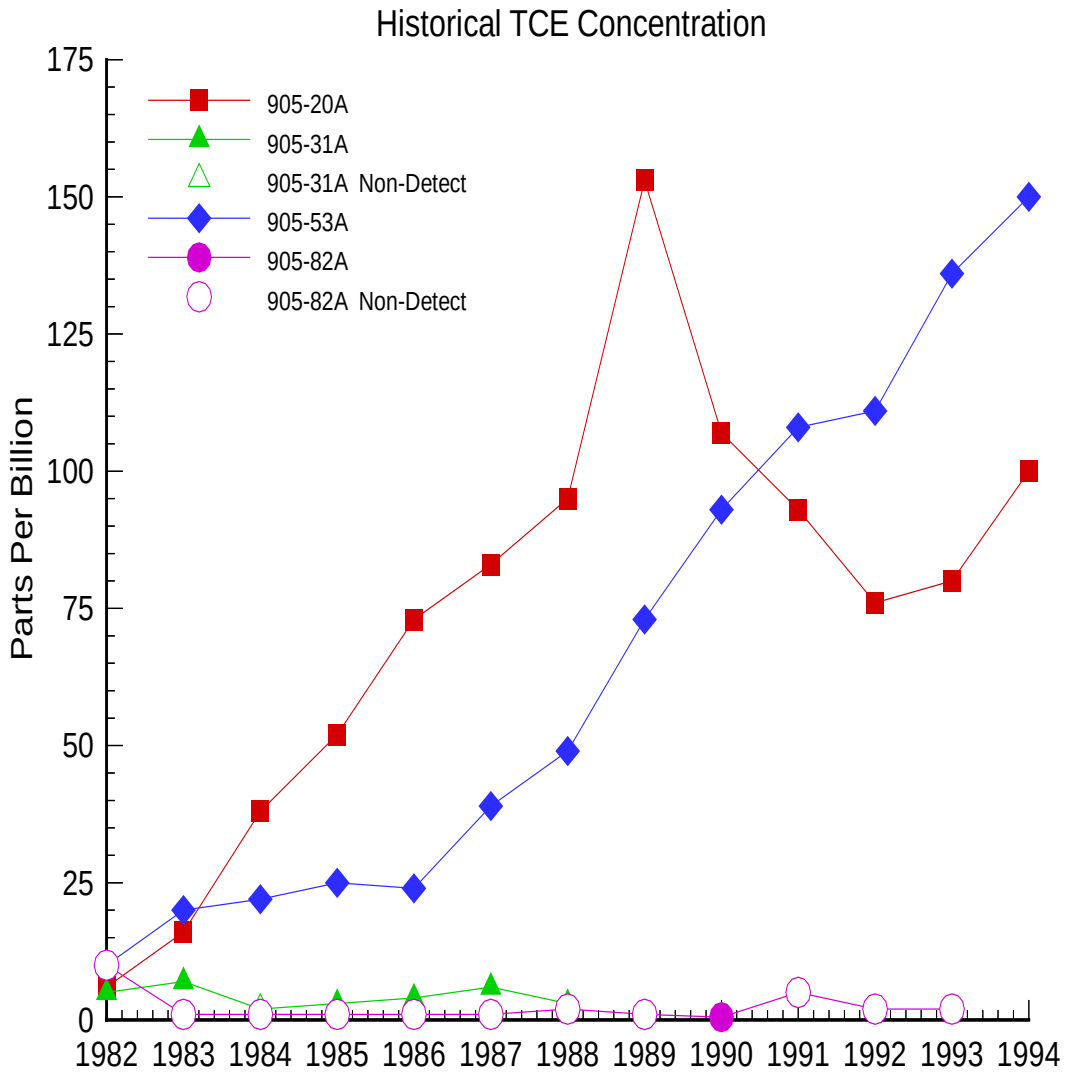


Figure 13: Historical Trichloroethylene and Tetrachloroethylene concentrations for the A/M Area Production Wells.

Table 4: Historical Summary of Chlorocarbon Concentrations in A/M Area Production Wells.

	905-20A		**905-31A**		**905-53A**		**905-68A**		**905-82A**	
Year	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE
1982	≈ 6	na	≈ 5	na	10	na	≤ 10	na	≤ 10	na
1983	16	≤ 1	7	≤ 1	20	1	≤ 1	na	≤ 1	≤ 1
1984	38	≤ 2	≤ 2	≤ 1	22	≤ 2	≤ 2	≤ 2	≤ 1	≤ 1
1985	52	≤ 1	3	≤ 1	25	3	≤ 1	≤ 1	≤ 1	≤ 1
1986	73	≤ 1	4	≤ 1	24	4	≤ 1	≤ 1	≤ 1	≤ 1
1987	83	1.4	6	2	39	5	≈ 1	≤ 1	≤ 1	≤ 1
1988	95	≤ 2	3	≤ 2	49	≤ 5	≤ 1	≤ 2	≤ 2	≤ 2
1989	153	≤ 4	a	a	73	6	≤ 3	≤ 1	≤ 1	≤ 1
1990	107	2	a	a	93	7.6	2.5	≤ 1	0.5	0.6
1991	93	4.7	a	a	108	8.6	3	≤ 2	≤ 5	≤ 2
1992	76	≤ 2	a	a	111	10	≤ 2	≤ 2	≤ 2	≤ 2
1993	80	≈ 4	a	a	136	17	≤ 2	≤ 2	≤ 2	≤ 2
1994	100	2	a	a	150	10	ND	ND	ND	ND

Notes: All Concentrations in $\mu g/l$ (parts per billion).
na - indicates No Data Available
ND - Not Detected
a - Production well 905-31A was removed from service in November of 1988.

4.3 Historical Monitoring Well Concentrations

Since the discovery of chlorinated solvents in the subsurface, the Savannah River Site has installed an extensive series of groundwater monitoring wells. The purpose of this system is provide information on groundwater conditions and quality within the A/M Area. With regards to organic contamination in the Crouch Branch Aquifer, there are 37 monitoring wells identified as either in the Crouch Branch Aquifer or in the vicinity of the Crouch Branch source. Table 5 presents trichloroethylene and tetrachloroethylene concentrations for these monitoring wells along with screen elevation information. In examining the concentrations for wells screened within the Crouch Branch Aquifer it is important to note that the majority of the wells are screened immediately below the Crouch Branch Confining Unit. Although located laterally downgradient from the source zone several of these wells are located vertically above or below the flowline from the source zone. As a result, many of the monitoring wells in the Crouch Branch Aquifer are not located in the trajectory of the plume as conceptualized in Figure 12. This is an important consideration when mapping the extent and size of the plume in the Crouch Branch Aquifer. Neglecting the vertical positioning of a monitoring well can easily result in inaccurate mapping with anomalous "bulls-eye" features of high concentration. These features often differ from available soil core headspace data and do not agree with the conceptual model based upon fundamentals of groundwater flow, the hydrostratigraphy of A/M Area, and mechanisms of contaminant transport.

In examining and discussing the historical concentrations from monitoring wells associated with organic contamination in the Crouch Branch Aquifer, the wells are divided into different groups. These groups are:

1. Monitoring Wells Upgradient from Source Zone
2. Monitoring Wells At or Near the Source Zone
3. Monitoring Wells Immediately Downgradient from Source Zone
4. Monitoring Wells Influenced by Production Wells
5. Monitoring Wells Outside the Lateral Extent of the Plume

4.3.1 Monitoring Wells Upgradient from Source Zone

Of the 37 monitoring wells identified with the Crouch Branch Aquifer, 10 of these monitoring wells are installed upgradient of the source zone. These wells are critical in identifying local groundwater flow directions and ascertaining the principle flow direction from the source zone into the Crouch Branch Aquifer. These wells include MSB 29TA, MSB 48TA, MSB 54TA, MSB 55TA, MSB 69TA, MSB 77TA, MSB 82A, MSB 82TA, MSB 83TA, and MSB 85TA.

MSB 29TA is north of the SRTC Complex adjacent to Road 1 and serves as a background well for water quality in the A/M Area. As shown in Figure 24 the historical concentrations at monitoring well MSB 29TA have been below 5 $\mu g/l$ for trichloroethylene and essentially non-detects for tetrachloroethylene. The monitoring well is screened relatively high with respect to other wells in the Crouch Branch Aquifer and is most likely associated with misinterpretation of lithology during installation. This is possibly a result of the transitional hydrostratigraphy within the vicinity of the SRTC complex associated with the identified facies change (Blackhawk Geometrics, 1996).

Monitoring well MSB 82TA is located north of the SRTC complex near the intersection of Road 1 and Road D 1. The well is screened in the upper most portion of the Crouch Branch Aquifer and possibly in the up dip equivalent of the "Middle Sand" portion of the Crouch Branch Confining Zone. The historical concentrations of trichloroethylene and tetrachloroethylene are presented in Figure 48 and indicate

trichloroethylene concentrations on the order of 50 $\mu g/l$ for trichloroethylene and non-detects for tetrachloroethylene. The trichloroethylene concentrations observed are most likely associated with downward migration of contaminants from the shallow sediments. It is these effects that are believed to be the source of the 50 $\mu g/l$ concentration observed at MSB 82TA.

Screened 30 feet above monitoring well MSB 82TA is monitoring well MSB 82A, as shown in Figure 47 the historical concentrations of trichloroethylene at monitoring well dramatically increase from "Non-Detect" immediately after installation to 2,256 $\mu g/l$ reported in 2Q93. This dramatic increase quickly decreases in two quarters and since 4Q93 trichloroethylene concentrations at this well have been reported in the 100-200 $\mu g/l$ range. Examination of the historical concentrations for monitoring well MSB 85TA presented in Figure 50 show a similar increase and decrease between installation and 3Q93, with maximum concentrations two orders of magnitude lower than those reported at MSB 82A. A similar increase and decrease was observed at monitoring well MSB 67D (Jackson et al., 1996b) during the same period with an order of magnitude higher concentrations. This increase was identified with the possible presence of DNAPL using indirect techniques at the elevation of monitoring well MSB 67D. It is unknown why three different monitoring wells, located along three separate horizons show similar concentration patterns during the period from 1Q92 through 3Q93. It is likely that these events are related and may be related to preferential pathways resulting from filled channels or stream beds.

Completing the upgradient suite of monitoring wells are MSB 48TA, MSB 54TA, MSB 55TA, MSB 69TA, MSB 77TA, and MSB 83TA. As shown in Figure 1 these wells are located northeast of the SRTC complex. The historical trichloroethylene and tetrachloroethylene concentrations for these wells are presented in Figures 41, 42, 43, 45, 46, and 49. As shown in these figures the historical concentrations at these monitoring wells have been below 5 $\mu g/l$, with the majority of the samples reported as "Non-Detect." As shown in Figure 4 these wells are in the extreme northeast corner of the A/M Area and provide quantitative information on hydraulic conditions and local directions of groundwater flow.

4.3.2 Monitoring Wells At or Near the Source Zone

Within the SRTC complex solvents were used in two 200 gallon degreasers located in the basement of 773-A. Spent solvents from these degreasers were released to a trade waste stream leading to the A-01 Outfall. This trade waste stream is the primary source of chlorinated solvent contamination within the SRTC complex and within the deeper Crouch Branch Aquifer. As shown in Figure 1 monitoring well cluster MSB 47 is located near the influent of the trade waste stream and ASB 8 is located near the effluent of the waste stream at the A-01 Outfall. Investigations using indirect techniques have indicated the possible presence of DNAPL in the shallow sediments at each of these locations (Jackson et al., 1996b). Historical groundwater concentrations at MSB 47C have been at the 10,000 $\mu g/l$ level with those at the deeper MSB 47B at the 2,000 $\mu g/l$ level (Jackson et al., 1996b). As shown in Figure 40, historical trichloroethylene concentrations at monitoring well MSB 47TA have slowly increased from 468 $\mu g/l$ reported in 3Q87 to 758 $\mu g/l$ reported in 3Q95. The concentrations observed at MSB 47TA are a result of the downward migration of groundwater from the source zones in the above Tertiary sediments.

Well cluster ASB 8 is located at the effluent of the trade waste stream associated with solvent releases in the SRTC complex. Although significantly high aqueous concentrations have been observed in the shallow ASB 8, ASB 8C, and ASB 8B wells of this cluster (Jackson et al., 1996b), there have been no significant aqueous concentrations in monitoring wells ASB 8A and ASB 8TA reported. As shown in Figure 16 and 17 the trichloroethylene and tetrachloroethylene concentrations have been historically reported as "Non-Detect." The direction of groundwater flow from ASB 8 is downward towards the southwest, thus causing the dissolved plume to miss the deeper wells in the ASB 8 cluster. The magnitude of aqueous concentrations entering the Crouch Branch Aquifer within the vicinity of the SRTC complex is best appreciated from examining the historical concentrations for monitoring wells

ASB 6AA and ASB 6TA. These two monitoring wells are located laterally and vertically downgradient from the elevated concentrations observed at ASB 8, ASB 8C, and ASB 8B. The historical trichloroethylene and tetrachloroethylene concentrations for wells ASB 6AA and ASB 6TA are presented in Figure 14 and 15. As shown in Figure 14 the historical concentrations at monitoring well ASB 6AA are similar to those presented for monitoring well ASB 8B (Jackson et al., 1996b). Historically the average trichloroethylene concentration at monitoring well ASB 6AA is 2,914.8 $\mu g/l$ with a value of 2,840.0 $\mu g/l$ reported in 3Q95. Monitoring well ASB 6AA is laterally and vertically downgradient from ASB 8B and serves to characterize the magnitude of the aqueous concentration entering the Crouch Branch Aquifer. The long-term effectiveness of pump and treat program in the Northern Sector can be evaluated from future groundwater concentrations at this monitoring well. Located approximately 40 feet deeper than ASB 6AA is monitoring well ASB 6TA. As reflected by the slightly lower concentrations presented in Figure 15 this monitoring well is believed to be located on the lower edge of the dissolved plume entering the Crouch Branch Aquifer.

4.3.3 Monitoring Wells Immediately Downgradient from Source Area

Upon entering the Crouch Branch Aquifer the general flow direction is toward the southwest. Immediately downgradient from the SRTC source zone are monitoring wells MSB 37A, MSB 37TA, MSB 42TA and MSB 66TA. These wells serve to characterize the lateral and vertical thickness of the aqueous plume in the Crouch Branch Aquifer.

As shown in Figure 5 monitoring well cluster MSB 37 is located immediately down gradient from the identified source area. Within this cluster monitoring well MSB 37TA is located in the Crouch Branch Aquifer. As presented in Figure 33 the historical concentrations for trichloroethylene have increased steadily from 902 $\mu g/l$ reported in 2Q85 to 2,890 $\mu g/l$ reported in 2Q95. Also presented in Figure 33 are the historical concentrations for tetrachloroethylene, which behave similar to those concentrations observed for trichloroethylene. Insight on specific source zones and groundwater flow patterns may be obtained from examining historical ratios of trichloroethylene and tetrachloroethylene, along with other constituents. Located 40 feet above monitoring well MSB 37TA is monitoring well MSB 37A. As shown in Figure 32 the concentrations reported at this monitoring well increase in a similar manner as those presented in Figure 33. The concentrations at MSB 37A are much lower than those observed at the deeper MSB 37TA. Beginning in 4Q92 an increase above the established trend is observed. This increase may be associated with changes in operation of the A/M Area production wells.

The first estimate on the extent of transverse spreading along the flowpath is obtained by comparing the historical concentrations for MSB 37TA, previously presented in Figure 33, to those observed at MSB 66TA, presented in Figure 44. As shown in Figure 1, monitoring well MSB 66TA is located northeast of MSB 37TA. As indicated in Figure 5 both of these monitoring wells are located along the 208 foot potentiometric contour at an elevation of approximately 32 feet above mean sea level. As presented in Figure 44, the historical concentrations at monitoring well MSB 66TA have been well below those observed at MSB 37TA. The distance between the two wells is 646 feet and provides a reasonable estimate to the width of the plume at this position. It is important to note that numerous parameters influence the width of the plume, most notably the ratio of longitudinal to transverse dispersivity.

To further refine the estimate on the width of the plume, and to obtain an estimate on the vertical thickness of the plume, the historical concentrations at monitoring well MSB 42TA are examined. The historical concentrations for trichloroethylene and tetrachloroethylene are presented in Figure 38. As shown in Figure 1 this well is located due south of monitoring well MSB 37TA. One important difference is the elevation of the screen zone compared to that of MSB 37TA. As presented in Table 5, monitoring well MSB 42TA is screened at an elevation of 45.8-40.5, 5 foot above the screen zone of monitoring well MSB 37TA. As presented in Figure 38 the historical concentrations for both trichloroethylene and

tetrachloroethylene were gradually increasing from 1Q97 to 4Q91, with concentrations below 10 $\mu g/l$. In 2Q92, both trichloroethylene and tetrachloroethylene concentrations increased compared to historical values. After this period the historical trichloroethylene concentrations have continued to increase with a concentration of 33 $\mu g/l$ trichloroethylene reported in 3Q95. A similar increase is also observed in Figure 32 at monitoring well MSB 37A. The increase observed in 2Q92 may be attributed to the decreases in production well usage in the A/M Area, which may cause the plume to move laterally or vertically depending upon volume pumped. As presented (Haselow, 1989), during operation of production wells 905-20A and 905-53A, a significant portion of the dissolved trichloroethylene plume is captured. As presented in this previous investigation (Haselow, 1989, Figure 6, page 12) monitoring well MSB 42TA is located slightly outside the capture zone associated with production well 905-20A. During idle pumping periods, local hydraulic conditions may result in the plume shifting more to the southeast, resulting in the increase observed at monitoring well MSB 42TA. Since the well is screened above the elevation of monitoring well MSB 37TA, and there is a slight downward gradient present in the Crouch Branch Aquifer, the concentrations at MSB 42TA do not reach the levels observed at MSB 37TA.

4.3.4 Monitoring Wells Influenced by Production Wells

As presented in Figure 32 and Figure 38 and discussed in the previous section, the historical concentrations at monitoring wells MSB 37A and MSB 42TA may have been effected by the operation of the production wells in the A/M Area. Production wells 905-20A and 905-53A have had a significant effect on controlling distribution of organic contaminants in the Crouch Branch Aquifer. A better understanding on the effect that these wells have can be obtained from examining the historical trichloroethylene and tetrachloroethylene concentrations of monitoring wells within the vicinity of the production well field as well as those concentrations from monitoring wells immediately downgradient from the production wells.

The first two wells in this suite are monitoring wells in the MSB 34 cluster. As shown in Figure 4 this well is located 250 feet downgradient from production well 905-53A. In addition, the well cluster is unique in that there are two wells located in the Crouch Branch Aquifer. The first well is monitoring well MSB 34TB having a screen elevation of 70 feet. As identified from historical concentrations at the elevation of MSB 37TA and MSB 42TA the dissolved plume is located at the 20-30 foot elevation, well below this monitoring well. As presented in Figure 29 the historical trichloroethylene and tetrachloroethylene concentrations at monitoring well MSB 34TB have been consistently reported as "Non-Detect". Although plume containment and control is achieved in this vicinity during the operation of 905-53A, the historical "Non-Detects" reported are a result of the screen elevation and not a result of the containment effects associated with operations at 905-53A.

In addition to monitoring well MSB 34TB, monitoring well MSB 34TA is also screened in the Crouch Branch Aquifer. The elevation of this monitoring well is 90 feet below sea level. As presented in Figure 28 the concentrations prior to 3Q93 at this monitoring well were traditionally below detectable limits. Although downgradient from production well 905-53A, the elevation of the dissolved plume as determined from the concentrations observed at MSB 37TA is well above the elevation of this monitoring well. However, since 3Q93 the trichloroethylene concentrations have increased steadily with a value of 2.39 $\mu g/l$ reported in 3Q95. These increases in trichloroethylene are attributed to downward migration via the wellbore of production well 905-53A. The driving force for downward migration via the production wells is the head difference between the Crouch Branch and McQueen Branch Aquifers. Within the Crouch Branch Aquifer a slight downward gradient exists as determined from the head measurements from MSB 34TA and MSB 34TB presented in Table 5. The vertical gradient is far less than the lateral gradient and is not sufficient enough to cause a 100 foot vertical migration between monitoring wells MSB 37TA and MSB 34TB. This production well has been idle for extensive periods in recent years and recent modifications have eliminated this migration pathway.

Similar to well cluster MSB 34, cluster MSB 12 has two wells in the Crouch Branch Aquifer. Monitoring well MSB 12TB is screened in the upper portion of the aquifer and MSB 12TA is screened in the lower portion of the aquifer. As shown in Figure 18 and 19 the historical concentrations for these wells have been primarily below detection limits. The "Non-Detects" are a result of the vertical screening of the two wells and the variable operation of the A/M Area production wells. The downgradient positioning of the well cluster from production wells 905-20A and 905-53A prevent contamination from reaching this cluster during periods of operation. Monitoring well MSB 12TB is screened at the proper elevation to intercept the main portion of the plume in the Crouch Branch Aquifer. It is anticipated that concentrations at this monitoring well should begin to increase and become variable due to the changes in the operation schedule of the production wells. The positioning of monitoring well MSB 12TA downgradient from MSB 34TA and production well 905-53A suggests that concentrations may increase in the future at this location in a manner similar to those observed at MSB 34TA. Concentrations at MSB 12TA would be a result of downward migration via the wellbore followed by lateral migration in the lower portion of the Crouch Branch Aquifer. Unlike historical concentrations upgradient of the production wells, the future concentrations at MSB 12TA and MSB 12TB should increase and then decrease similar to plumes associated with pulse-source injection.

As with monitoring well MSB 34TB, monitoring wells MSB 21TA and MSB 27TA are located downgradient of the A/M Area production wells. As presented in Figures 20 and 23 the historical concentrations at each of these wells have been below detection limits. Monitoring well MSB 27TA is screened slightly above the elevation of the plume established by historical data from monitoring wells MSB 37A and MSB 66TA. Monitoring well MSB 21TA is screened at the proper elevation and concentrations at this well should begin to pulse due to the variable operation of the production wells.

Additional monitoring wells located in the Crouch Branch Aquifer that may have been influenced by the A/M Area production wells are located near the A-014 Outfall. These wells are MSB 31A, MSB 35TA, and MSB 38TA. Of these three wells, monitoring well MSB 31A is screened the deepest at an elevation of 17 feet. The remaining two wells are screened slightly higher at an elevation above 30 feet. As presented in Figures 26, 30, and 34 the concentrations at these wells have been historically below detection limits for both trichloroethylene and tetrachloroethylene. It is believed that monitoring wells MSB 35TA and MSB 38TA are screened above the plume trajectory. Monitoring well MSB 31A is at the proper elevation to intercept the plume, however the operation of the production well system may have prevented the migration of the plume to this position. If production wells 905-20A and 905-53A continue to sit idle, it is anticipated that concentrations of trichloroethylene will soon be detected at monitoring well MSB 31A.

Initially, the most striking information on the effect that the production wells may have had on historical concentrations is available from examining the historical trichloroethylene and tetrachloroethylene concentrations at monitoring well MSB 23TA presented in Figure 21. As shown in this figure, prior to 4Q89 historical concentrations were below detection limits. Beginning in 1989 through 4Q92 numerous samples were reported with concentrations ranging from non-detect to in excess of 50 $\mu g/l$ trichloroethylene. Following this period the historical concentrations have stabilized at slightly above 5 $\mu g/l$ trichloroethylene. The period of high fluctuation corresponds to period when the operation of production wells was variable and initial conclusions would indicate a correlation between the operation of the production wells and the historical concentrations at MSB 23TA. However, examination of the analytical data indicates that each of the quarterly samples were split and as many as 5 different analysis were made. A cursory review indicates that those results greater than 25 $\mu g/l$ are associated with samples that were diluted at a ratio of 5:1. Samples from the same split analyzed with no dilution ratios have reported concentrations on the order of 5 $\mu g/l$. Based on this information the elevated concentrations observed between 1989 and late 1991 are believed to be an artifact or error in sample analysis and not on the variable operation of the production wells. Additional information supporting this conclusion is the fact that the monitoring well is screened at an elevation of 60 feet, well above the

elevation of the plume established at MSB 37TA. In addition to well MSB 23TA, monitoring well MSB 23TR was installed in 1994 and is located 20 feet below the elevation of MSB 23TA. As shown in Figure 22 the historical concentrations since installation at this location have been below detection limits.

4.3.5 Monitoring Wells Outside the Extent of Contamination

In addition to the historical concentrations for those monitoring wells previously discussed, there are six additional monitoring wells in the Crouch Branch Aquifer that are outside the extent of the aqueous plume. These monitoring wells are MSB 30A, MSB 33TA, MSB 36TA, MSB 39TA, MSB 40TA, MSB 41TA, and MSB 43TA. The historical concentrations for trichloroethylene and tetrachloroethylene for these monitoring wells are presented in Figures 25, 27, 31, 35, 36, 37, and 39. For the most part all of the historically reported values from these wells have been at or below detection limits. The only exception to this is a value of 20.3 $\mu g/l$ trichloroethylene reported at monitoring well MSB 33TA in 1Q95. This result is qualified as an estimated quantity. As of this writing there have been no subsequent samples to validate this concentration level. As presented in the following section, information from depth discrete soil samples indicate that monitoring wells MSB 36TA, MSB 40TA, and MSB 41TA may be located within the lateral extent of the plume but not screened at the proper elevation to intercept the plume.

Table 5: 1996 Average Head and Concentrations for Monitoring wells located in the either the Crouch Branch Aquifer or in the vicinity of the Crouch Branch source.

Well ID	SRS Easting	SRS Northing	Screen Elevation		Head	TCE	PCE	Quarter
ASB 6AA	52643.90	105727.00	82.80	78.10	218.03	2750	19.8	4Q96
ASB 6TA	52671.30	105749.50	40.00	34.50	214.50	736	7.25	4Q96
ASB 8A	53117.50	106369.30	83.50	77.90	220.10	≤ 2	≤ 2	4Q96
ASB 8TA	53124.70	106375.80	24.60	19.40	216.63	≤ 2	≤ 2	4Q96
MSB 12TA	47127.30	102266.70	-102.80	-112.80	192.07	≤ 2	≤ 2	4Q96
MSB 12TB	47133.00	102260.10	14.50	-5.50	193.66	≤ 5	≤ 5	1Q95
MSB 21TA	47218.20	103980.90	22.60	17.30	195.22	≤ 2	≤ 2	1Q95
MSB 23TA	49225.80	104298.80	65.40	60.40	201.35	1.30	≤ 2	3Q96
MSB 23TR	49036.00	104278.50	40.80	35.90	200.05	≤ 2	≤ 2	1Q95
MSB 27TA	49486.50	104951.40	55.90	50.60	201.30	≤ 2	≤ 2	3Q96
MSB 29TA	51245.70	107330.40	63.90	58.60	212.40	1.20	≤ 2	3Q96
MSB 30A	48004.10	105727.40	36.90	26.90	199.56	≤ 2	≤ 2	1Q95
MSB 31A	50100.20	101979.30	22.00	12.00	199.13	≤ 2	≤ 2	1Q95
MSB 33TA	51734.00	98018.20	23.40	18.10	195.69	20.3	≤ 2	1Q95
MSB 34TA	50536.60	104905.80	-91.90	-101.90	202.40	3.20	≤ 2	3Q96
MSB 34TB	50537.90	104891.60	75.80	65.80	203.88	≤ 2	≤ 2	1Q95
MSB 35TA	50919.60	102101.60	38.20	32.90	199.35	≤ 2	≤ 2	3Q96
MSB 36TA	49503.00	100507.70	53.40	48.40	195.00	≤ 2	≤ 2	3Q96
MSB 37A	51439.80	105295.00	73.70	68.10	208.58	113	24.6	1Q95
MSB 37TA	51449.80	105301.30	35.10	29.80	208.40	2000	102	3Q96
MSB 38TA	49810.40	102434.90	32.00	26.70	199.23	≤ 2	≤ 2	1Q95
MSB 39TA	48357.70	100830.60	49.70	44.40	192.70	≤ 2	≤ 2	3Q96
MSB 40TA	48277.20	97660.40	29.00	23.70	190.29	≤ 2	≤ 2	1Q95
MSB 41TA	53429.70	102176.50	26.70	21.40	206.95	≤ 2	≤ 2	3Q96
MSB 42TA	51581.70	104545.60	45.80	40.50	205.50	42.2	21.4	3Q96
MSB 43TA	49281.80	107275.80	40.30	35.00	203.45	622	149	3Q96
MSB 47TA	52219.00	106987.70	55.10	50.10	216.35	674	≤ 40	3Q96
MSB 48TA	54089.20	107925.80	107.80	102.50	222.54	≤ 2	≤ 2	3Q96
MSB 54TA	52985.80	108446.30	80.90	75.30	227.54	≤ 2	≤ 2	3Q96
MSB 55TA	52014.70	108322.80	91.60	86.20	214.40	≤ 2	≤ 2	3Q96
MSB 66TA	51096.70	105842.60	35.50	30.80	206.40	3.53	6.62	3Q96
MSB 69TA	52418.40	107772.50	80.30	74.60	215.85	≤ 2	≤ 2	3Q96
MSB 77TA	54208.90	107053.80	82.90	77.60	222.84	≤ 2	≤ 2	1Q95
MSB 82A	51978.40	107529.50	126.10	121.10	228.70	90.1	≤ 8	3Q96
MSB 82TA	51964.20	107525.70	93.80	88.40	214.40	46.6	≤ 2	3Q96
MSB 83TA	52410.90	108416.30	75.70	70.20	215.80	≤ 2	≤ 2	3Q96
MSB 85TA	53137.20	107831.20	88.20	82.80	220.90	2.43	≤ 2	3Q96

Note: All Concentrations Reported in $\mu g/l$.

4.4 Depth Discrete Soil Sampling

In order to satisfy requirements of the Part B permit for the M-Area Hazardous Waste Management Facility, the Savannah River Site is currently pursuing an aggressive characterization program to determine the extent of the contamination and the hydrostratigraphy that controls groundwater flow in the Cretaceous Aquifer system. The primary method being employed in the characterization program is the collection and analysis of soil cores from the Cretaceous age sediments beneath the A/M Area (WSRC, 1993a) (WSRC, 1994). An integral part of this characterization effort is the collection of bulk soil samples from discrete horizons with subsequent analysis for volatile organics using a headspace analysis procedure developed at the Savannah River Site (Looney et al., 1993). This sampling technique provides a vertical profile of the dissolved contaminant distribution that is not available using conventional monitoring wells. The depth discrete data is combined with monitoring well data to allow investigators to develop an accurate representation of the distribution of contaminants within the Crouch Branch Aquifer. When combining these two different data sources it is important to note that the applied method may be less accurate for sandier soils than samples collected with a traditional HydroPunch. As identified (Eddy et al., 1991, page 42, 43) the headspace method may result in volatile organic loss during sampling in sediments of less than 30% clay. It is expected that these effects would increase with sample depth as a result of drainage from the core during collection. As with any screening method the headspace data was collected to allow investigators to cost effectively understand the dynamics and extent of organic contaminants within the Crouch Branch Aquifer. By understanding the advantages and disadvantages of the data, investigators can effectively assess the extent of contamination within the scope of the current and proposed remediation program so that resources can be appropriately directed to establish realistic remediation goals. The depth discrete data serves as a screening tool for cost-effective assessments and should not be used for definitive regulatory requirements.

The review of depth discrete soil concentrations follows along the same line as the examination of historical monitoring well concentrations. The soil borings are examined with respect to there location with the suspected source zone, the A/M Area production wells, and the direction of groundwater flow. Since these samples are a one-time snap shot the direct influence of the production wells can only be assumed. The concentration profiles obtained from depth discrete sampling identify a plume of discrete thickness in the Crouch Branch Aquifer. The information derived from the depth discrete sampling supports historical concentrations reported at nearby monitoring wells. Table 6 presents the location of the soil borings and identifies significant concentrations of trichloroethylene and tetrachloroethylene reported in the Crouch Branch Aquifer.

4.4.1 Soil Borings Upgradient of the Source Zone

During the characterization program a total of four soil borings, two in Phase I and two in Phase II, were located upgradient of the suspected source zone. These soil borings are MCB 1SB, MCB 2SB, MCB 8SB/8ASB, and MCB 9SB. The equivalent aqueous concentrations for both trichloroethylene and tetrachloroethylene are presented in Figure 51, Figure 52, Figure 58, and Figure 59 for these borings. As shown in these figures the only samples collected with any detectable amounts of trichloroethylene and tetrachloroethylene were at boring MCB 2SB. As shown in Figure 52 trichloroethylene concentrations were reported on the order of 5-10 $\mu g/l$. This boring was drilled in late-July of 1993 and is adjacent to monitoring well MSB 85TA. At the time of drilling the unexplained increase in concentration observed at this well had subsided and soil concentrations were on the order of those reported at the monitoring well.

4.4.2 Soil Borings At or Near the Source Zone

During the Phase I characterization program soil samples were collected and analyzed at MCB 3SB. As shown in Figure 1, this soil boring is located northeast of the SRTC complex between monitoring well clusters MSB 47 and MSB 82. The equivalent aqueous concentrations for both trichloroethylene and

tetrachloroethylene are presented in Figure 53. As shown in this figure there were no significant concentrations of tetrachloroethylene detected from these sediment samples, while trichloroethylene concentrations were reported at 175 $\mu g/l$ at an elevation of 118 feet above mean sea level. The 175 $\mu g/l$ concentrations occur at the same elevation as monitoring well MSB 82A and are in agreement with reported concentrations in 3Q93 from this monitoring well.

Soil Borings Downgradient from the Source Zone During the Phase I and Phase II characterization programs, seven soil borings where drilled in the Central A/M Area, downgradient of the suspected Crouch Branch source zone. These soil borings are MCB 4SB, MCB 5SB, MCB 6SB, MCB 7SB, MCB 10SB, MCB 11SB, and MCB 12SB. The equivalent aqueous concentrations for both trichloroethylene and tetrachloroethylene are presented in Figures 54, 55, 56, 57, 60, 61, and 62 for these borings. Of these borings, only MCB 4SB, MCB 5SB, MCB 10SB, and MCB 11SB had trichloroethylene concentrations above detection limits in the Crouch Branch Aquifer. Based upon the positioning of boring MCB 7SB and MCB 12SB with respect to boring MCB-CH-1, drainage effects may have had an impact on samples collected at 30 foot below mean sea level. The highest of the reported concentrations were at MCB 4SB at an elevation of 21.2 feet. This well is located in the vicinity of monitoring well cluster MSB 37 which has screens at 70 feet (MSB 37A) and at 33 feet (MSB 37TA). As shown in Figures 32 and 33 the reported concentrations in 3Q93 were above those derived from the soil samples. This discrepancy is likely a result of VOC loss due to draining or possibly regions of low core recovery during drilling. The data obtained at MCB 4SB does show a discrete plume in the Crouch Branch with the total depth of the boring apparently penetrating to the vertical center of the plume. Examination of the depth discrete data from MCB 5SB, presented in Figure 55, shows a similar pattern in concentrations as that at MCB 4SB. This pattern is also observed in the vertical concentrations at MCB 10SB presented in Figure 60.

Soil samples collected from soil boring MCB 12SB had trichloroethylene concentrations reported at 1.2 $\mu g/l$ at an elevation of 244.7 feet below mean sea level and 1.6 $\mu g/l$ at 104.7 feet below mean sea level. Concentrations of this magnitude are near the detection limits of the analytic equipment used. This elevation is within the McQueen Branch Aquifer and corresponds with screen zones at production wells 905-20A, 905-30A, and 905-53A. All three of which have been identified as contributing to the migration of chlorinated solvent contamination from the Crouch Branch Aquifer into the McQueen Branch Aquifer. Modifications and abandonment activities during FY96 and FY97 have eliminated these migration paths.

4.4.3 Soil Borings at the Miscellaneous Chemical Basin

Soil boring MCB-CH-1 is located at SRS Easting 45069.0 and SRS Northing 96903.0 and was drilled to an elevation of -42.18 feet below mean sea level. The soil boring is one of several soil borings and monitoring wells associated with characterization activities associated with the Miscellaneous Chemical Basin. The distribution of trichloroethylene and tetrachloroethylene from depth discrete soil samples collected at MCB-CH-1 are presented in Figure 63. As shown in this figure, significant headspace concentrations were detected in the shallow Tertiary sediments both above and below the water table. The shallow contaminants found are associated with local releases of trichloroethylene and tetrachloroethylene at the Miscellaneous Chemical Basin while those contaminants reported between the 105 and 155 foot elevation are associated with southward migration of the dissolved plume from the M-Area Basin. Of particular interest in this investigation are the values of both trichloroethylene and tetrachloroethylene reported below mean sea level in the Cretaceous age sediments. As presented in Figure 63, trichloroethylene concentrations were reported at the 55 $\mu g/l$ with corresponding concentrations of tetrachloroethylene reported at 35 $\mu g/l$. If these concentrations were a result of vertical migration from the Lost Lake or M-Area aquifer zones then a constant contamination profile would have been observed. Instead the contamination profile has horizons where no contamination was detected. This leads to the conclusion that the deep contamination is a result of lateral migration in the Crouch Branch Aquifer. Figure 64 presents the reverse flowpath from soil boring MCB-CH-1. As shown in this figure, the upgradient source

is along a line to the northeast. Several monitoring wells and soil borings lie along this line. The majority of the monitoring wells are screened above the elevation where the contamination was detected. Additional characterization is needed in the Central and Northern Sector along this flow line.

Table 6: Locations and Concentrations of Significant Trichloroethylene and Tetrachloroethylene Values in the Crouch Branch Aquifer Derived from Depth Discrete Headspace Sampling.

SRS Easting	SRS Northing	Boring ID	Elevation	TCE	PCE
52780.00	108450.00	MCB 1SB	NA	ND	ND
52975.00	107750.00	MCB 2SB	40.0	7.3	ND
52035.00	107178.00	MCB 3SB	117.2	177.2	ND
51445.00	105008.00	MCB 4SB	21.2	329.3	37.1
51641.00	103983.00	MCB 5SB	10.5	161.1	45.6
50600.00	104750.00	MCB 6SB	NA	ND	ND
48750.00	100850.00	MCB 7SB	NA	ND	ND
52807.78	108457.57	MCB 8SBA	NA	ND	ND
54286.40	108646.74	MCB 9SB	NA	ND	ND
52302.92	105042.04	MCB 10SB	-17.1	67.8	ND
51937.25	103090.45	MCB 11SB	NA	ND	ND
50284.19	101570.48	MCB 12SB	-244.7	1.2	ND
45069.00	96903.00	MCB-CH-1	-32.2	55.0	35.0

Note: Concentrations are Equivalent Water Reported in $\mu g/l$.

4.5 Contamination Profiles Along Production Wells

To obtain quantitative estimates on the amount of chlorinated solvents that migrated into the McQueen Branch Aquifer depth discrete water samples were collected in 1996 as part of the production well modification activities (Jackson et al., 1996a). These samples were collected from the wellbore of production wells identified as contributing to the migration into the McQueen Branch Aquifer. Samples were collected using a stainless steel and Teflon Kemmerer sample bottle (See Appendix B). The results from this investigation are presented in Table 7.

Regional Observation Well LA-4 Depth discrete water samples were collected from 5 different elevations from the wellbore of regional observation well LA-4. These elevations correspond with the reported screen zones of the observation well. As presented in Table 7 concentrations were in the 5 to 10 $\mu g/l$ range for trichloroethylene with tetrachloroethylene values at detection limits.

Production Well 905-15A Depth discrete water samples were collected from 4 different elevations from the wellbore of production well 905-15A. This well had been out of service since the late 1960's. The sample elevations correspond with the reported screen zones and screen zones determined during the video surveys. As presented in Table 7 concentrations were in the 3 to 5 $\mu g/l$ range for trichloroethylene with slightly higher levels of tetrachloroethylene. The low values reported indicate that the well is in very poor communication with the aquifer as evident by screen conditions observed during the video survey.

Production Well 905-20A Depth discrete water samples were collected from 7 different elevations from the wellbore of process supply well 905-20A. These elevations correspond with the reported screen zones and screen zones determined during the video surveys. The sampling include the collection of sample PW 25 inside the lower casing above the weep screen. As presented in Table 7 the trichloroethylene concentrations range are in the 10 $\mu g/l$ to 25 $\mu g/l$ range for trichloroethylene. The concentration levels are significantly lower than those observed at production well 905-53A. This is believed to be a result of plume containment in the Crouch Branch Aquifer provided by the operation of production well 905-53A while sampling at production well 905-20A. Using the maximum reported concentration of 29 $\mu g/l$ with a downward velocity of 10 ft/min results in less than 0.0025 pounds per day of solvent migrating into the Crouch Branch Aquifer. For a conservative estimate the maximum concentrations reported at 905-53A are used and result in only 0.04 pounds per day of solvent released during idle periods. This migration rate at production well 905-20A would only occur when both production wells 905-53A and 905-20A were idle.

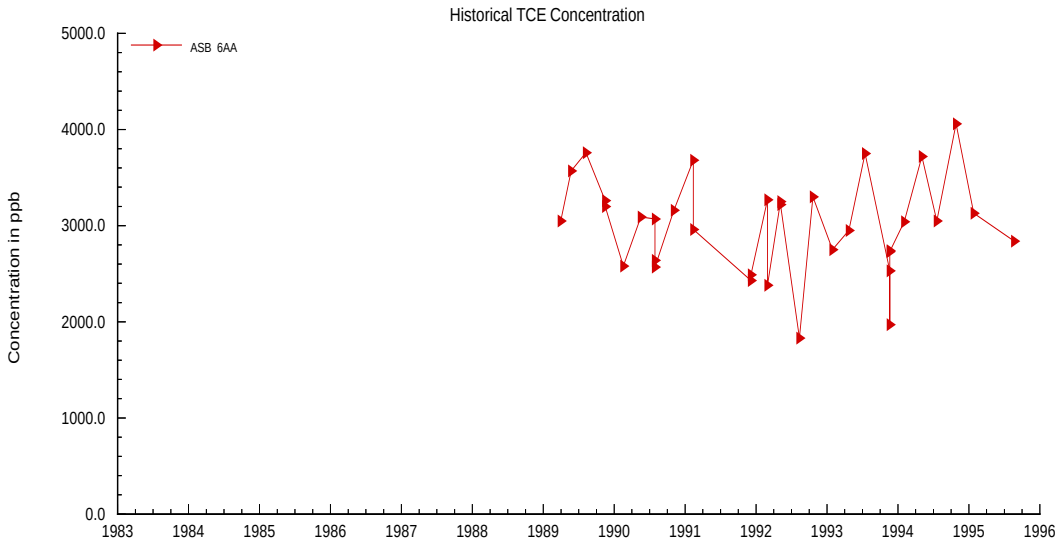
Production Well 905-53A Depth discrete water samples were collected from 12 different elevations from the wellbore of process supply well 905-53A. These elevations correspond with the reported screen zones and screen zones determined during the video surveys including sample PW 12 collected immediately inside the lower casing above the weep screen. As presented in Table 7 the trichloroethylene concentrations range from 12 $\mu g/l$ to 641 $\mu g/l$ for trichloroethylene. The 641 $\mu g/l$ concentration was collected at an elevation of 52.2 feet below mean sea level. This is the section below the first screen zone in the Crouch Branch Aquifer, slightly below the elevation of monitoring well MSB 37TA. The sample collected beneath the next screen interval had trichloroethylene concentrations reported at 18 $\mu g/l$ and reflects the tripping of the sampling mechanism while crossing the lap-joint. As presented in Table 7 the concentrations reported in the wellbore at the elevation of McQueen Branch Aquifer were in the 150 to 200 $\mu g/l$ range for trichloroethylene. A conservative estimate on the amount of mass transferred can be made using the reported 641 $\mu g/l$ trichloroethylene concentrations along with the 20 ft/min downward flowrate previously determined. This results in an estimated 0.13 pounds per day of solvent being released to the McQueen Branch Aquifer via the wellbore during idle periods.

Based upon the data collected, well construction features, hydrologic conditions, and production well operations, well 905-53A was the greatest contributor to migration of solvents into the McQueen Branch Aquifer. The well has a larger screen percentage in the Crouch Branch and is located hydraulically closer to the SRTC source zone than production wells 905-20A and 905-31A. This assumption is also supported by the magnitude of historical and depth discrete concentrations reported at this well versus other production wells in the A/M Area. Complementing this is the fact that production wells 905-20A and 905-31A have more screen sections in the McQueen Branch Aquifer and would reasonably extract more water from this aquifer zone than the Crouch Branch Aquifer. During periods of operation the positioning of these wells with relationship to production well 905-53A would result in the capture of a significant amount of solvent released to the McQueen Branch aquifer via well 905-53A.

Table 7: Summary of Organic Concentrations Determined from Depth Discrete Sampling at the A/M Area Production Wells

Well ID	Sample ID	Depth	Elevation	TCE	PCE
LA-4	PW 01	277 ft	80.0 ft	5.79	1.50
	PW 02	377 ft	-20.0 ft	5.67	1.59
	PW 03	427 ft	-70.0 ft	5.96	1.61
	PW 04	482 ft	-125.0 ft	12.53	1.35
	PW 05	552 ft	-195.0 ft	12.84	1.53
905-15A	PW 10	200 ft	176.5 ft	3.78	6.09
	PW 06	265 ft	111.5 ft	5.24	7.43
	PW 07	330 ft	46.5 ft	4.26	6.53
	PW 08	425 ft	-48.5 ft	5.07	7.18
	PW 09	Blank		ND	ND
905-20A	PW 25	300 ft	71.8 ft	12.30	1.99
	PW 26	370 ft	1.8 ft	21.29	3.79
	PW 27	401 ft	-29.2 ft	22.66	4.06
	PW 28	485 ft	-113.2 ft	11.73	1.95
	PW 29	594 ft	-222.2 ft	25.00	4.28
	PW 30	621 ft	-249.2 ft	14.83	2.35
	PW 31	660 ft	-288.2 ft	29.93	4.74
	PW 32	Blank		ND	ND
905-53A	PW 11	Blank		ND	ND
	PW 12	367 ft	14.8 ft	12	6.2
	PW 13	405 ft	-23.2 ft	253	28
	PW 14	434 ft	-52.2 ft	641	72
	PW 15	457 ft	-75.2 ft	18	ND
	PW 16	495 ft	-113.2 ft	230	24
	PW 17	537 ft	-155.2 ft	210	22
	PW 18	555 ft	-173.2 ft	204	18
	PW 19	582 ft	-200.2 ft	187	23
	PW 20	601 ft	-219.2 ft	146	27
	PW 21	637 ft	-255.2 ft	200	33
	PW 22	657 ft	-275.2 ft	224	17
	PW 23	Blank		ND	ND
	PW 24	Blank		ND	ND

Note: Concentrations are Reported in $\mu g/l$.



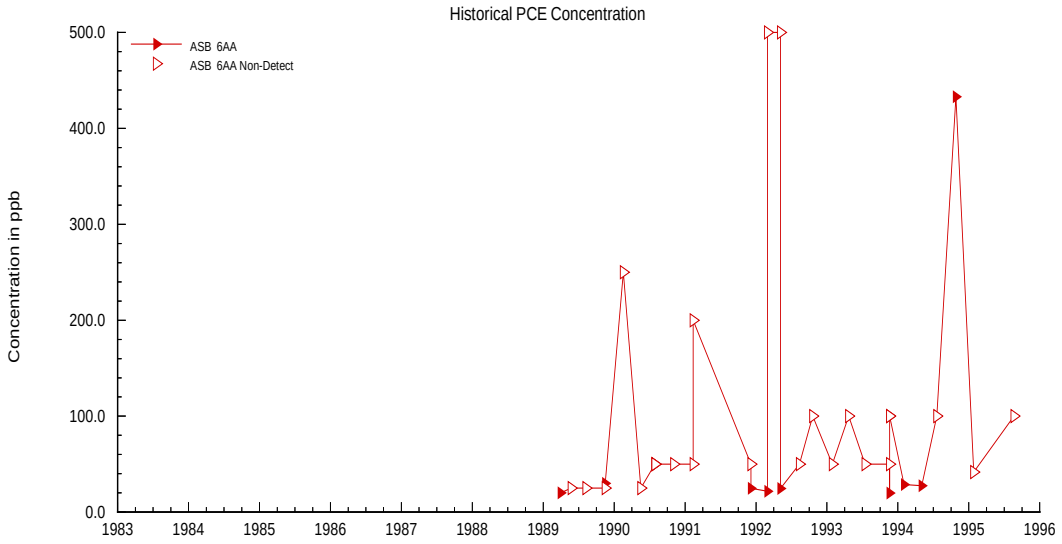
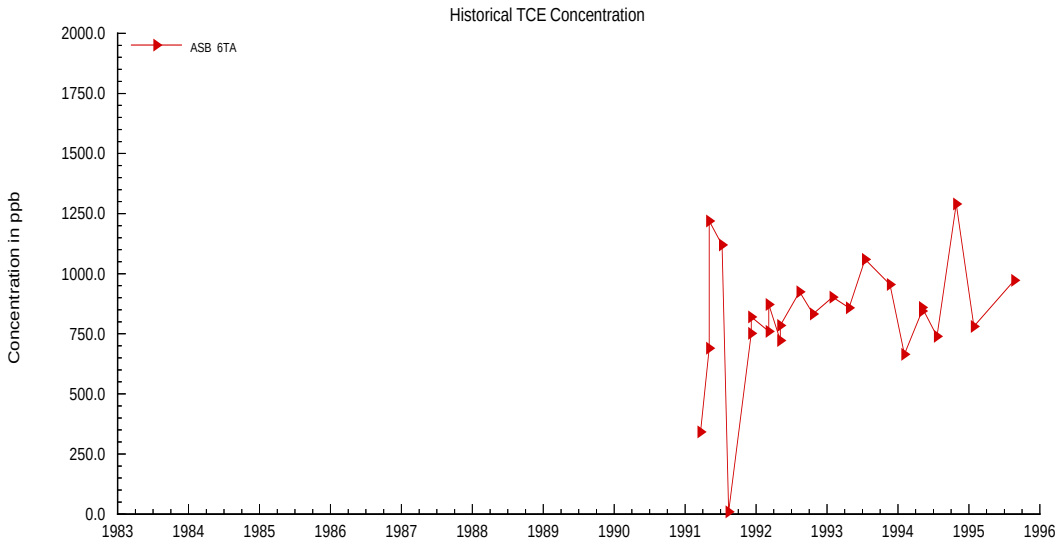


Figure 14: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well ASB 6AA used to identify the source area for the dissolved contamination in the Crouch Branch Aquifer.



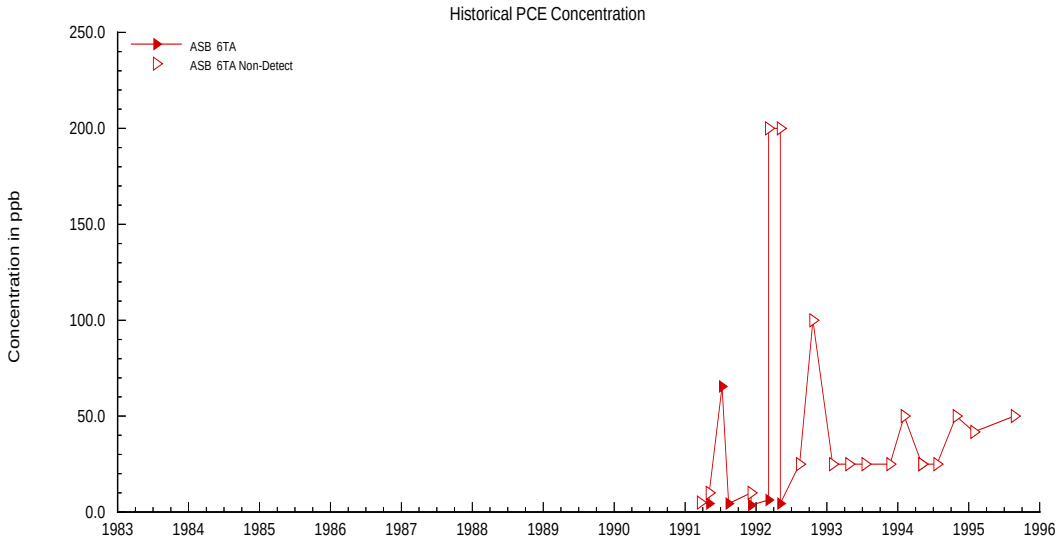
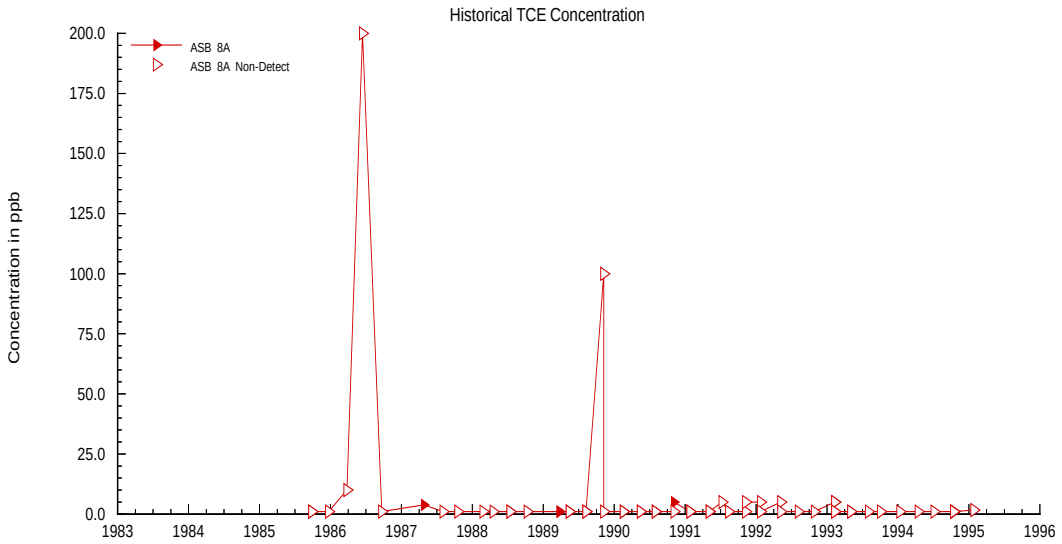


Figure 15: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well ASB 6TA used to identify the source area for the dissolved contamination in the Crouch Branch Aquifer.



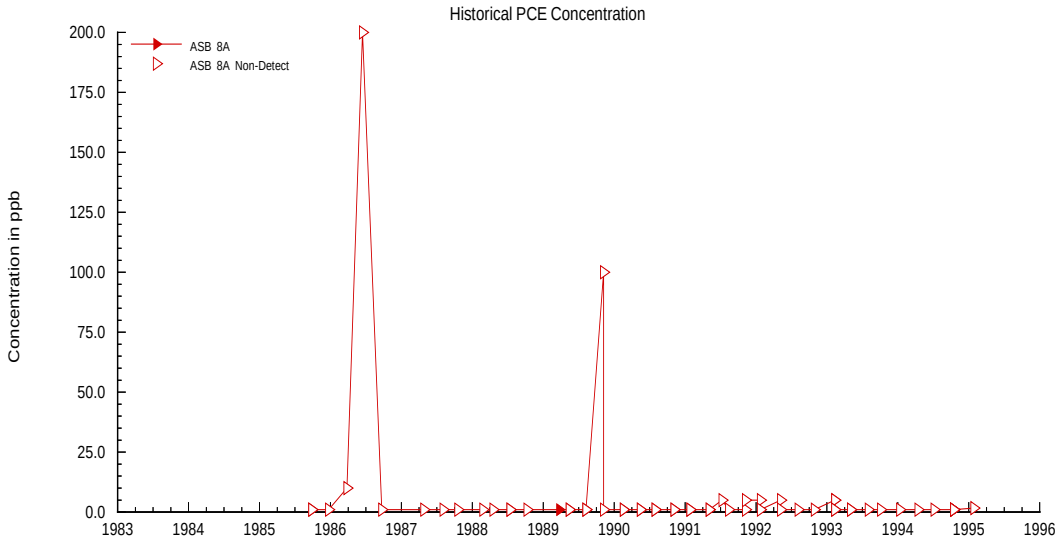
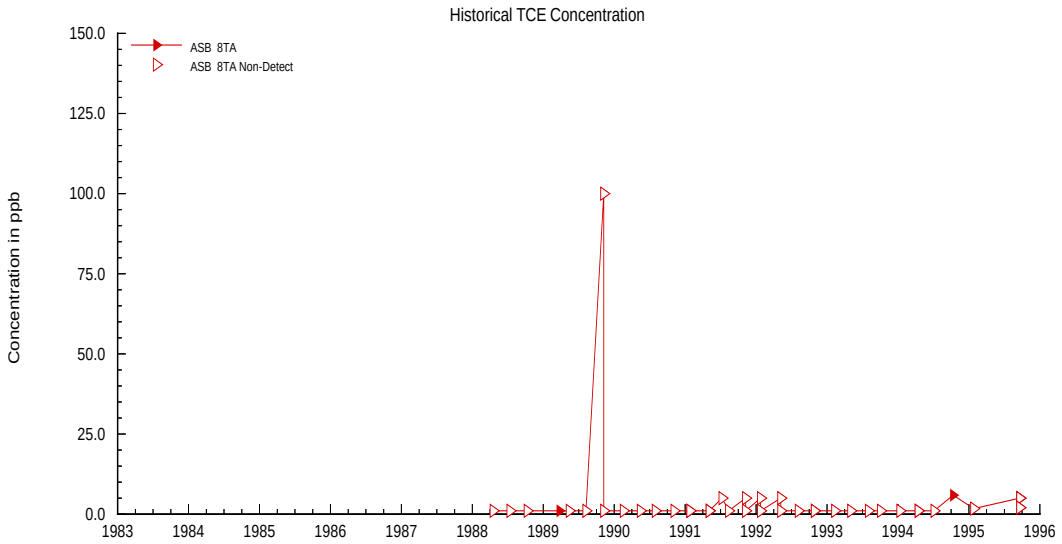


Figure 16: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well ASB 8A used to identify the source area for the dissolved contamination in the Crouch Branch Aquifer.



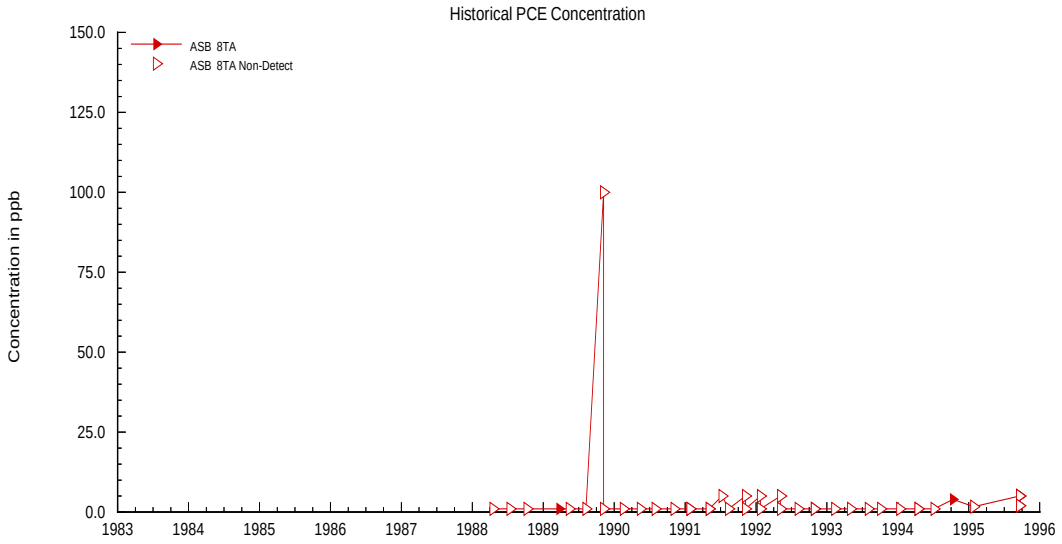
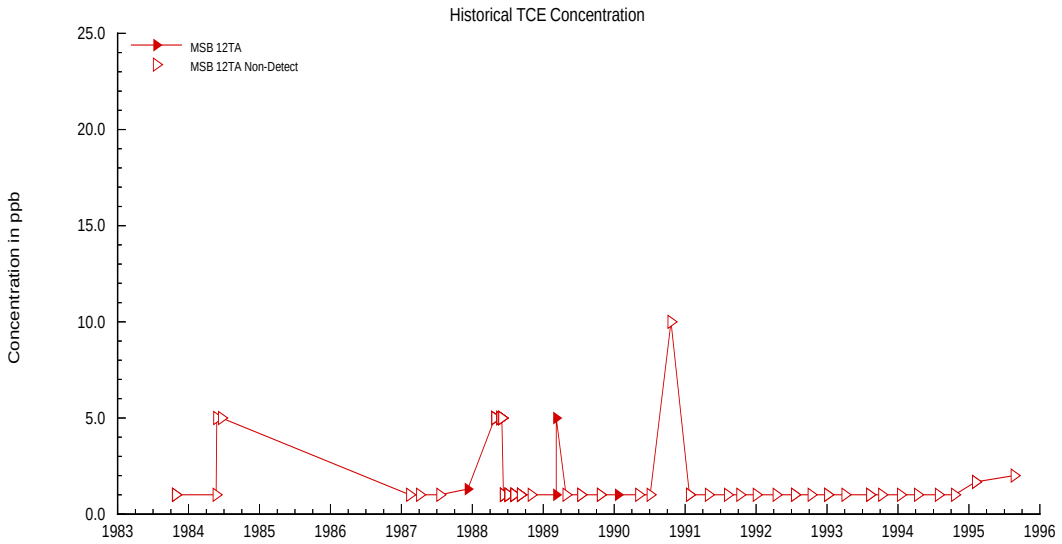


Figure 17: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well ASB 8TA used to identify the source area for the dissolved contamination in the Crouch Branch Aquifer.



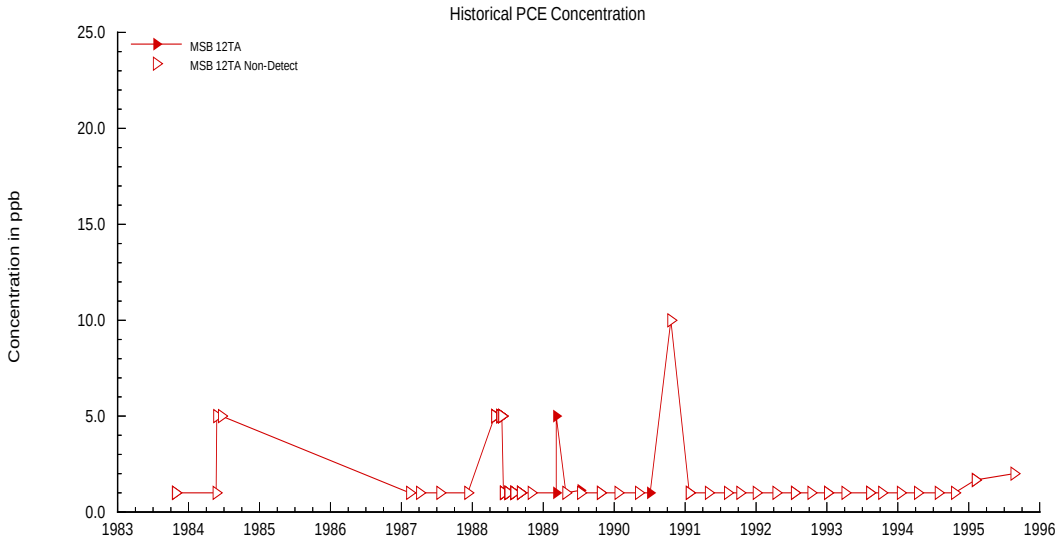
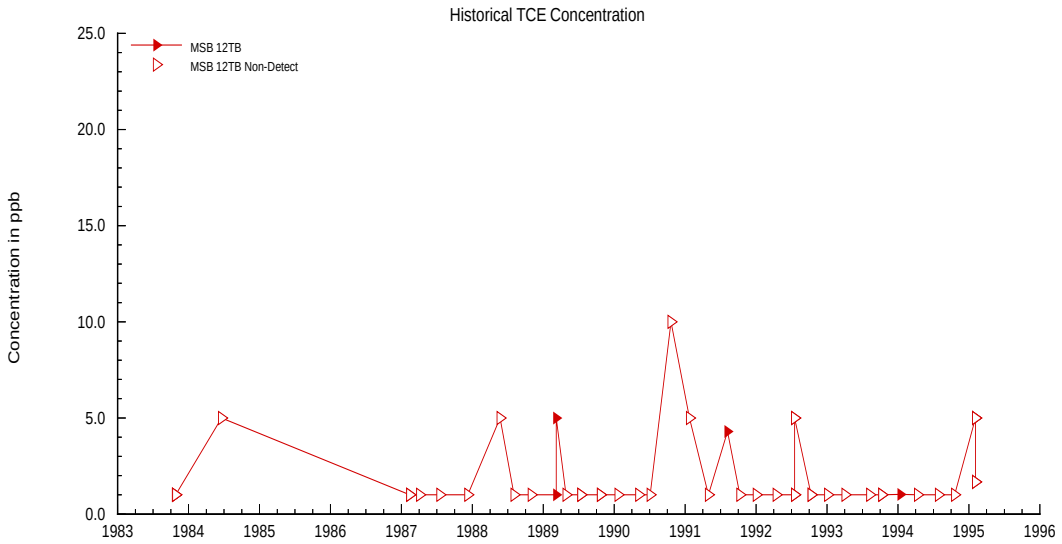


Figure 18: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 12TA associated with dissolved contamination in the Crouch Branch Aquifer.



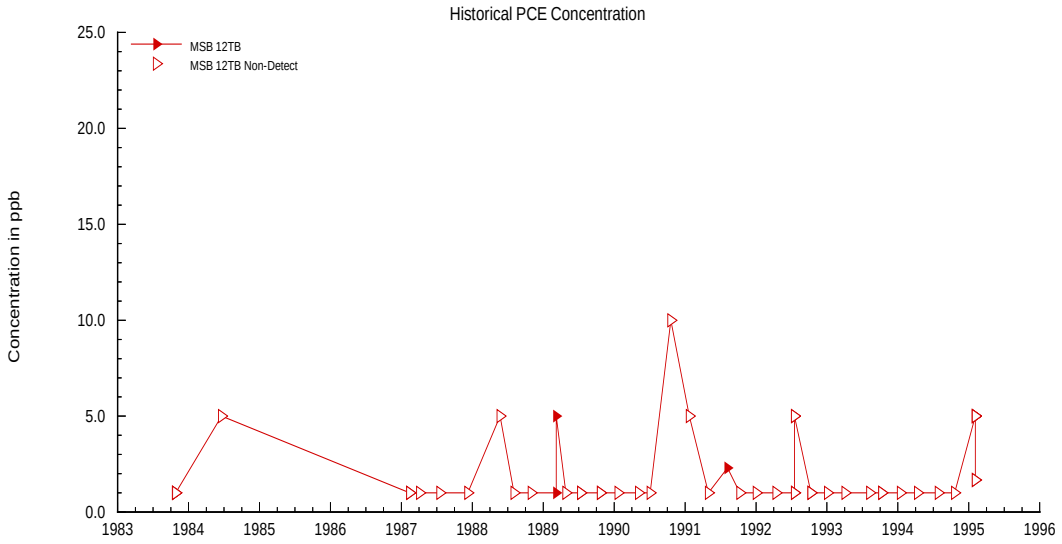
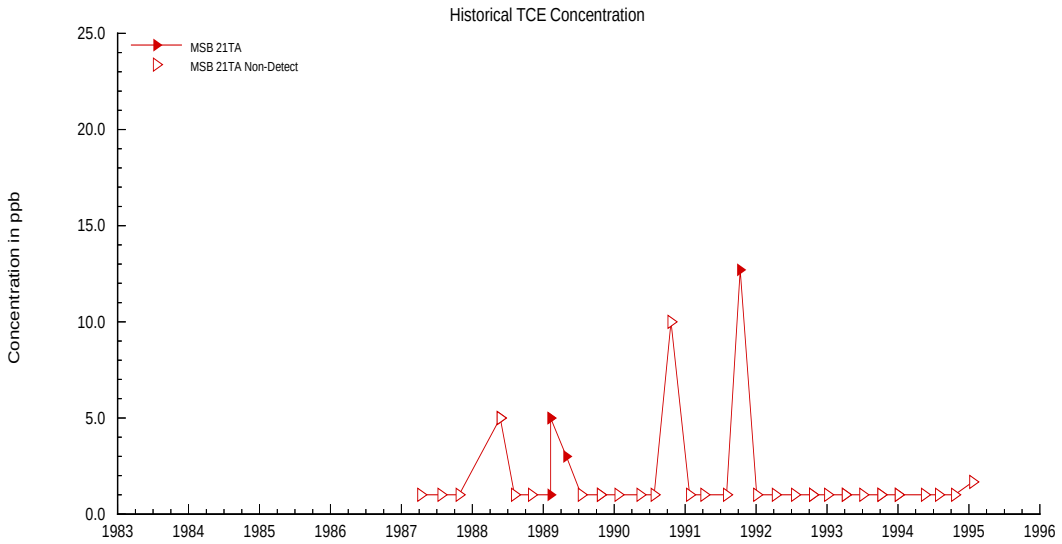


Figure 19: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 12TB associated with dissolved contamination in the Crouch Branch Aquifer.



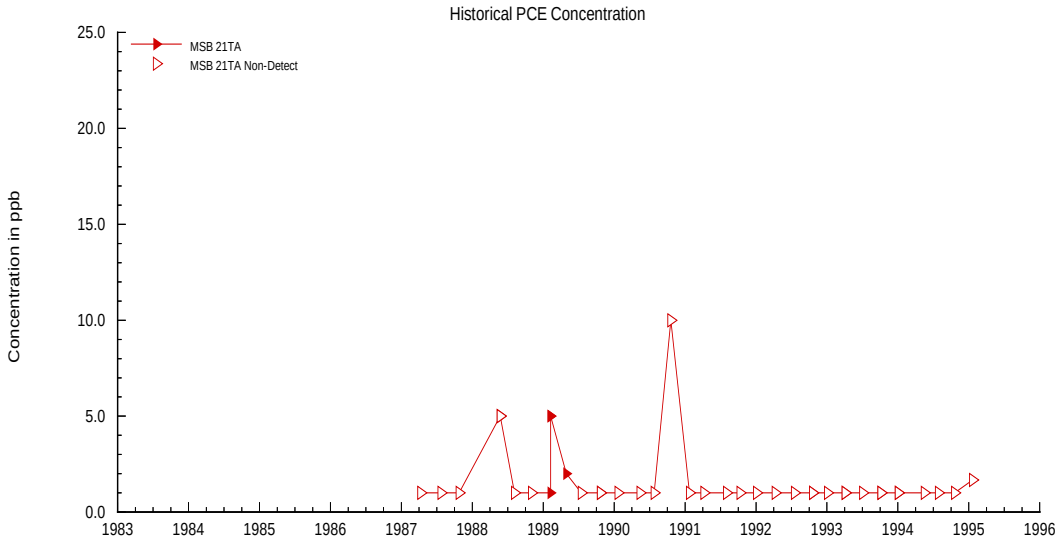
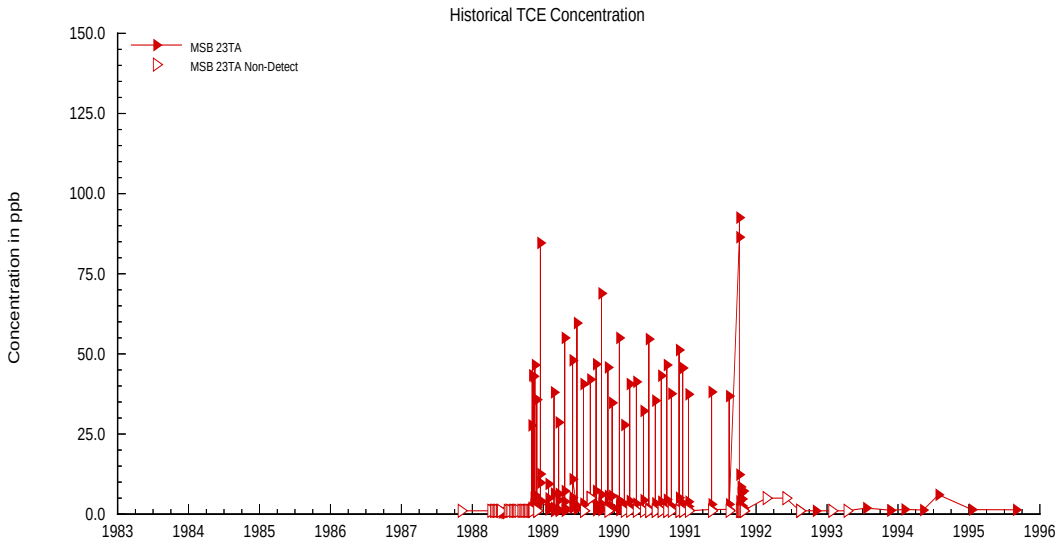


Figure 20: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 21TA associated with dissolved contamination in the Crouch Branch Aquifer.



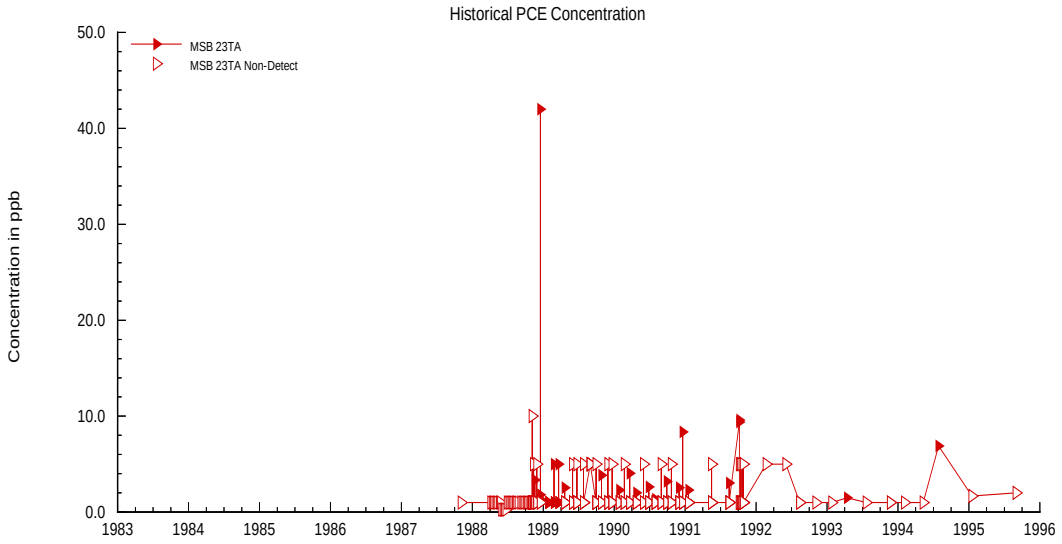
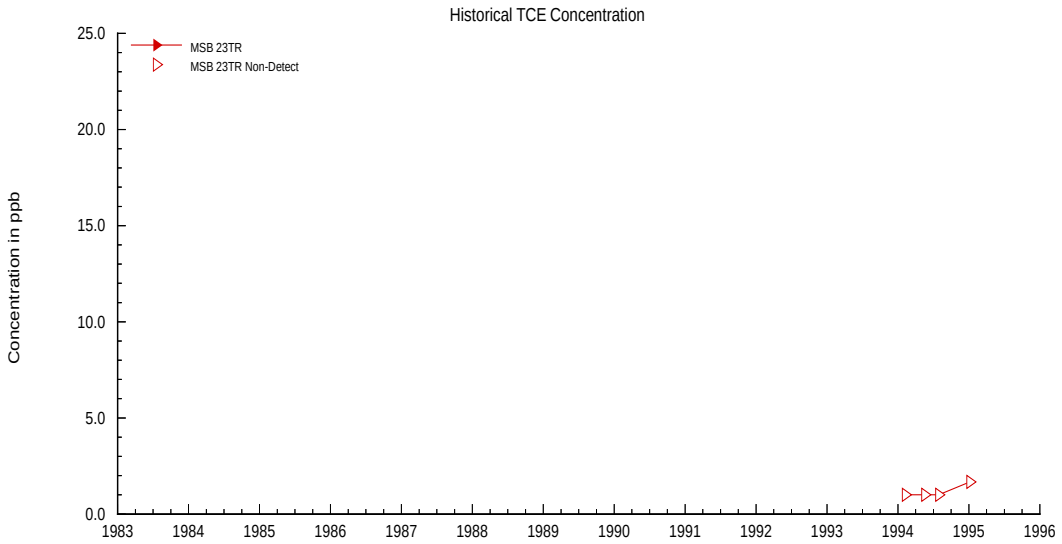


Figure 21: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 23TA associated with dissolved contamination in the Crouch Branch Aquifer.



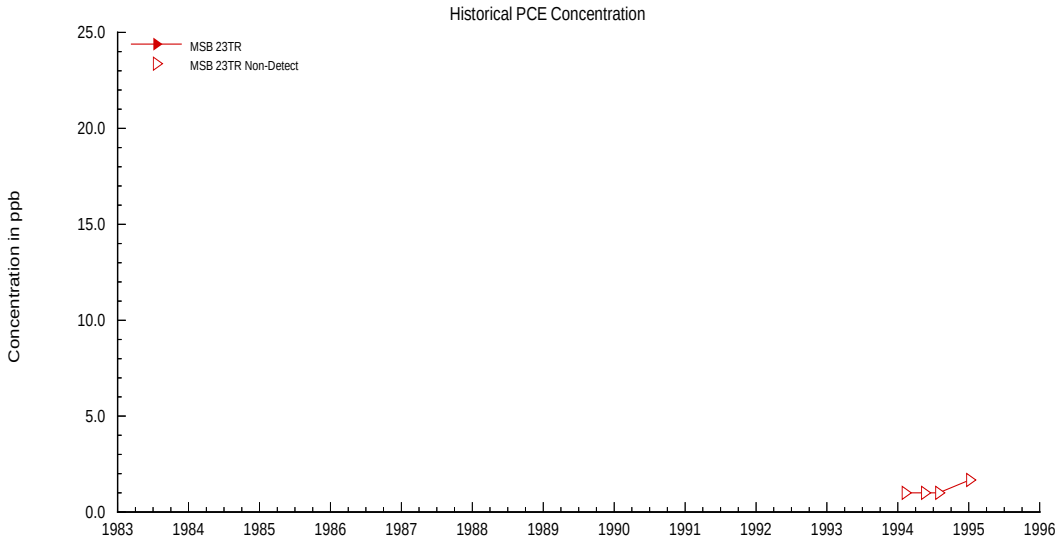
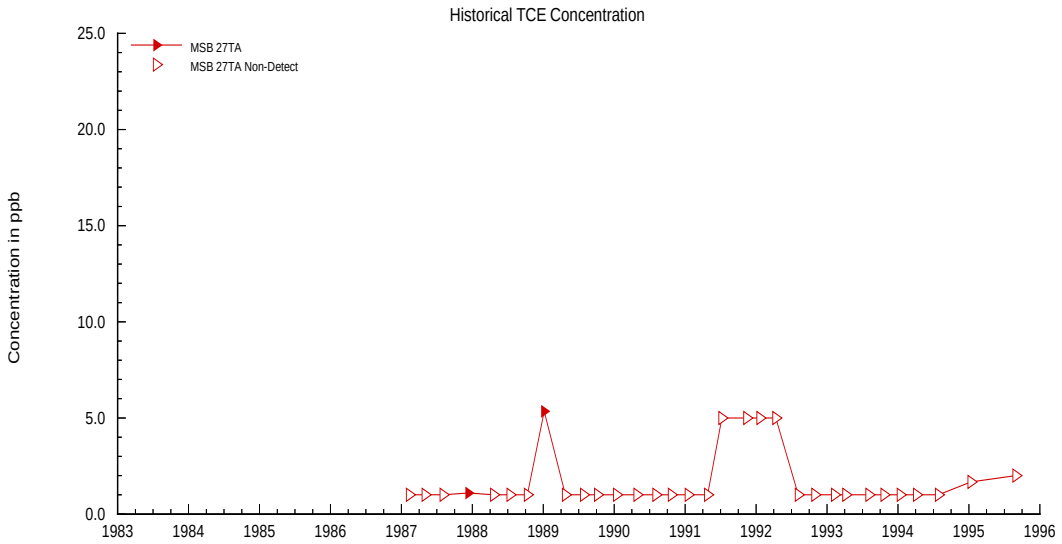


Figure 22: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 23TR associated with dissolved contamination in the Crouch Branch Aquifer.



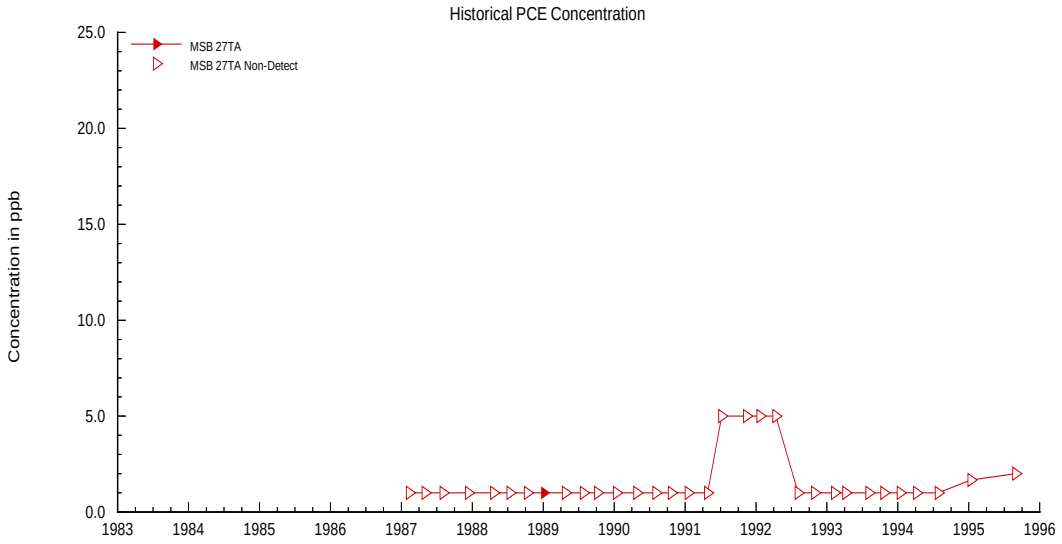
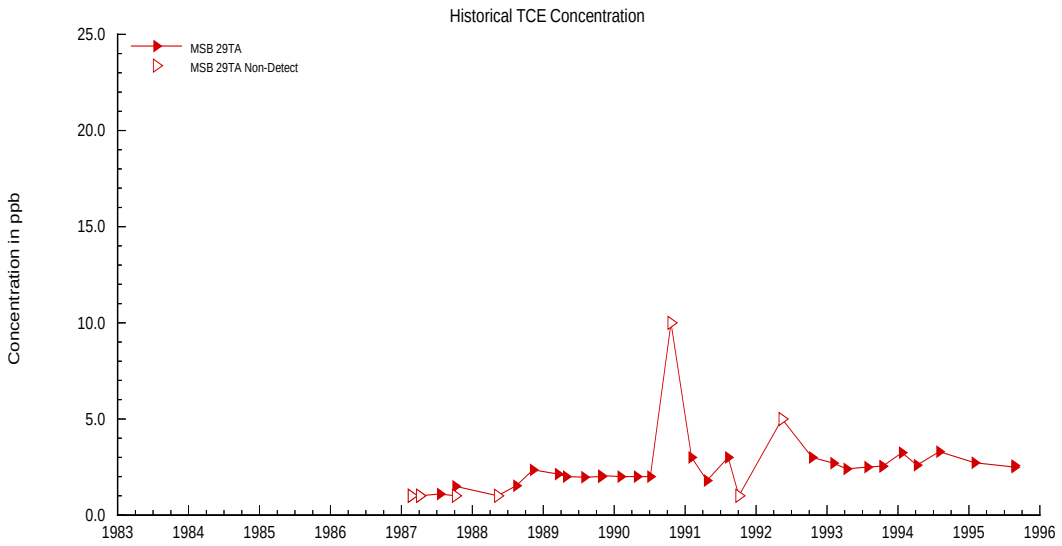


Figure 23: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 27TA associated with dissolved contamination in the Crouch Branch Aquifer.



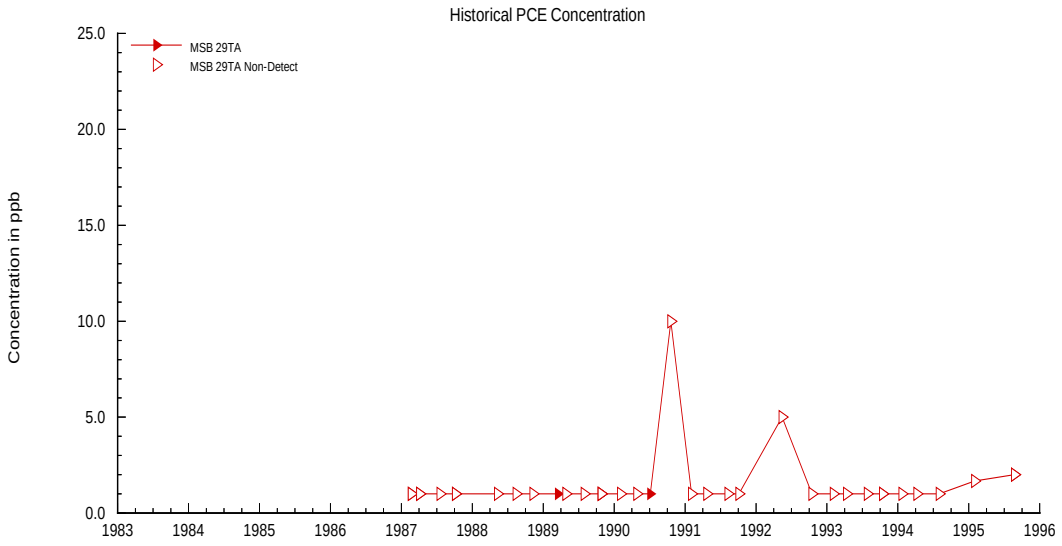
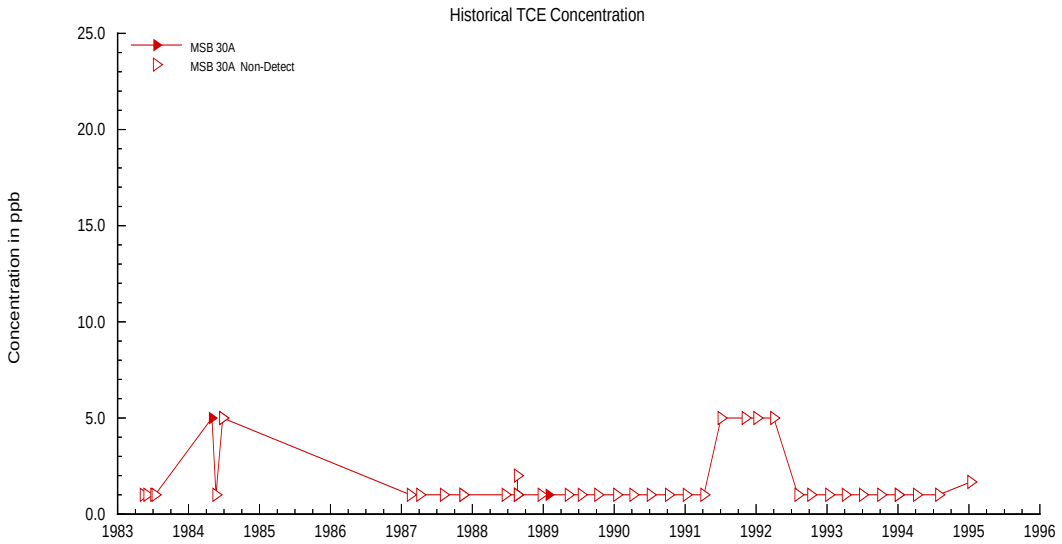


Figure 24: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 29TA located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.



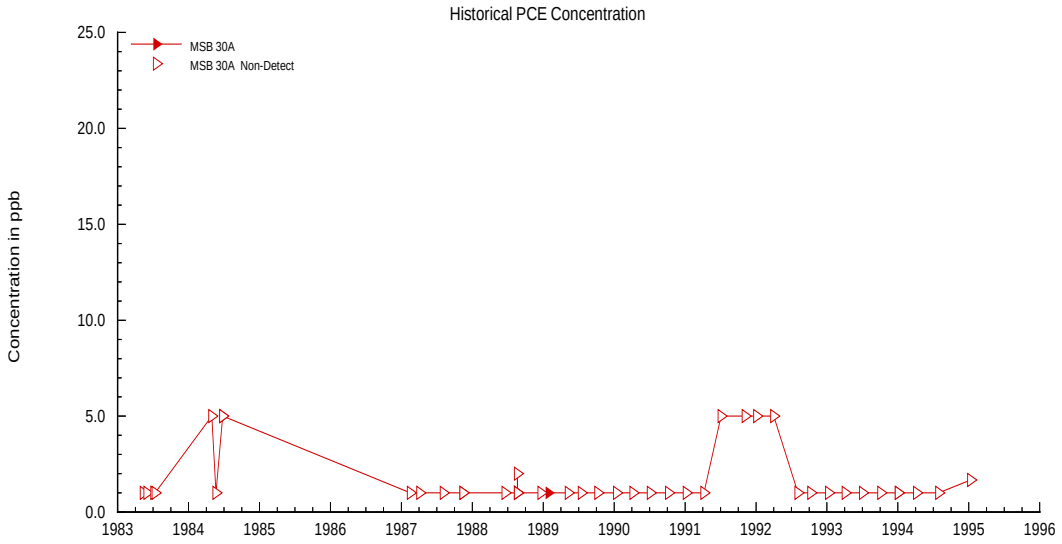
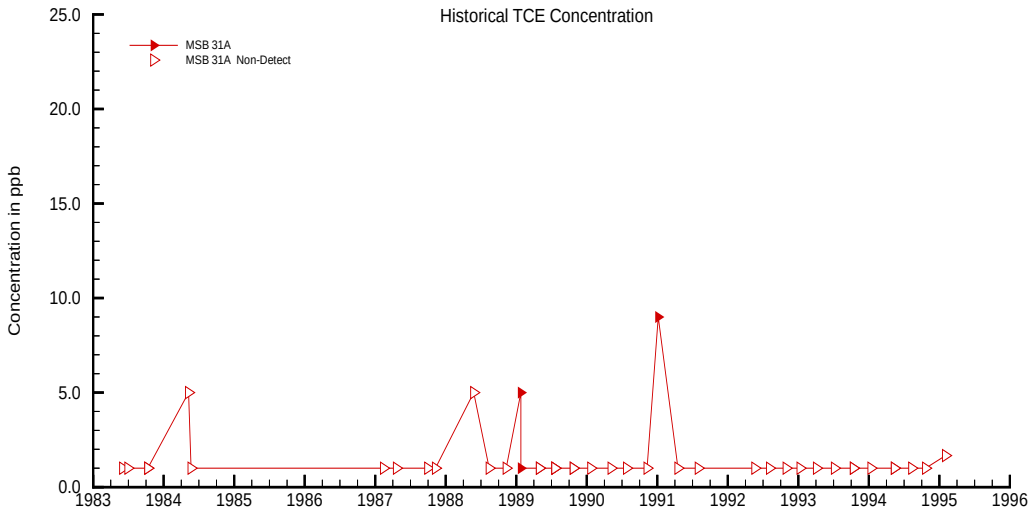


Figure 25: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 30A associated with dissolved contamination in the Crouch Branch Aquifer.



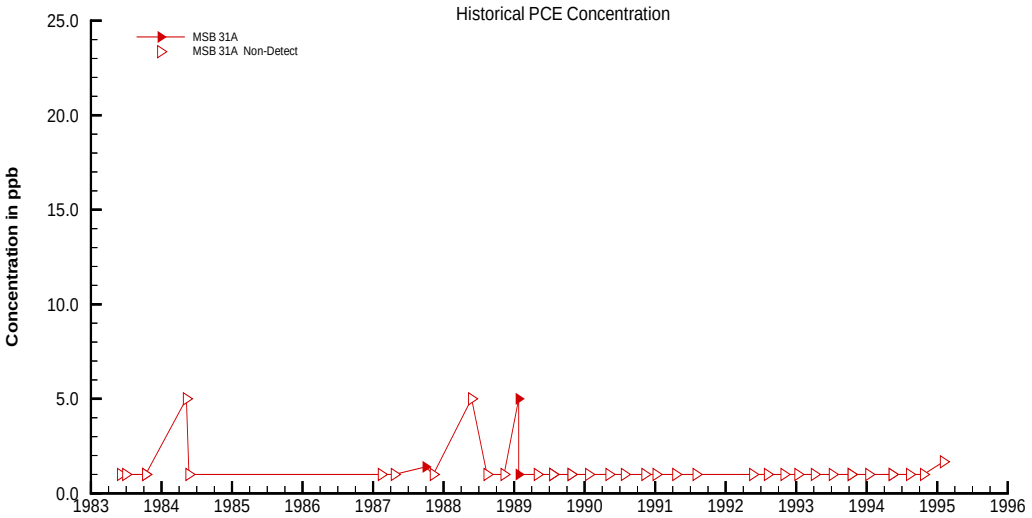
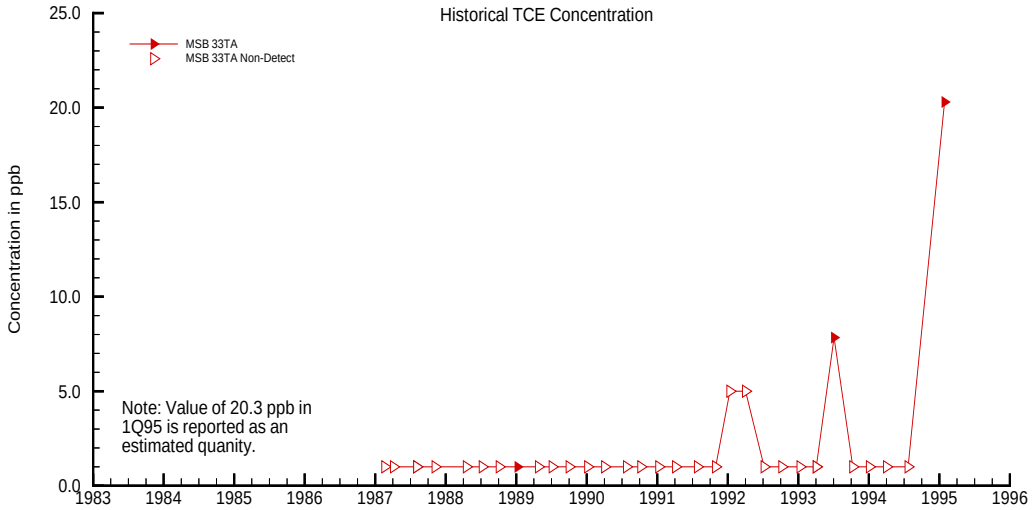


Figure 26: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 31A located downgradient of the A/M Area Production Well System.



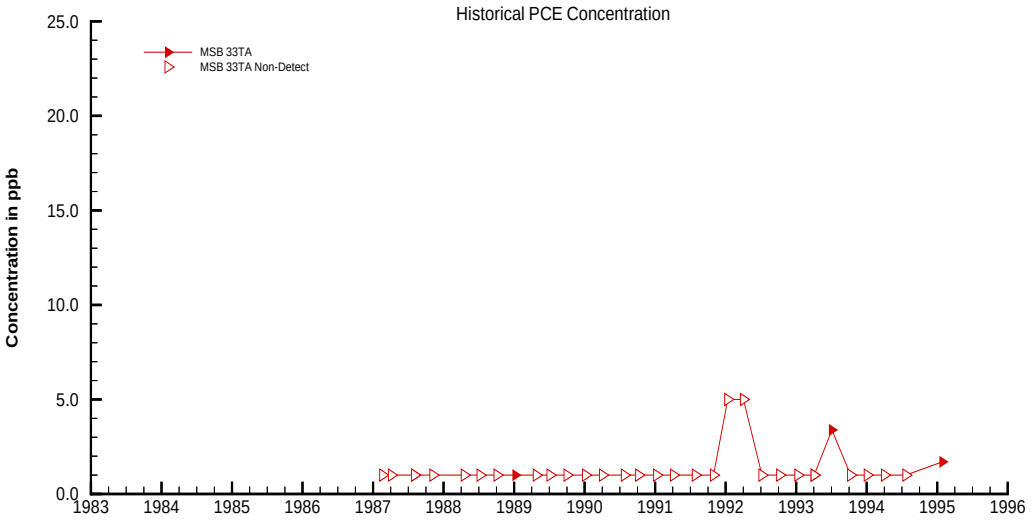
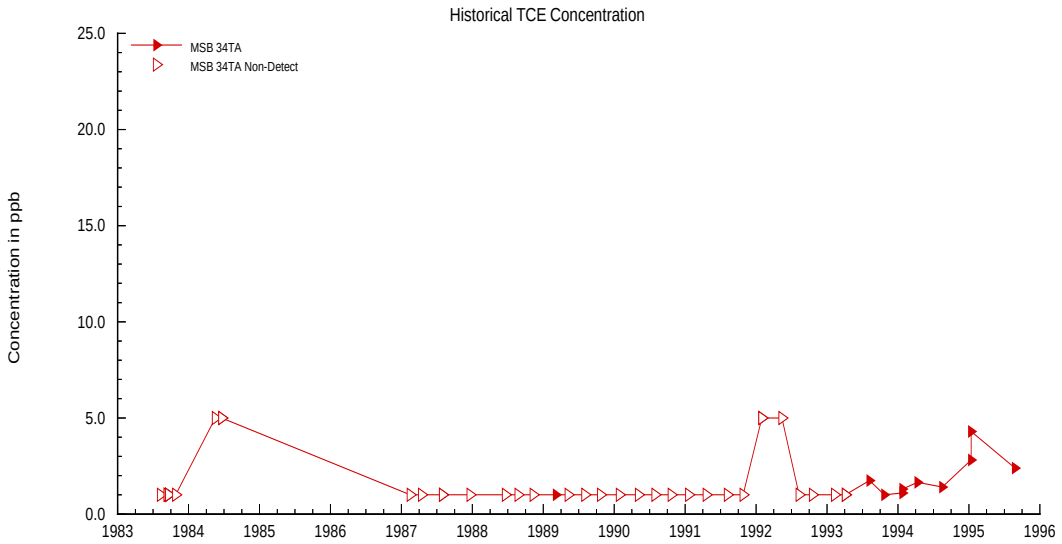


Figure 27: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 33TA associated with dissolved contamination in the Crouch Branch Aquifer.



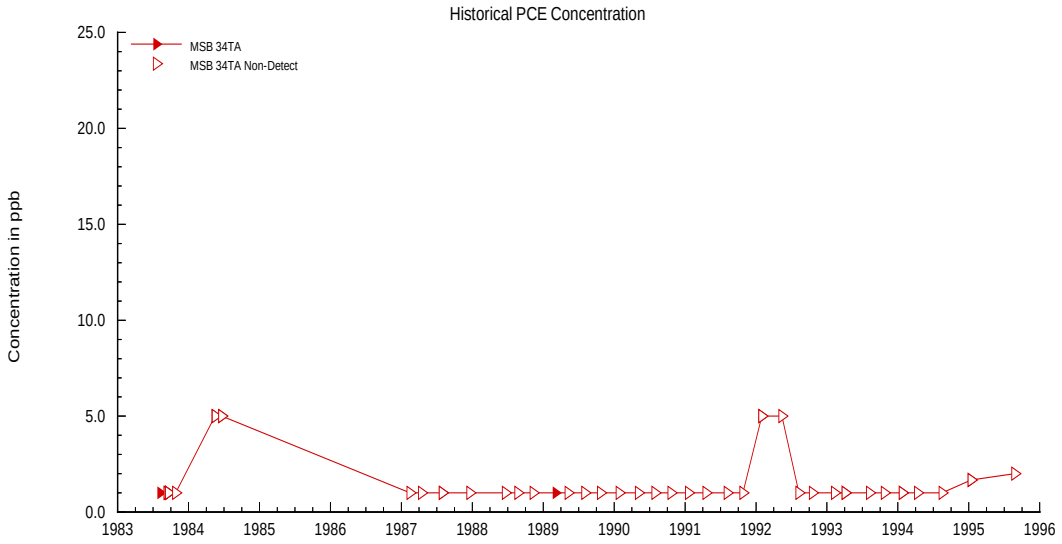
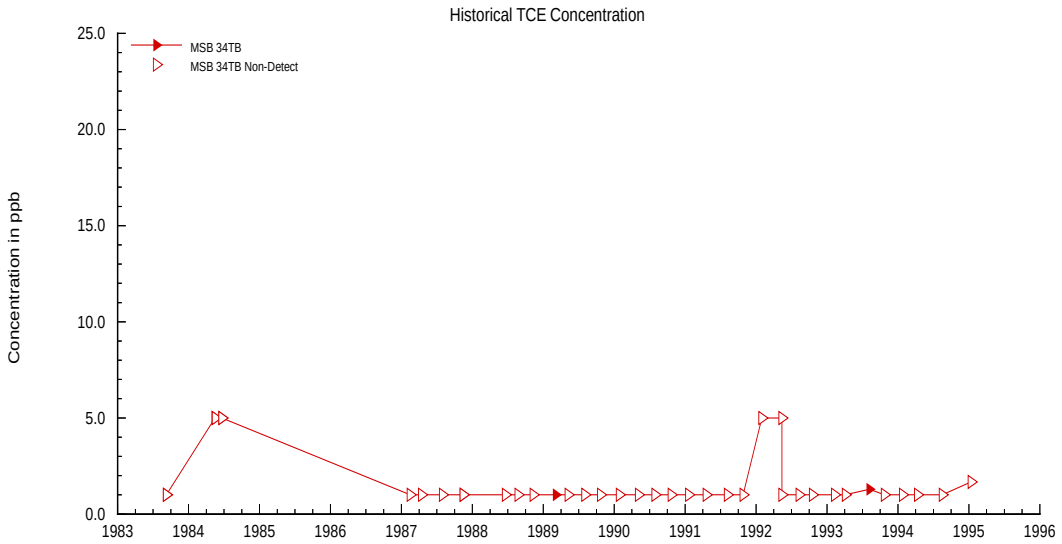


Figure 28: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 34TA associated with dissolved contamination in the Crouch Branch Aquifer.



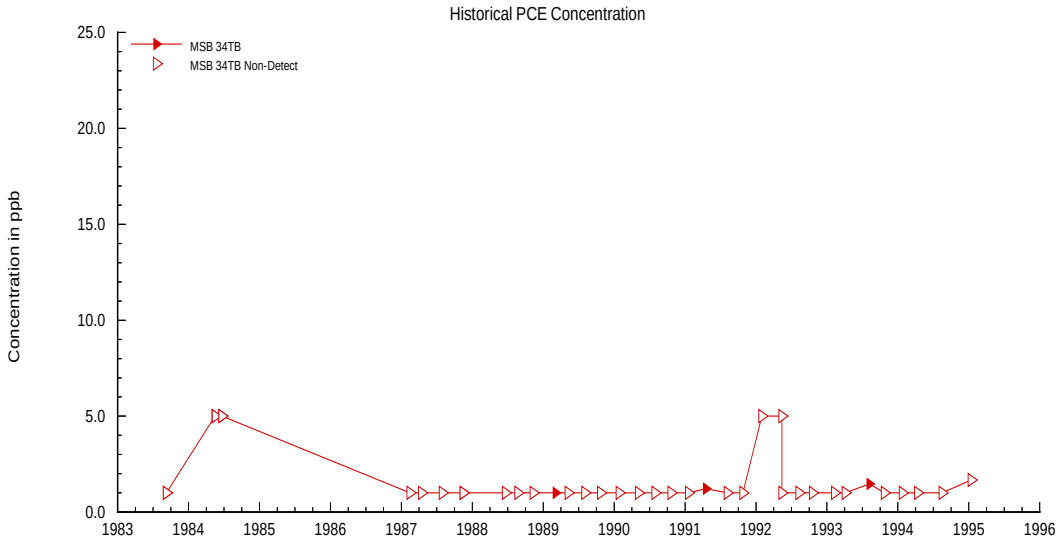
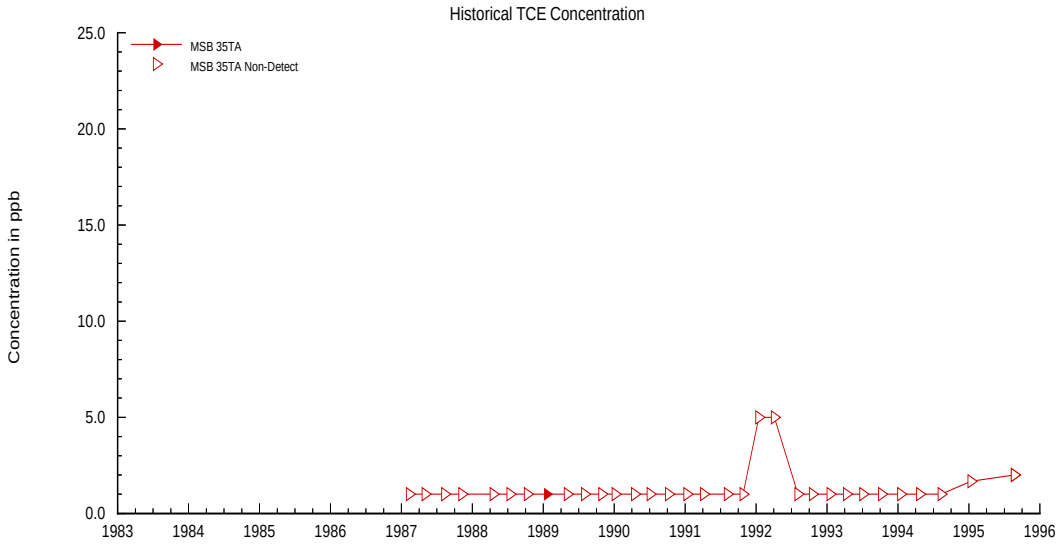


Figure 29: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 34TB associated with dissolved contamination in the Crouch Branch Aquifer.



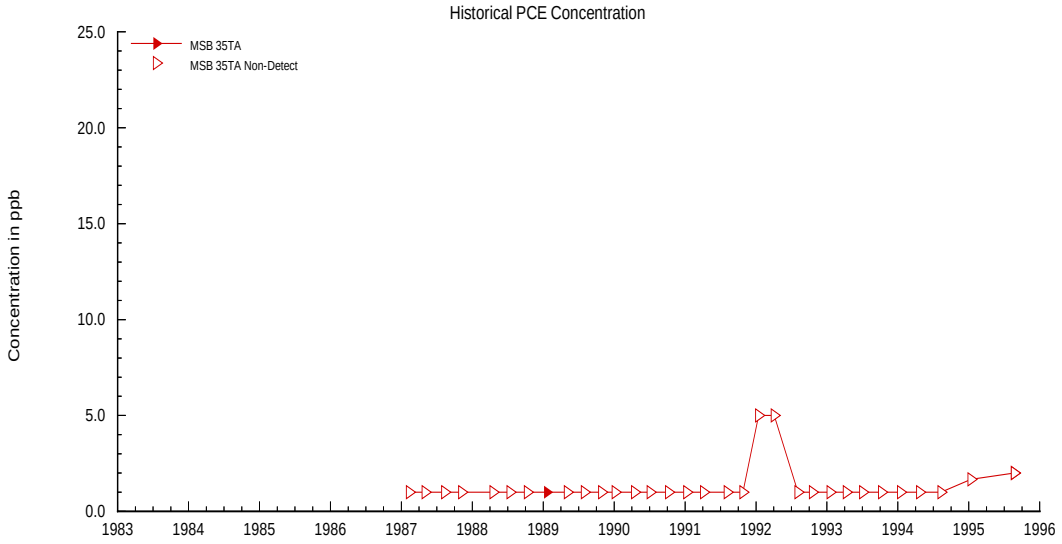
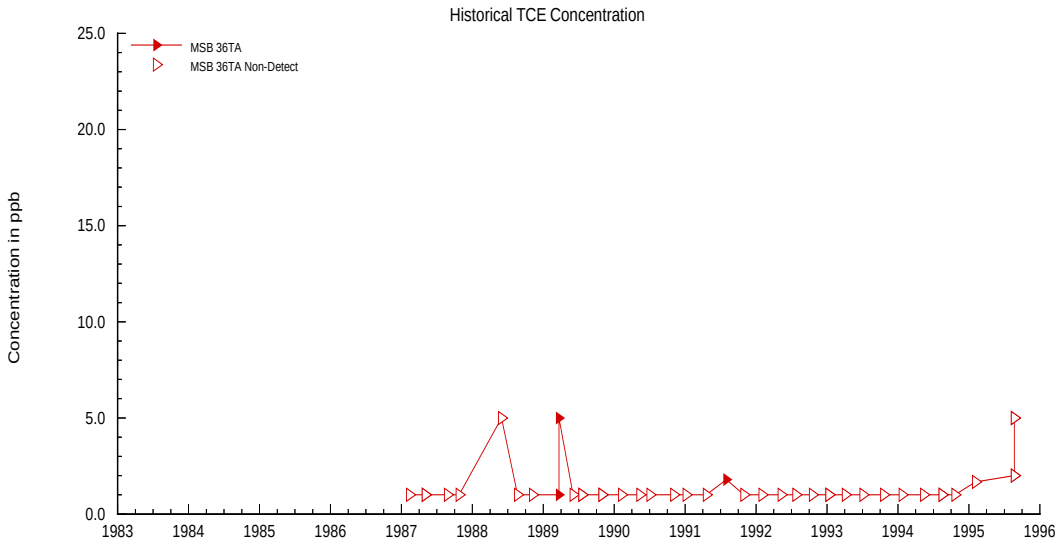


Figure 30: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 35TA located downgradient of the A/M Area Production Well System.



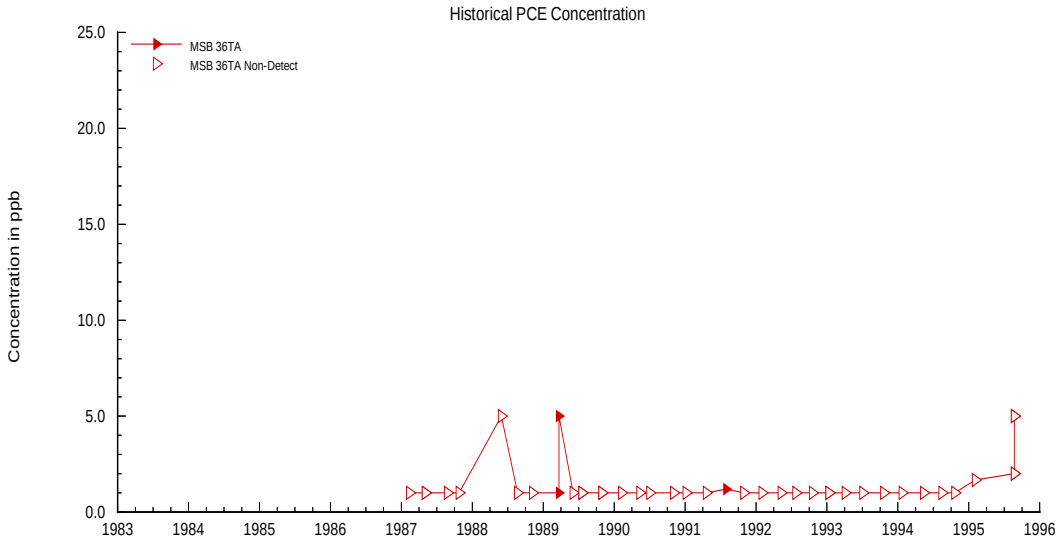
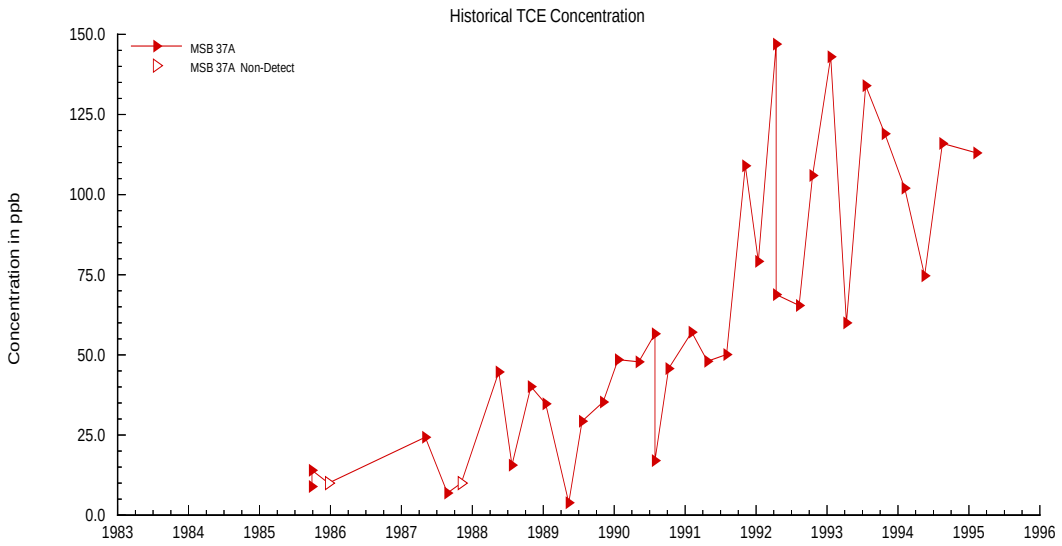


Figure 31: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 36TA associated with dissolved contamination in the Crouch Branch Aquifer.



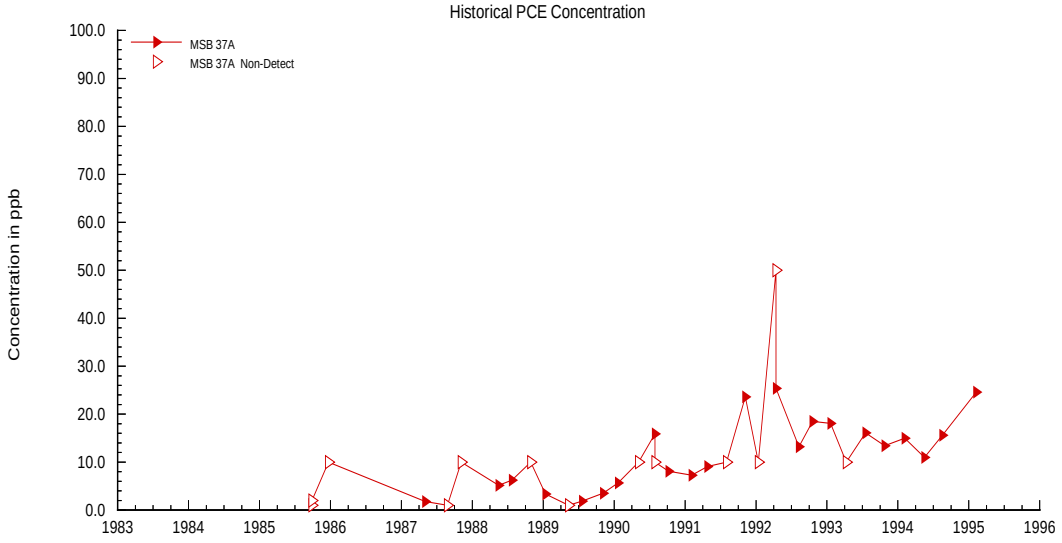


Figure 32: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 37A located downgradient from the source area in the SRTC complex associated with dissolved contamination in the Crouch Branch Aquifer.

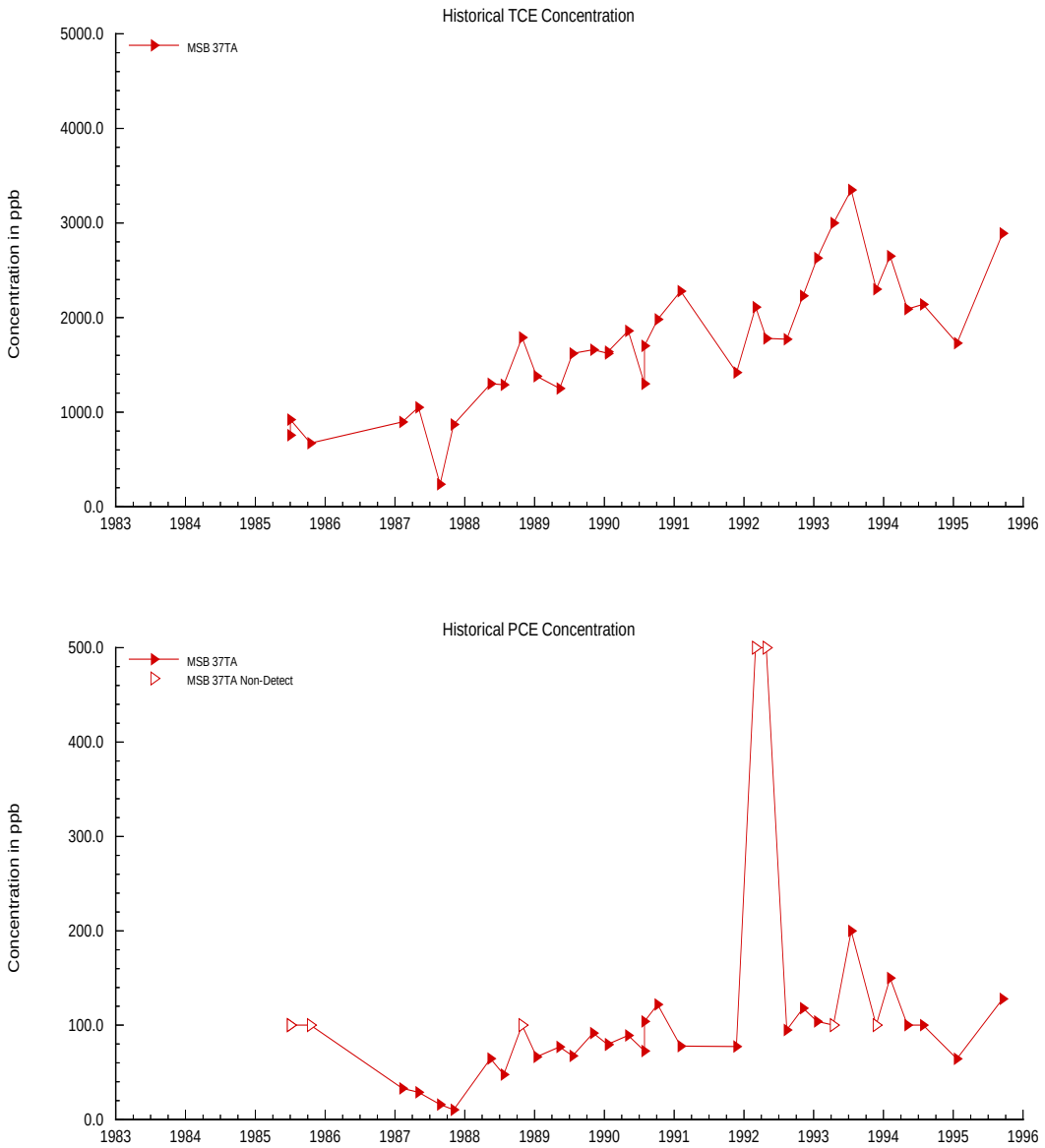
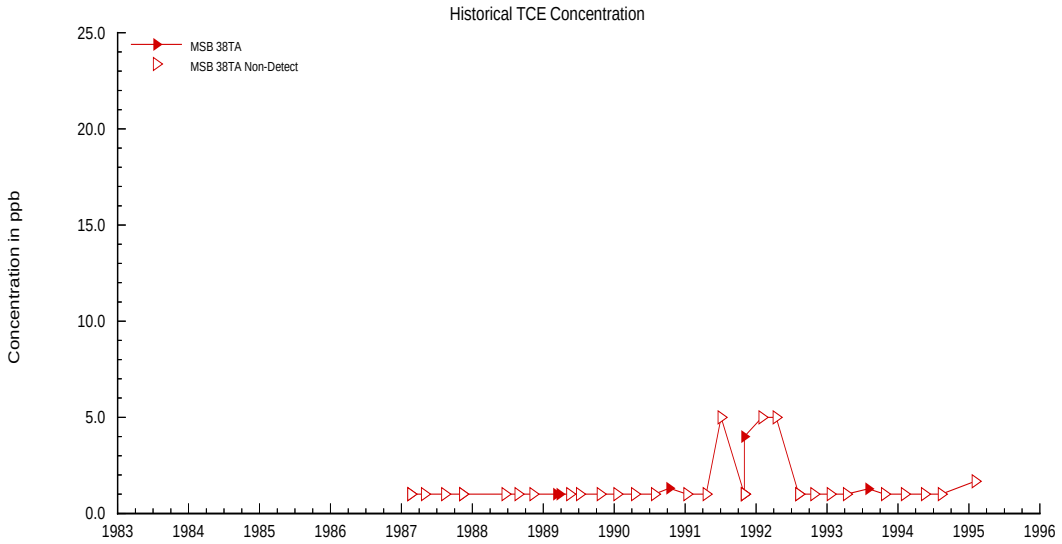


Figure 33: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 37TA located downgradient from the source area in the SRTC complex associated with dissolved contamination in the Crouch Branch Aquifer.



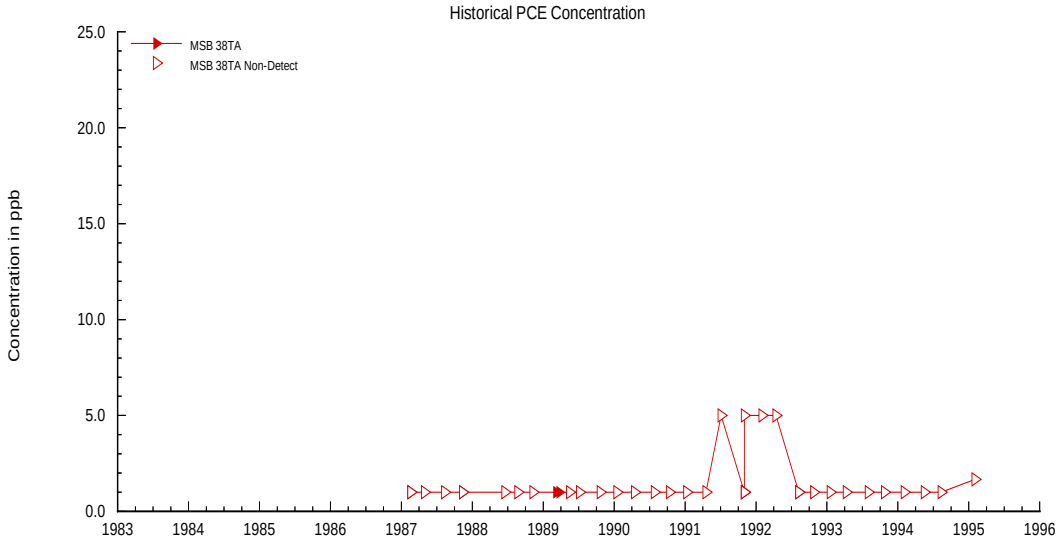
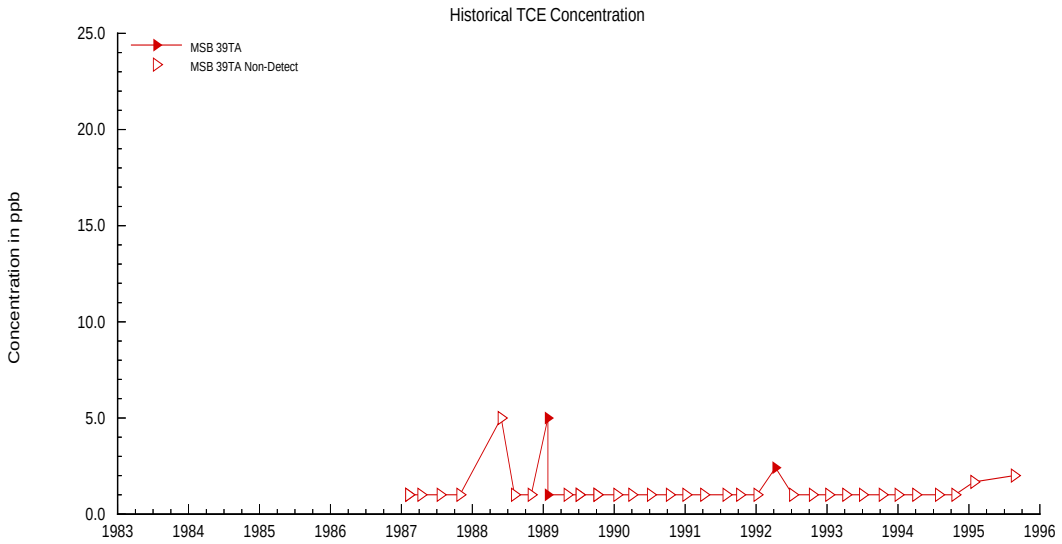


Figure 34: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 38TA located downgradient of the A/M Area Production Well System.



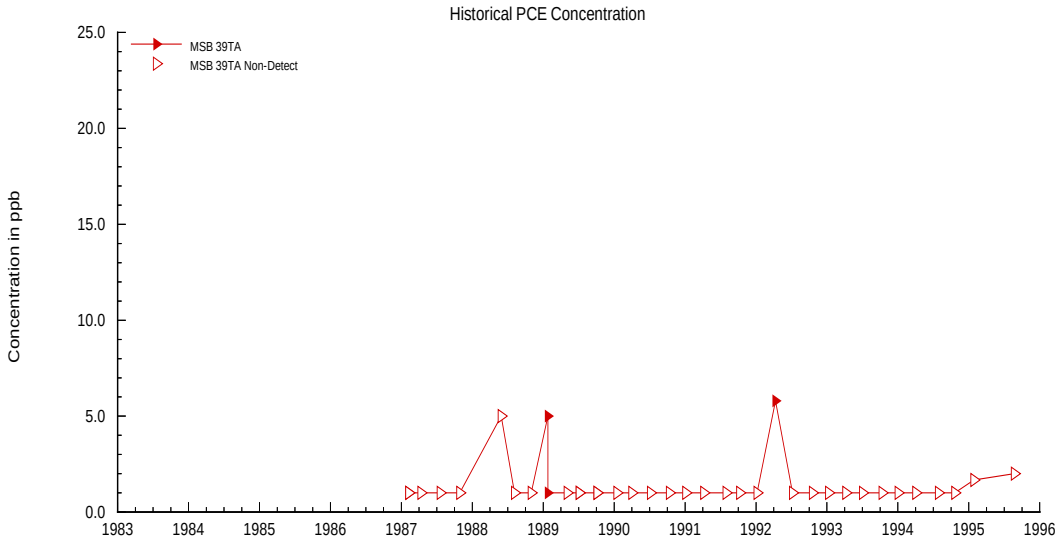
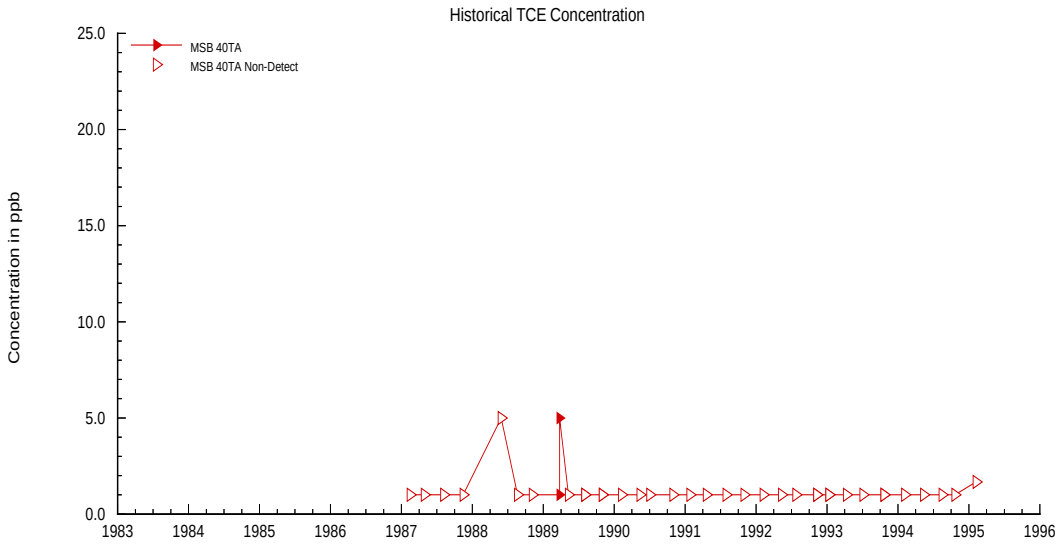


Figure 35: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 39TA associated with dissolved contamination in the Crouch Branch Aquifer.



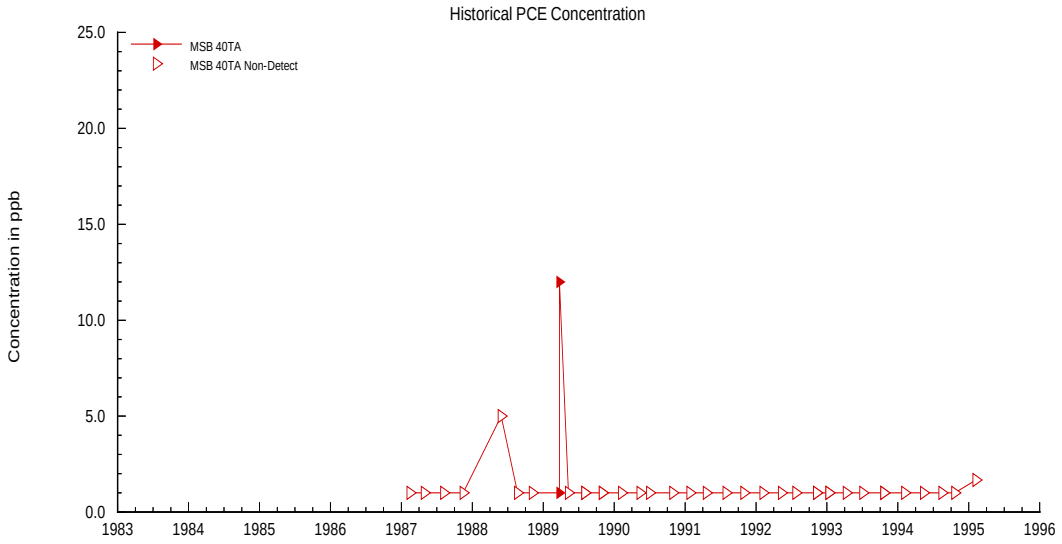
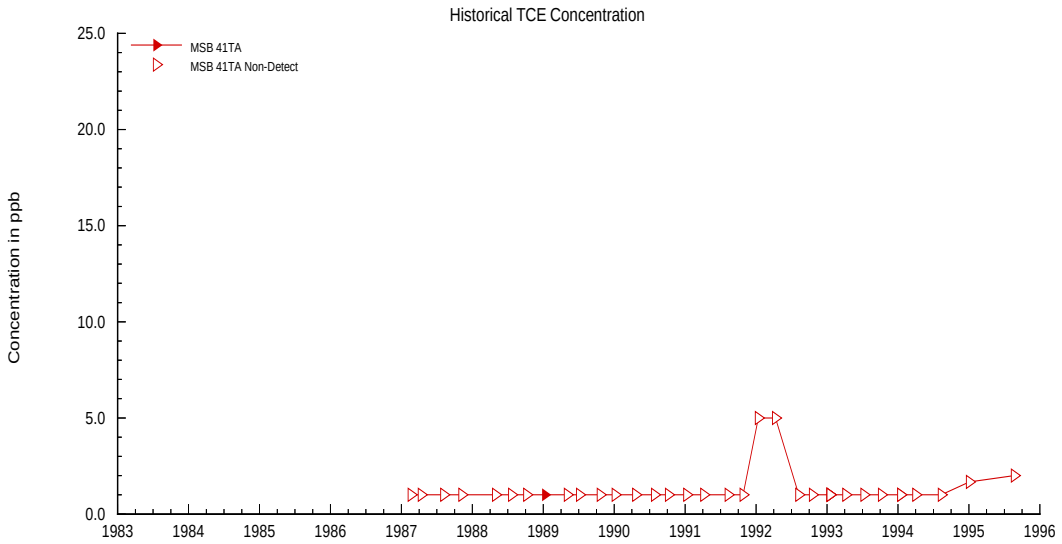


Figure 36: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 40TA associated with dissolved contamination in the Crouch Branch Aquifer.



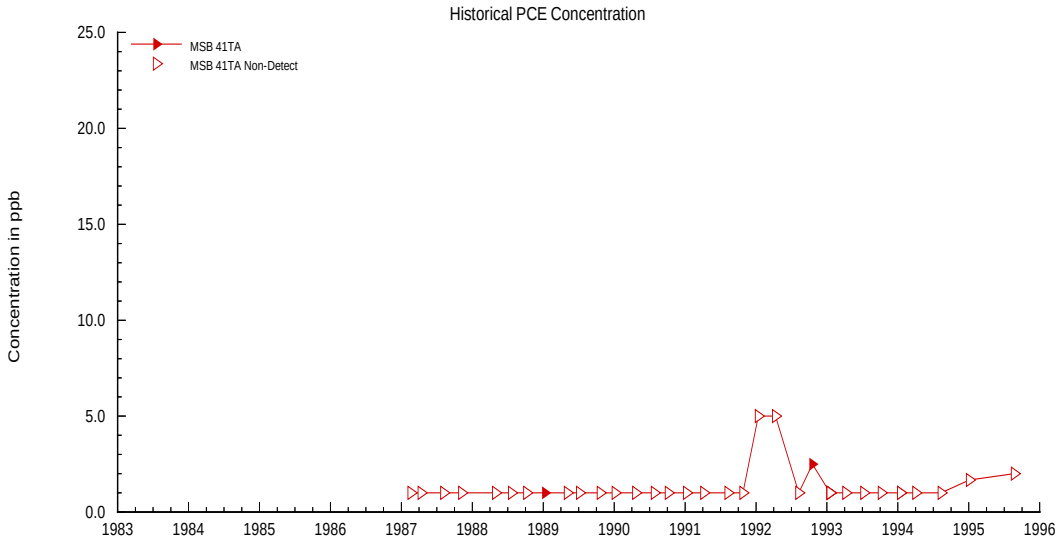
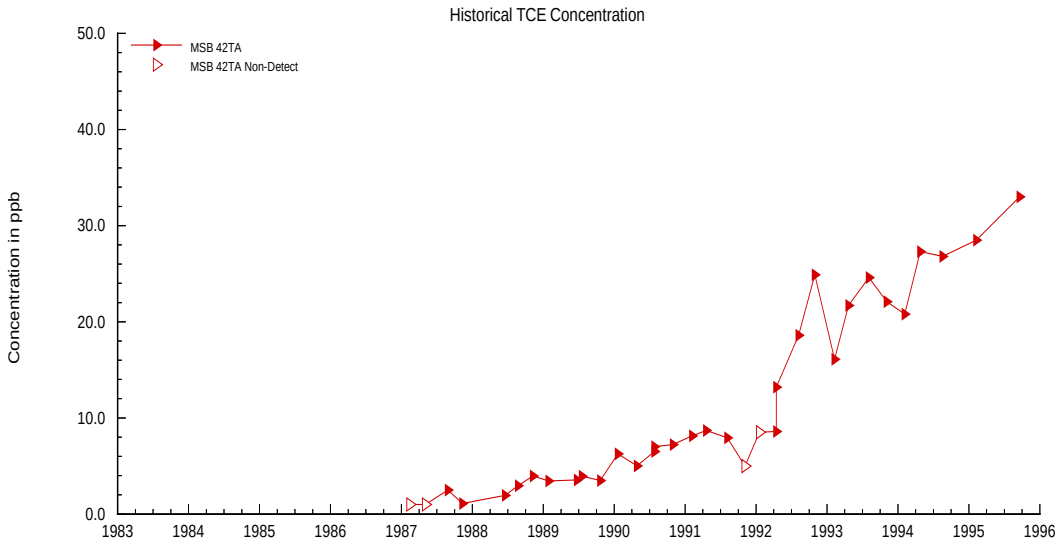


Figure 37: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 41TA associated with dissolved contamination in the Crouch Branch Aquifer.



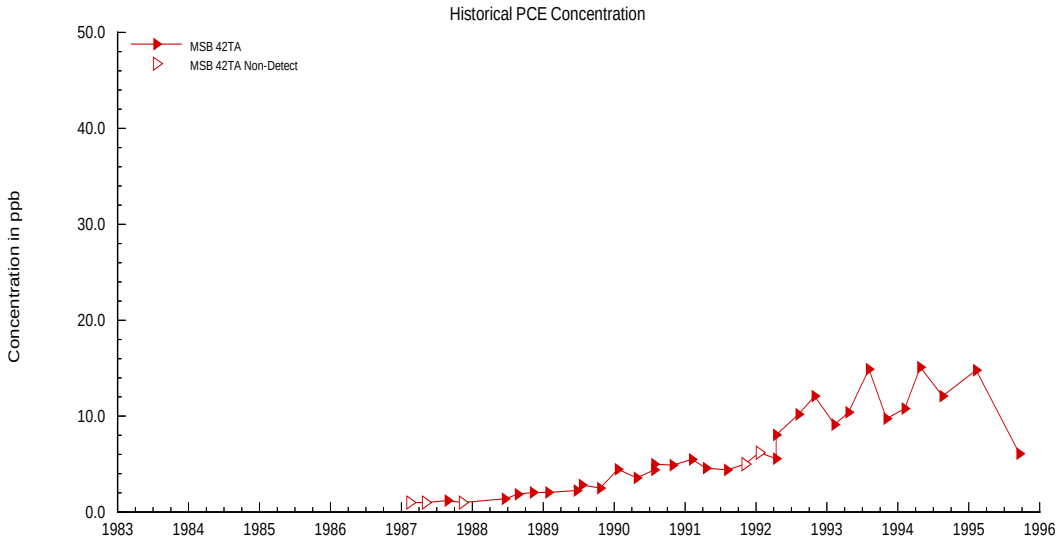
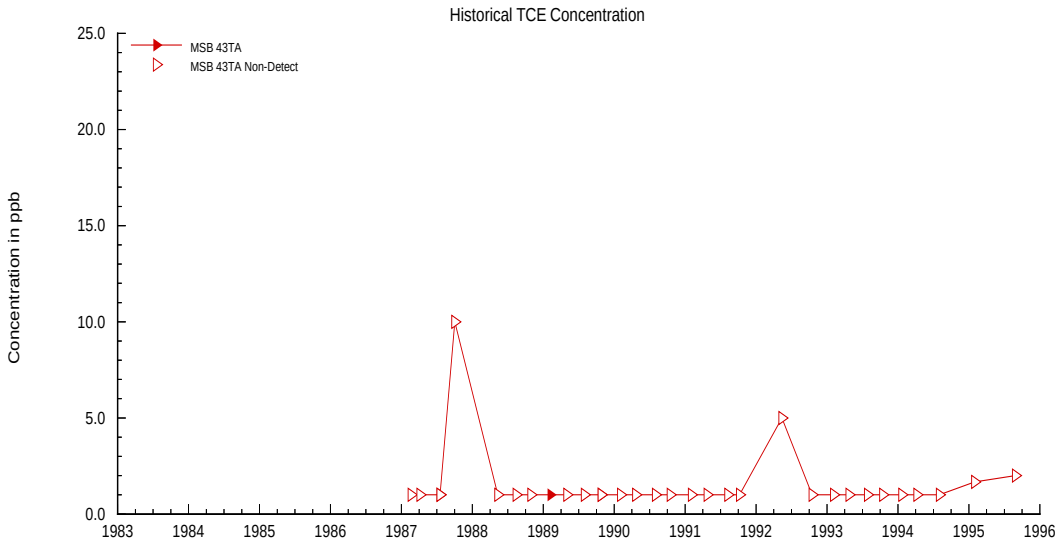


Figure 38: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 42TA associated with dissolved contamination in the Crouch Branch Aquifer.



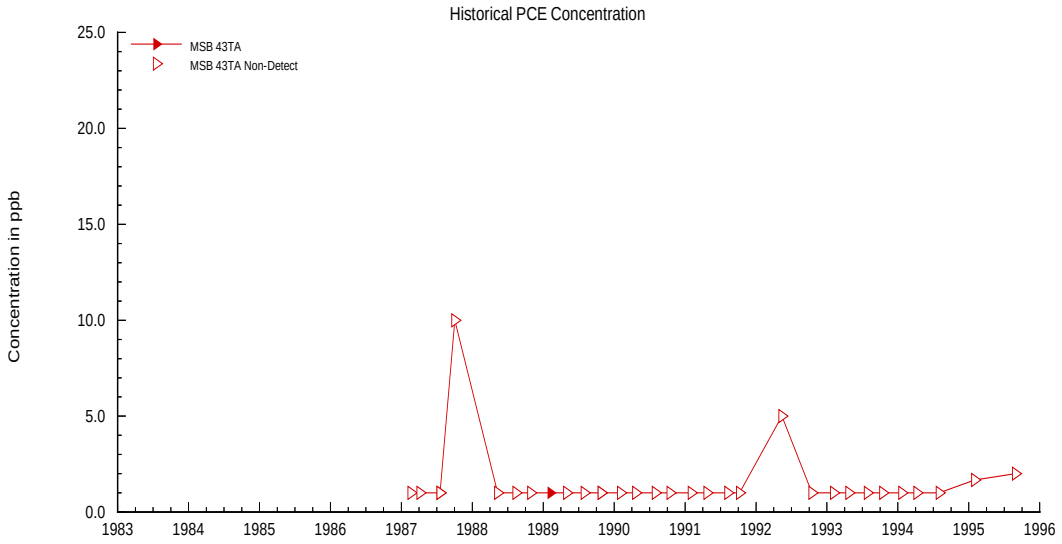
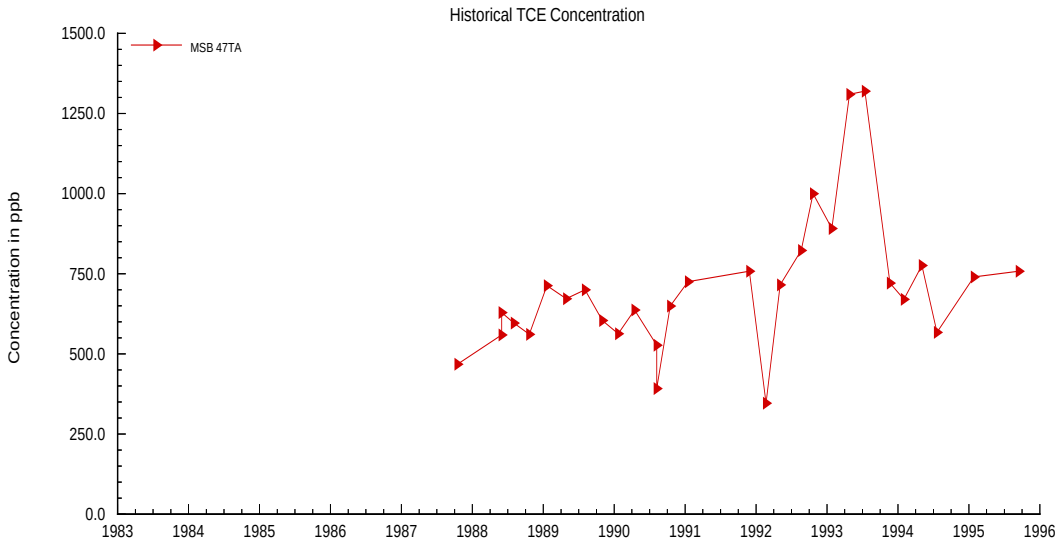


Figure 39: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 43TA associated with dissolved contamination in the Crouch Branch Aquifer.



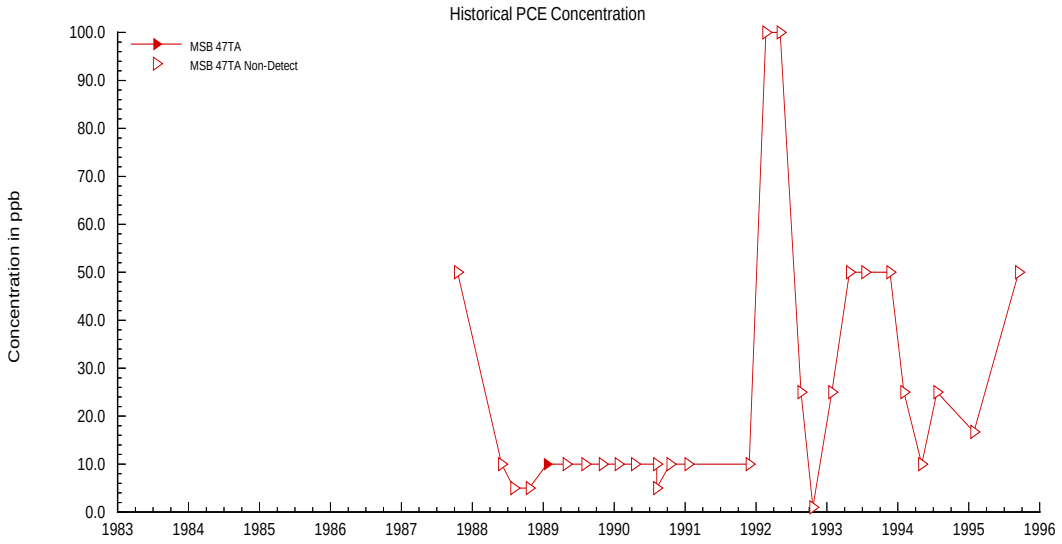
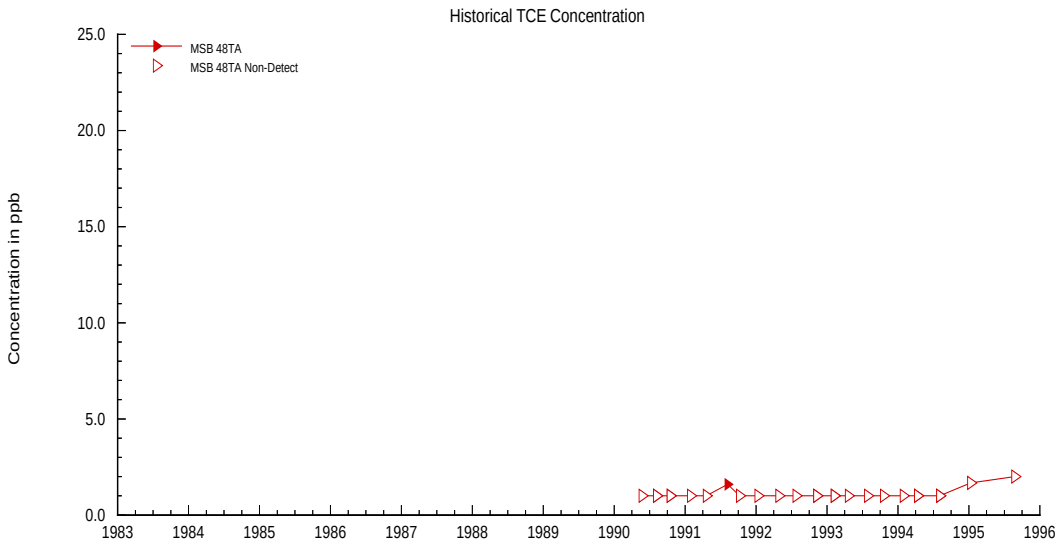


Figure 40: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 47TA used to identify the source area for the dissolved contamination in the Crouch Branch Aquifer.



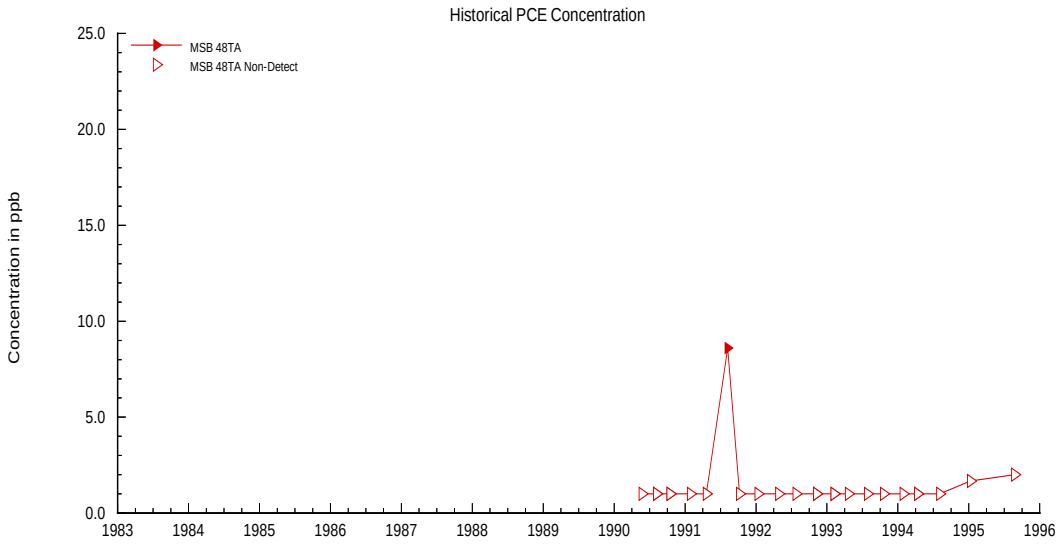
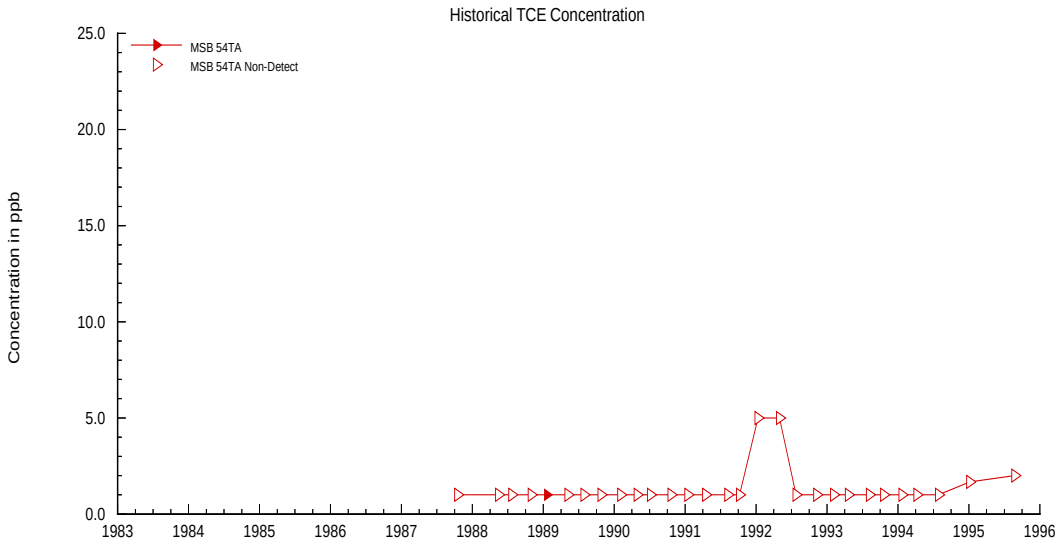


Figure 41: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 48TA located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.



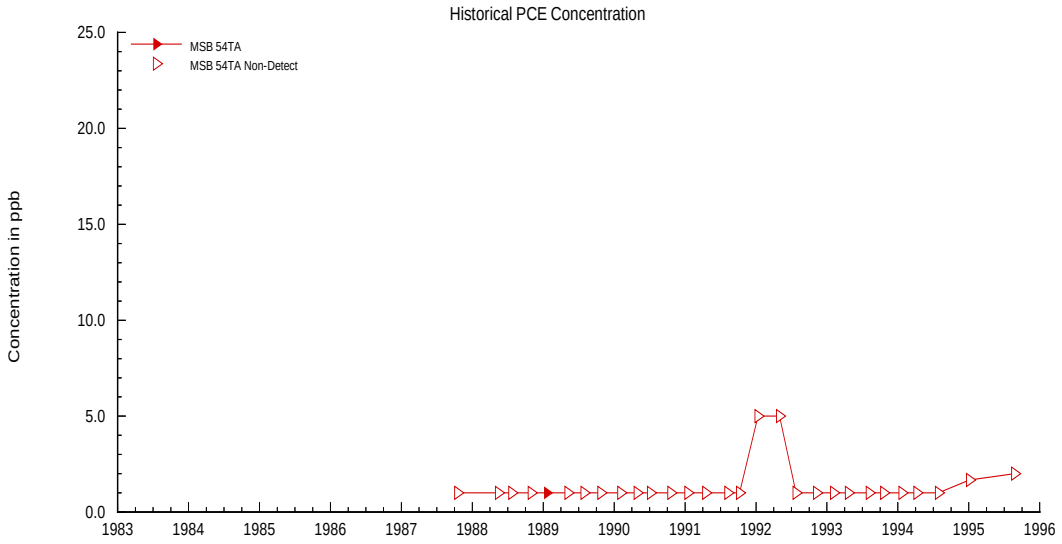
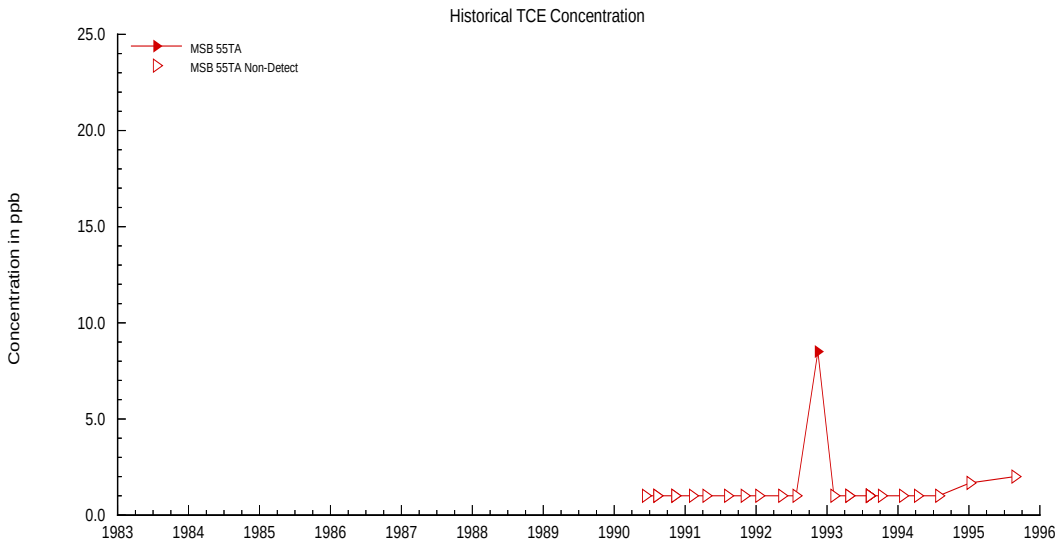


Figure 42: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 54TA associated with dissolved contamination in the Crouch Branch Aquifer.



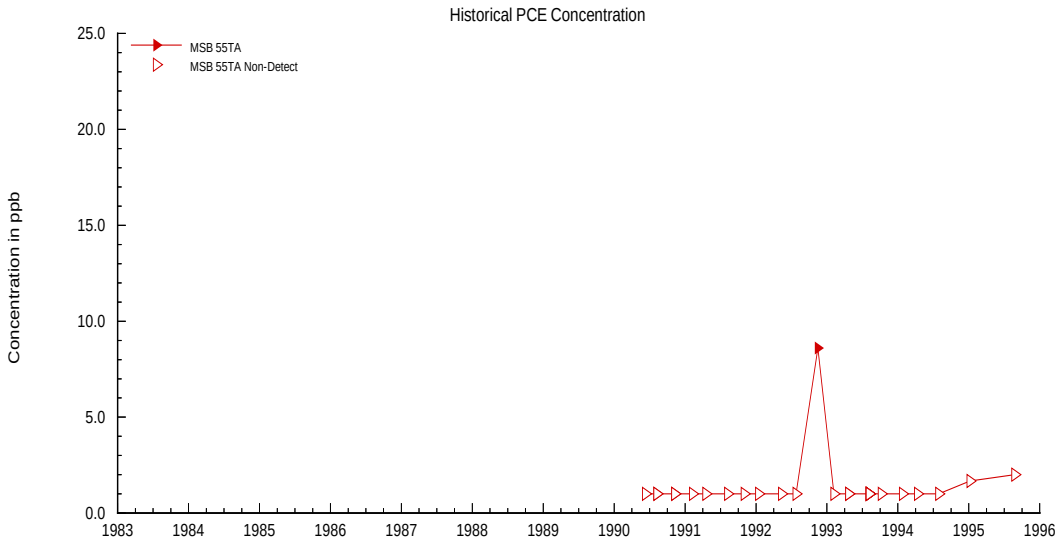
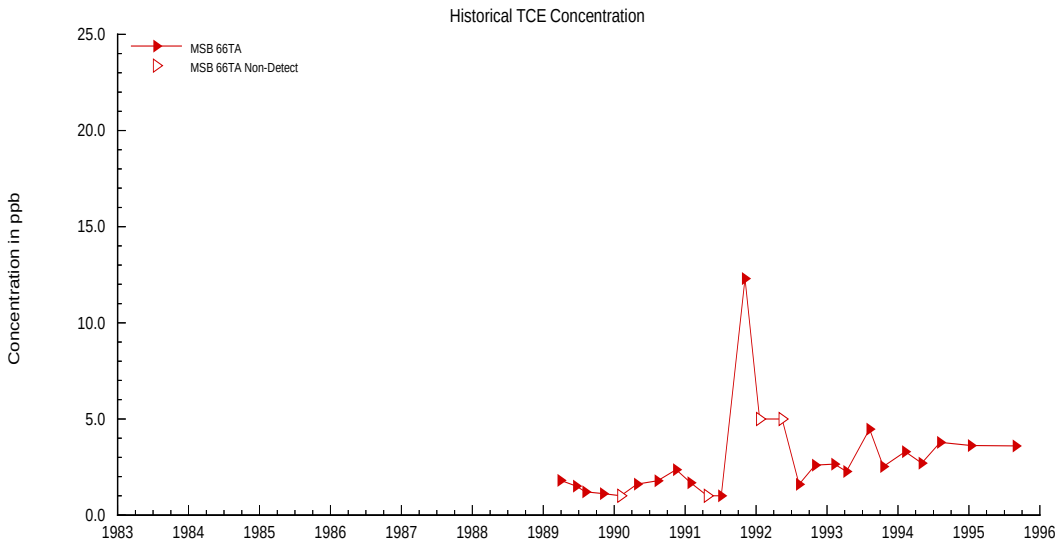


Figure 43: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 55TA located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.



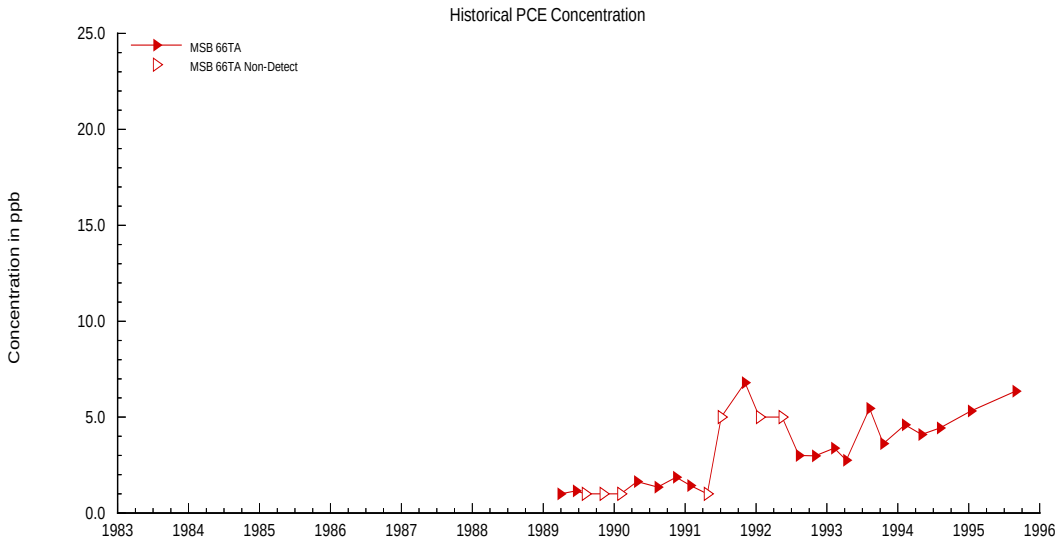
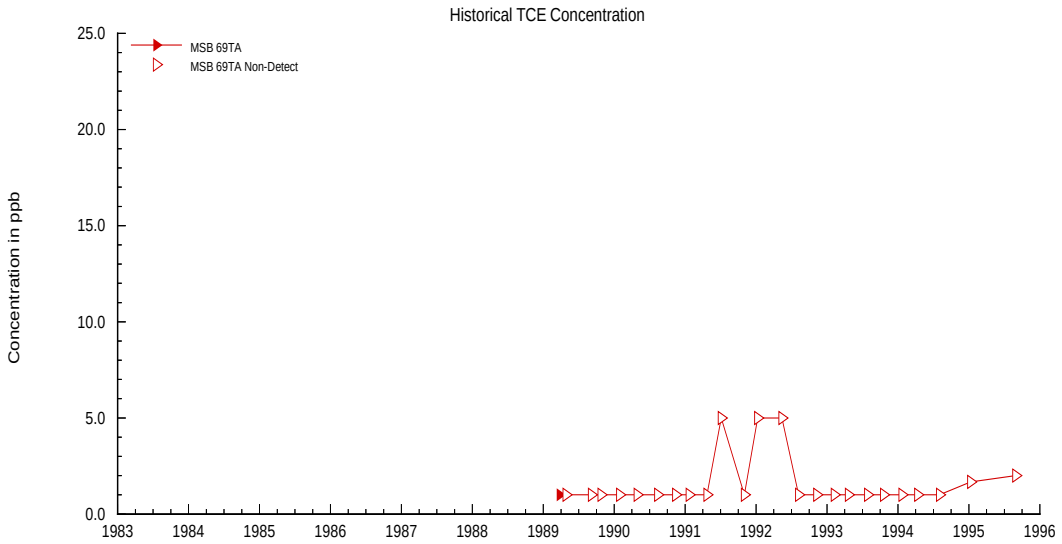


Figure 44: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 66TA located downgradient from the source area in the SRTC complex associated with dissolved contamination in the Crouch Branch Aquifer.



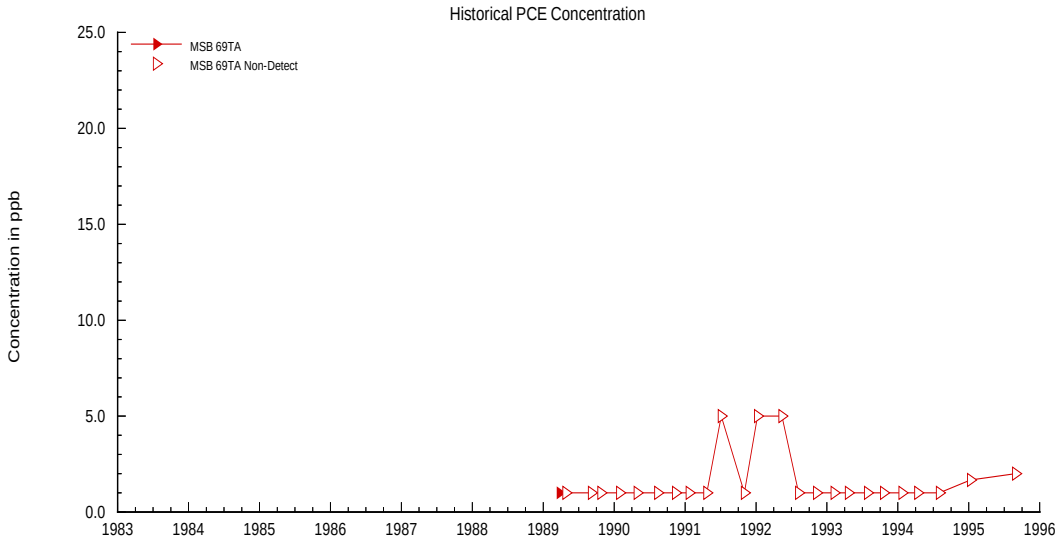
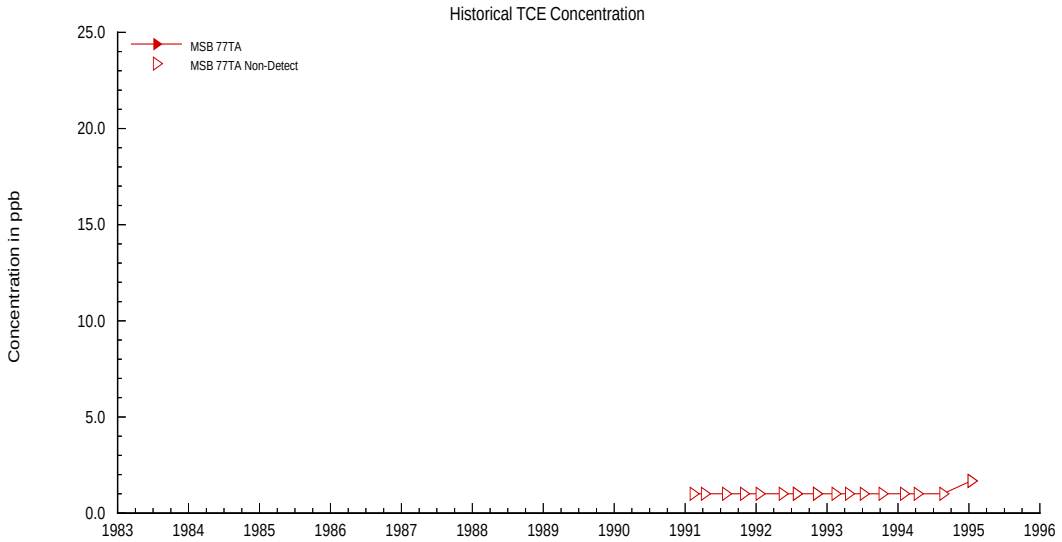


Figure 45: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 69TA associated with dissolved contamination in the Crouch Branch Aquifer.



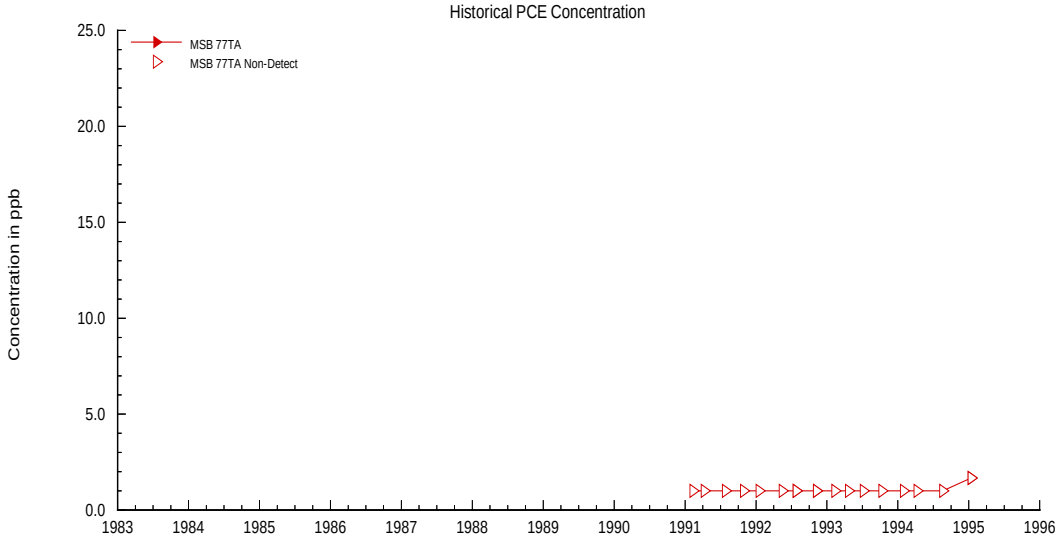


Figure 46: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 77TA located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.

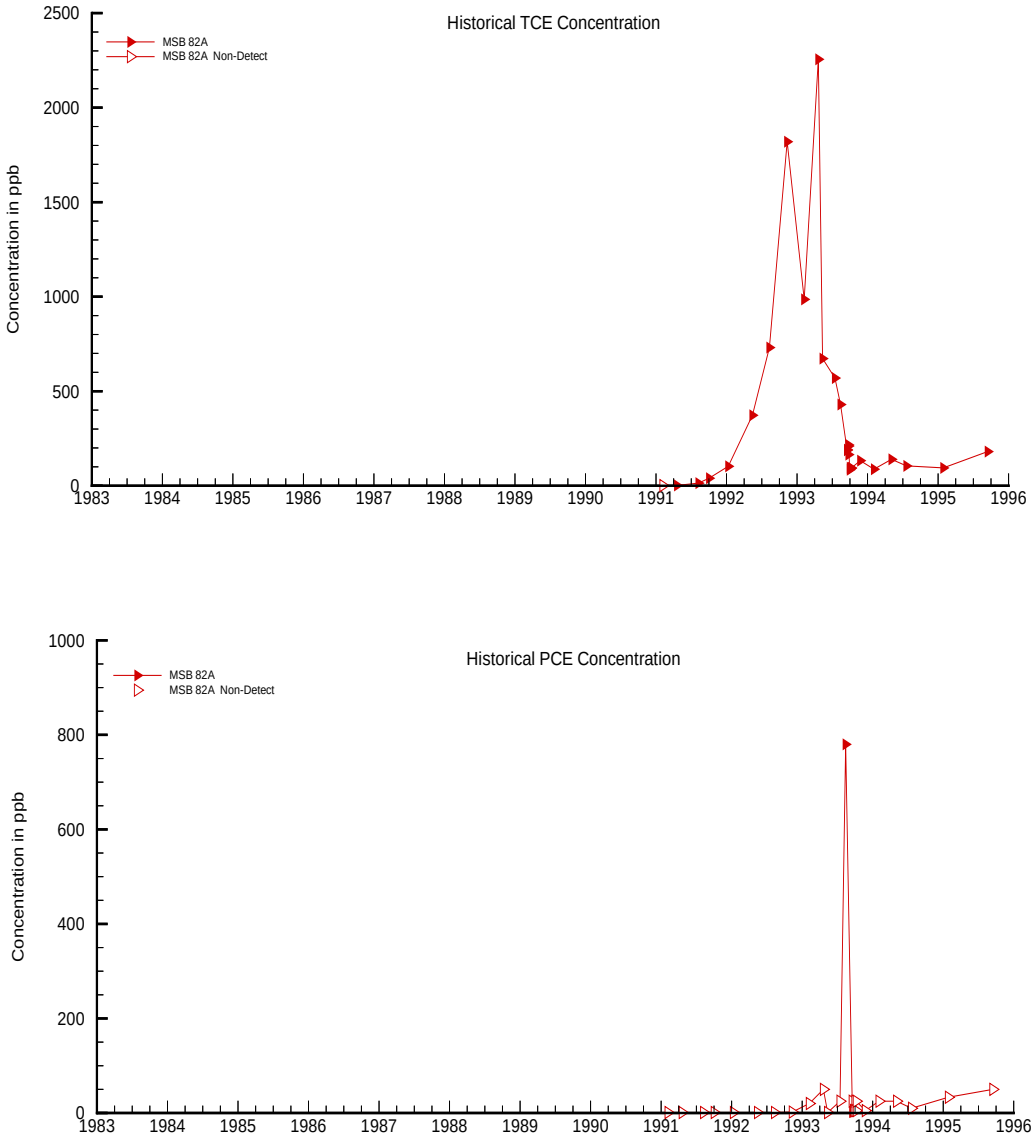
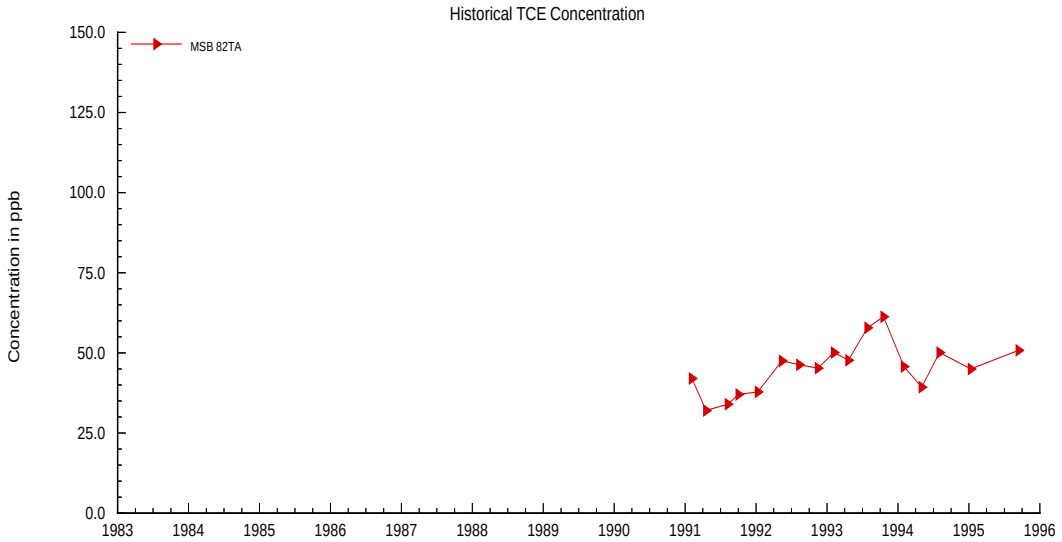


Figure 47: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 82A located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.



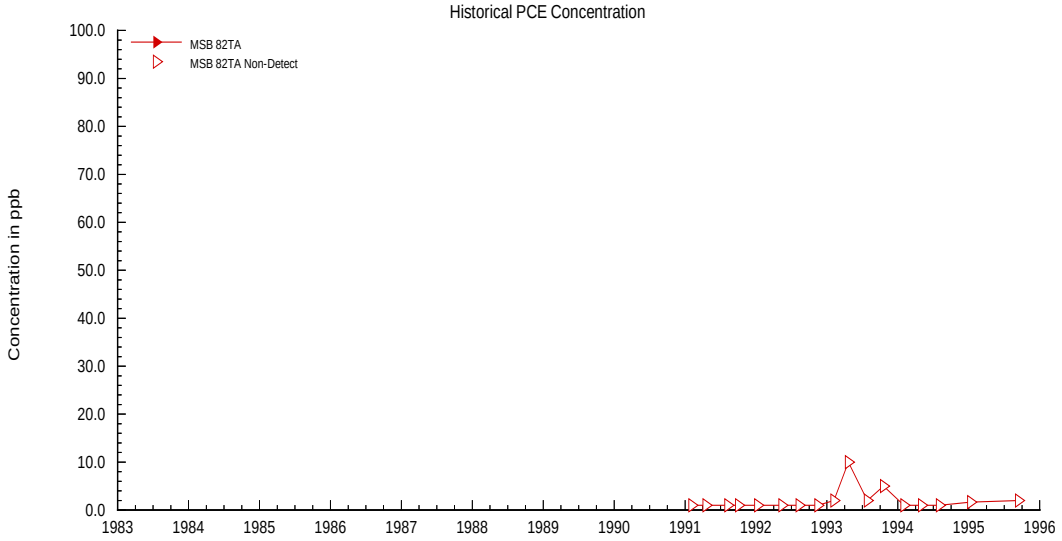
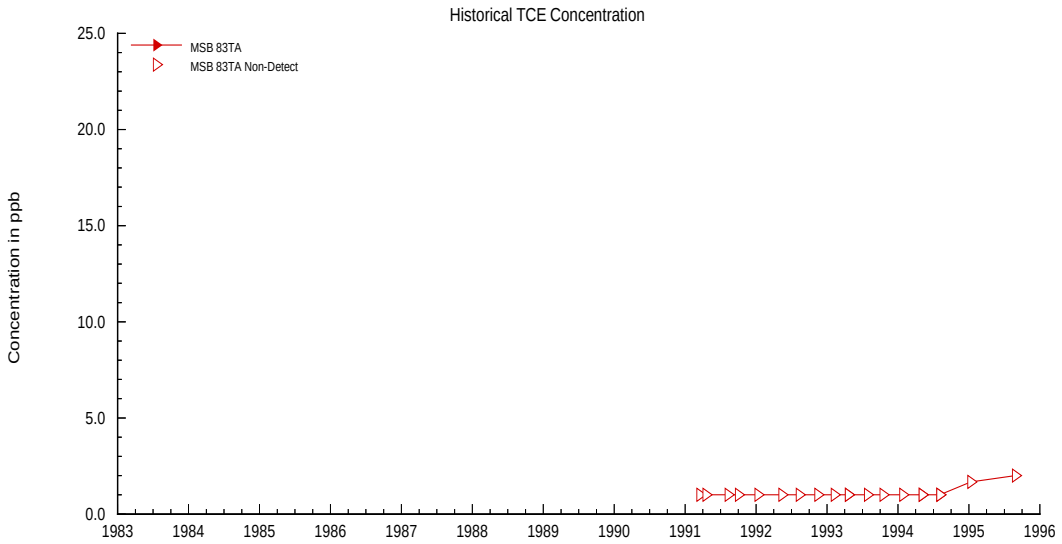


Figure 48: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 82TA located upgradient from the source zone associated with dissolved contamination in the Crouch Branch Aquifer.



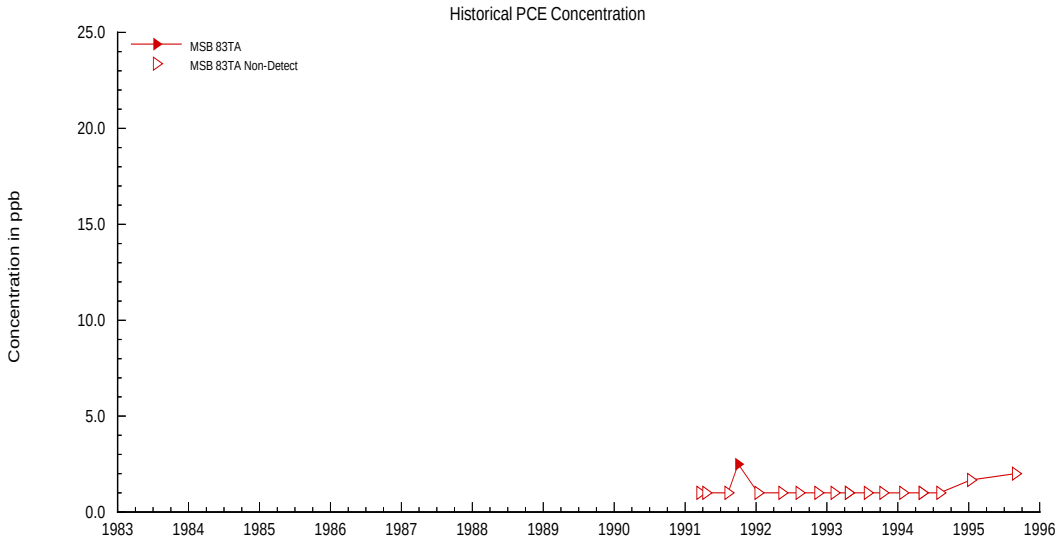
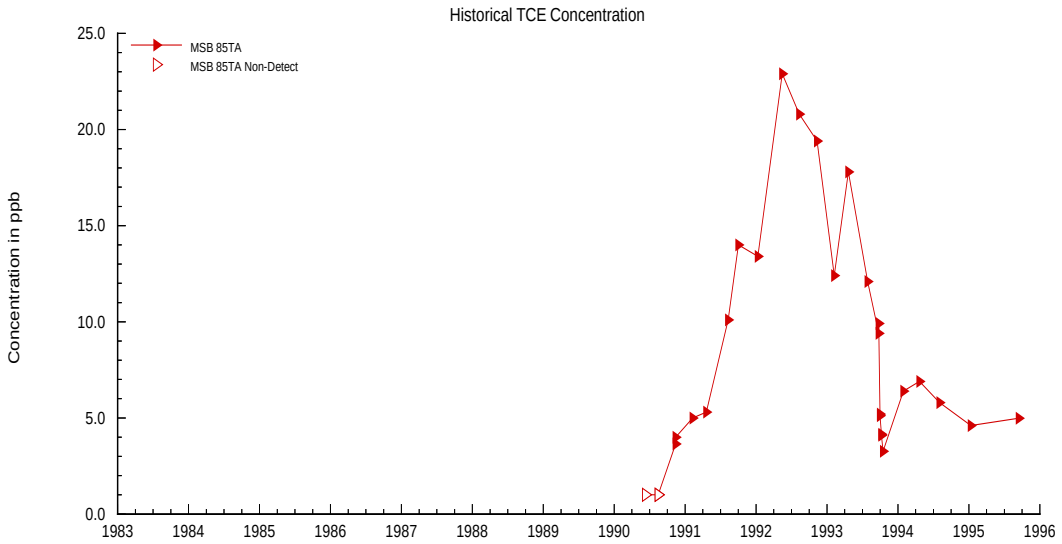


Figure 49: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 83TA associated with dissolved contamination in the Crouch Branch Aquifer.



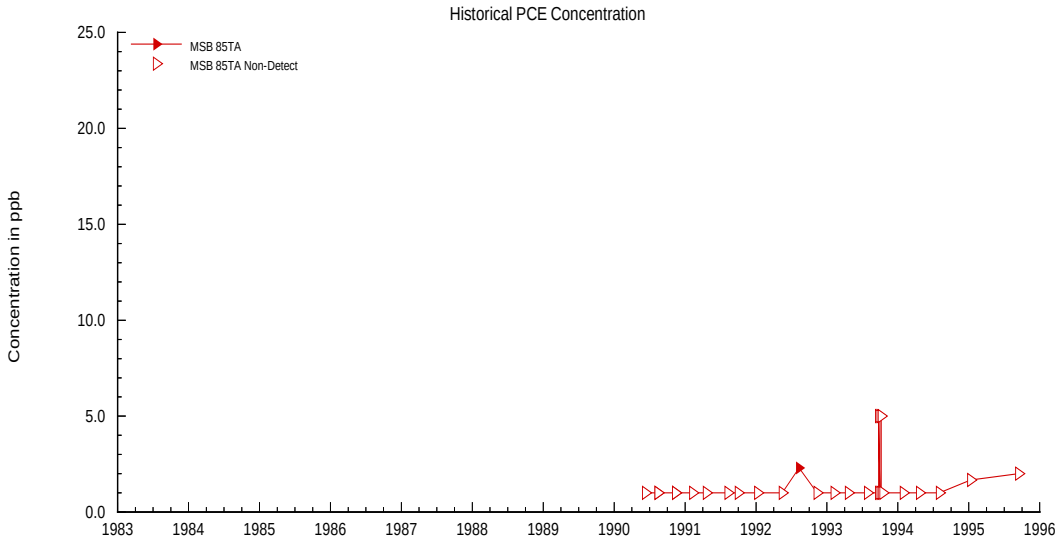


Figure 50: Historical Trichloroethylene and Tetrachloroethylene Concentrations for monitoring well MSB 85TA associated with dissolved contamination in the Crouch Branch Aquifer.

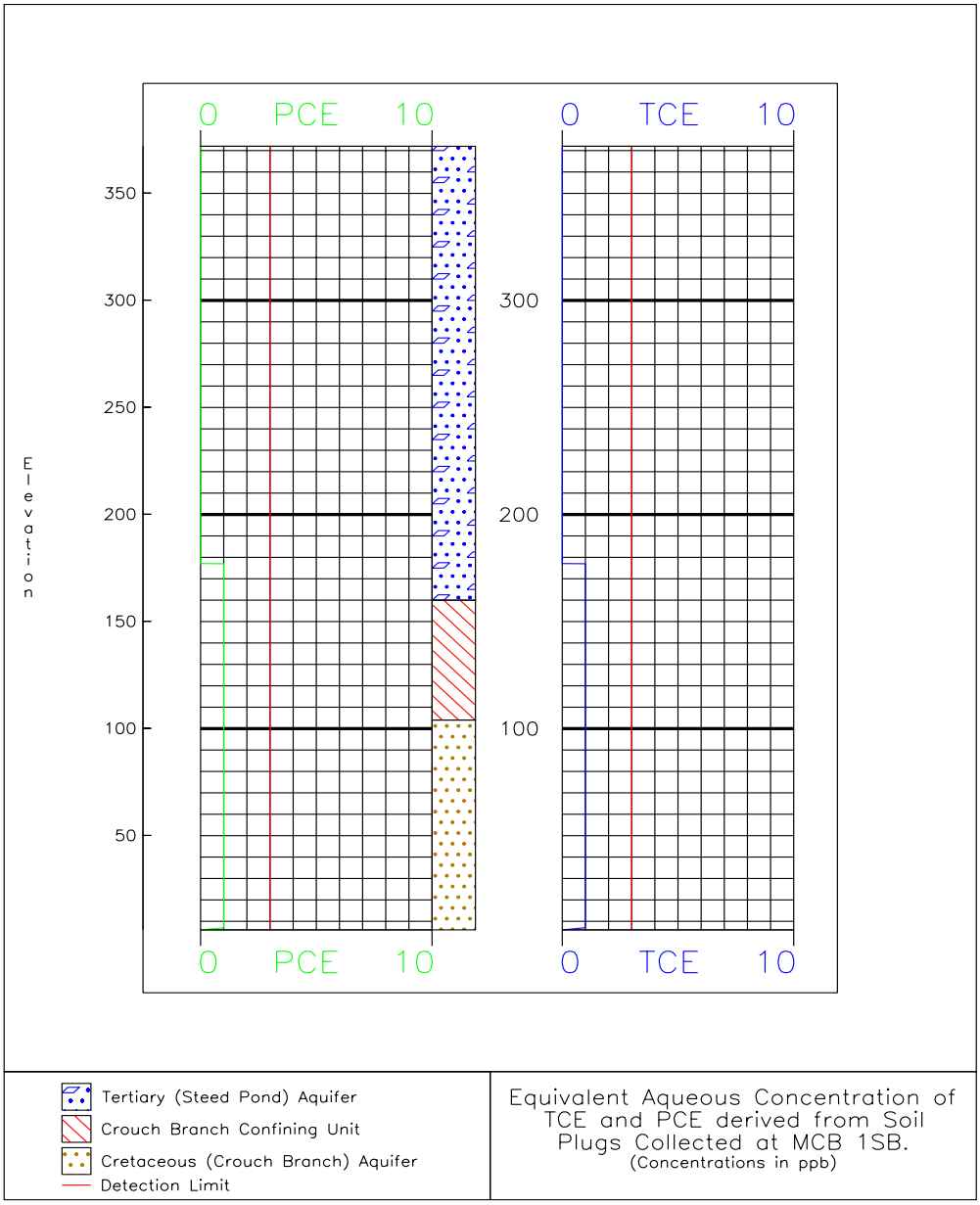


Figure 51: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 1SB, located Upgradient of the Suspected Source Zone.

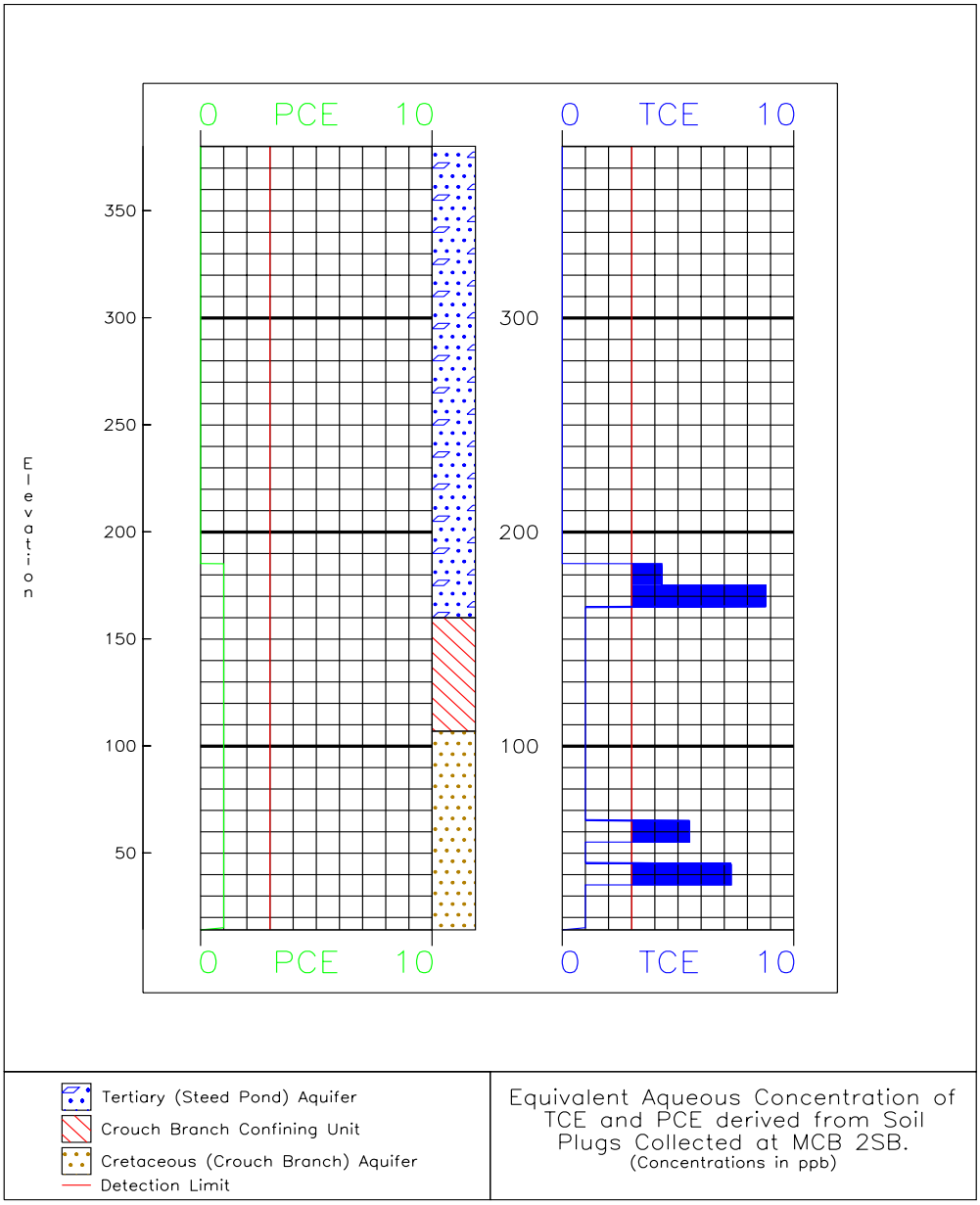


Figure 52: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 2SB, located Upgradient of the Suspected Source Zone.

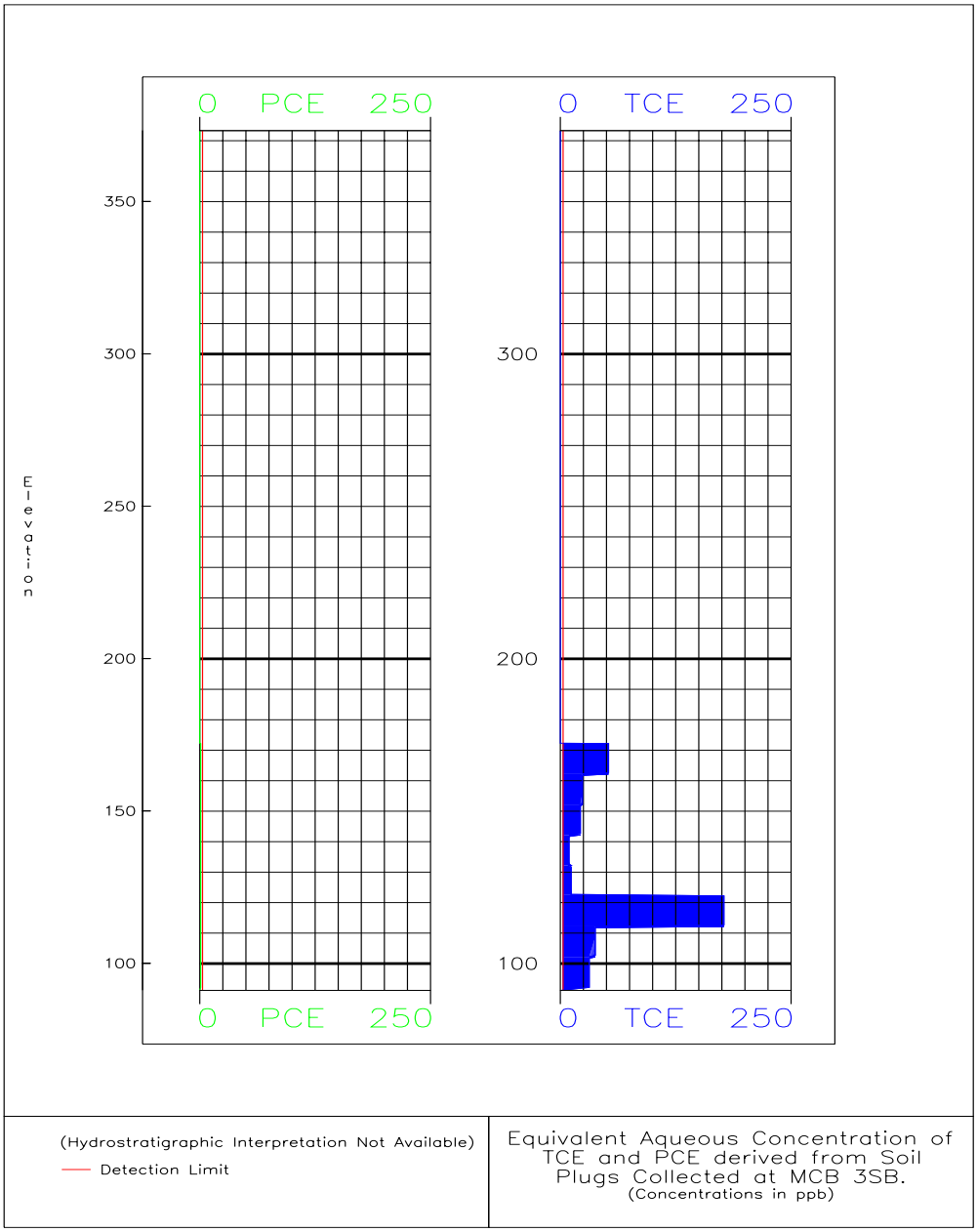


Figure 53: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 3SB, located near the Suspected Source Zone.

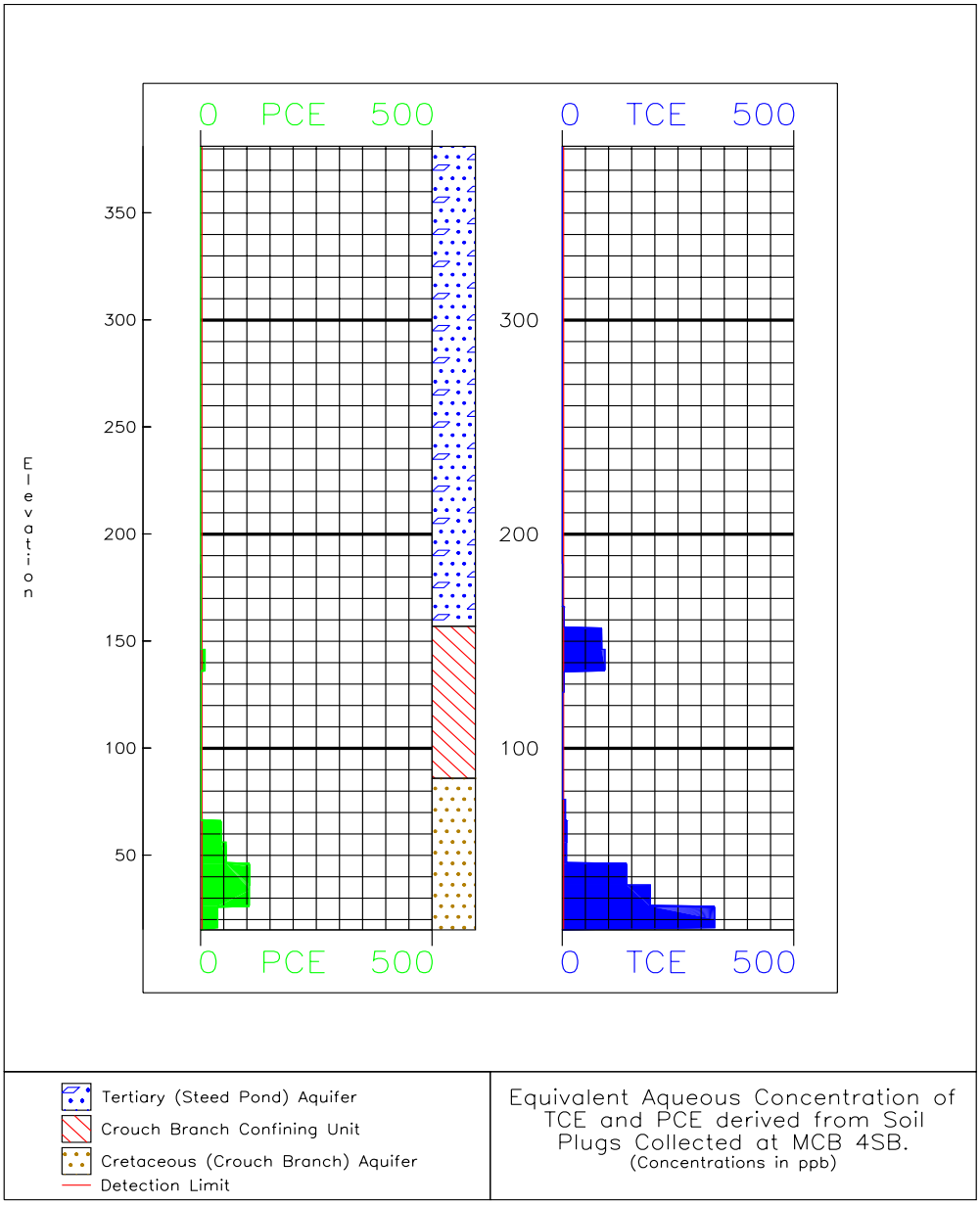


Figure 54: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 4SB, located downgradient from the Suspected Source Zone.

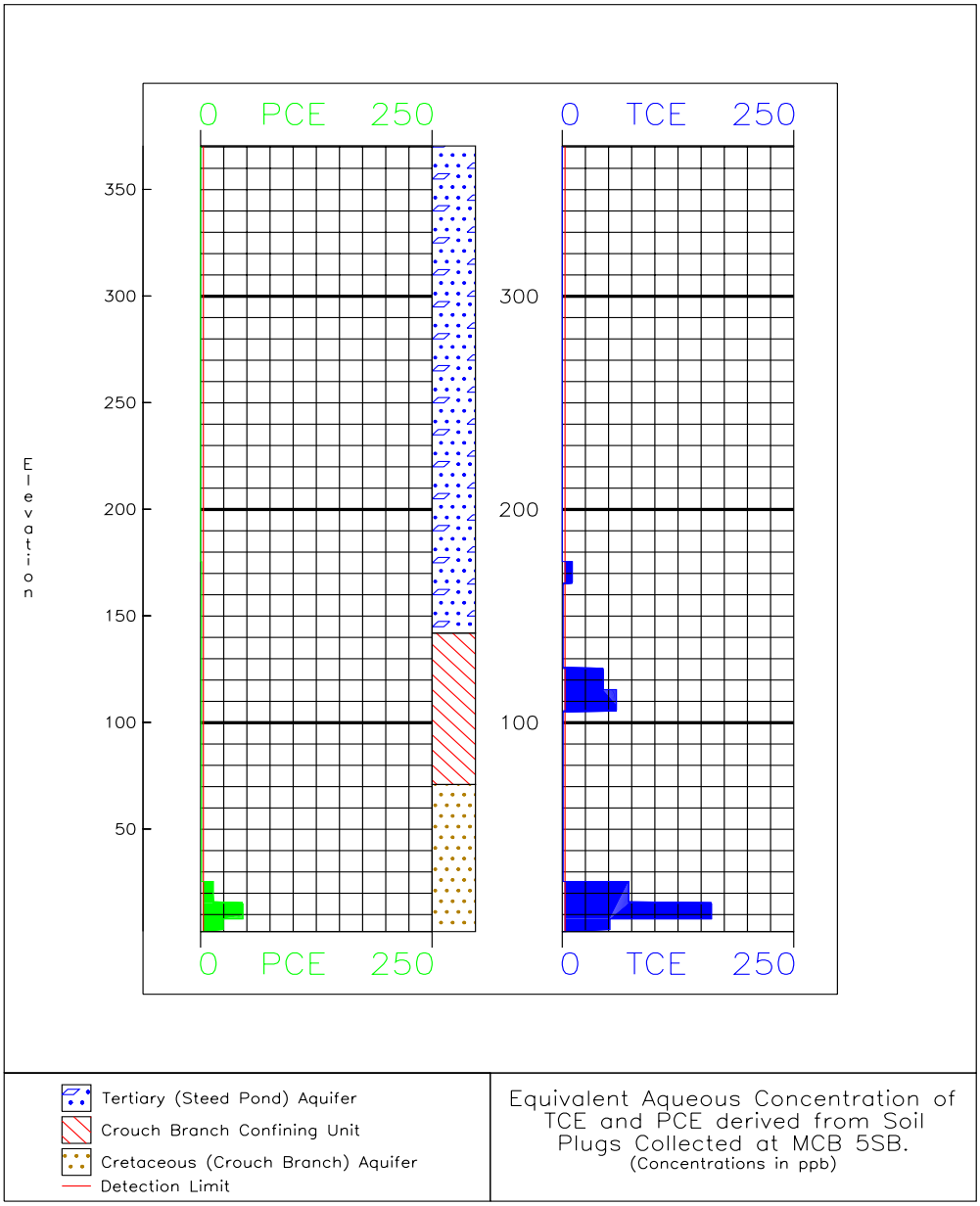


Figure 55: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 5SB, located downgradient from the Suspected Source Zone.

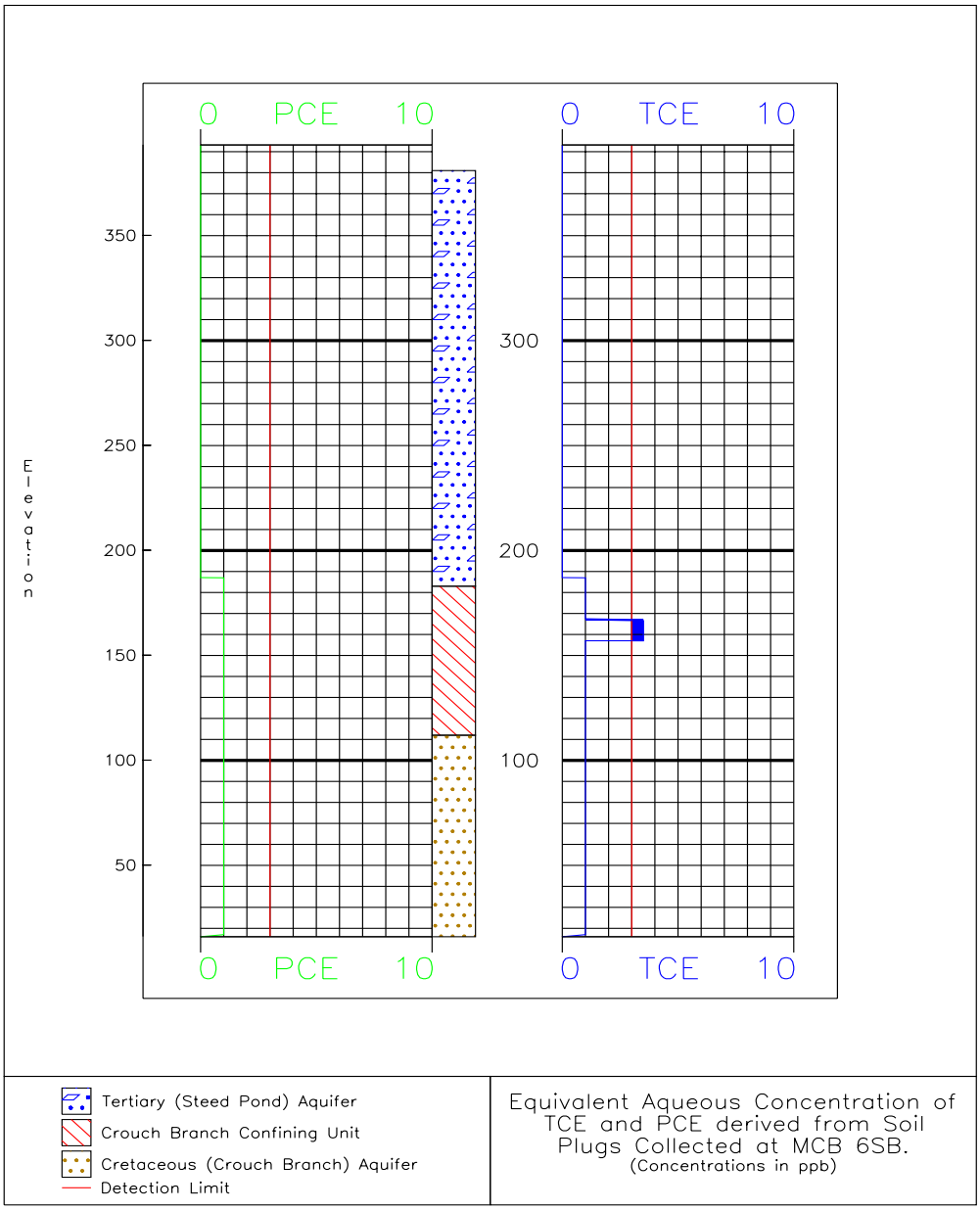


Figure 56: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 6SB, located downgradient from the Suspected Source Zone.

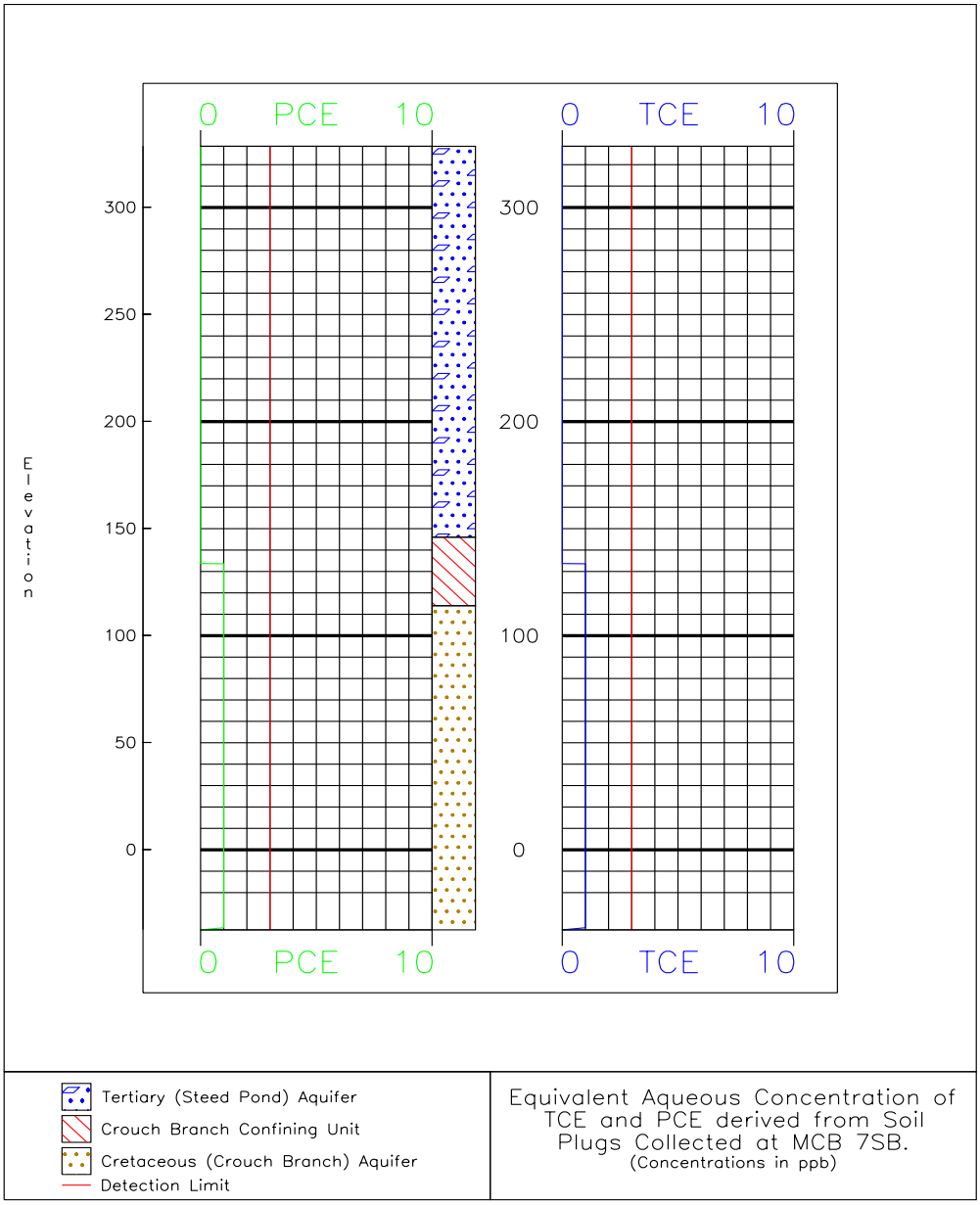


Figure 57: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 7SB, located downgradient from the Suspected Source Zone.

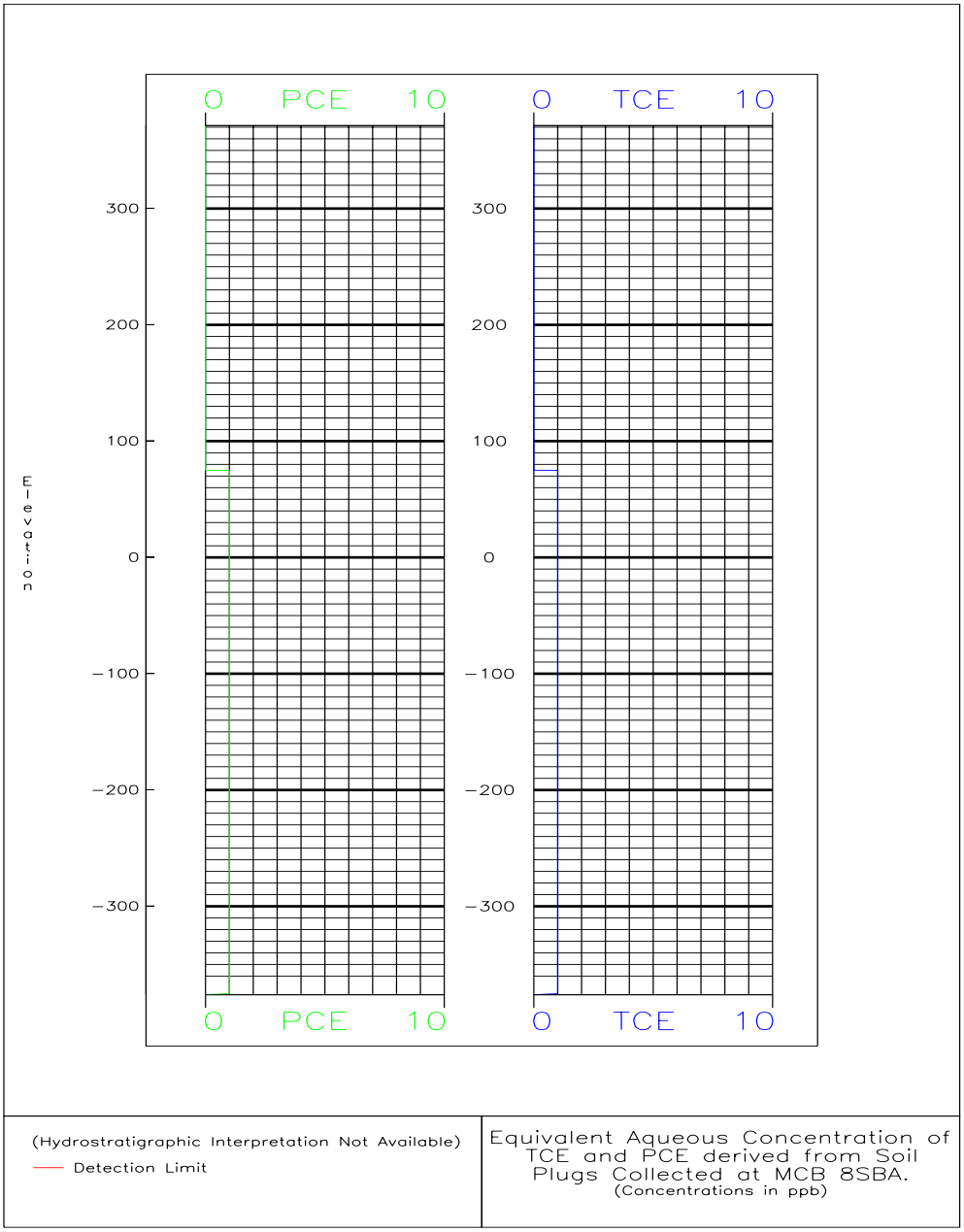


Figure 58: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MBC 8SBA, located Upgradient of the Suspected Source Zone.

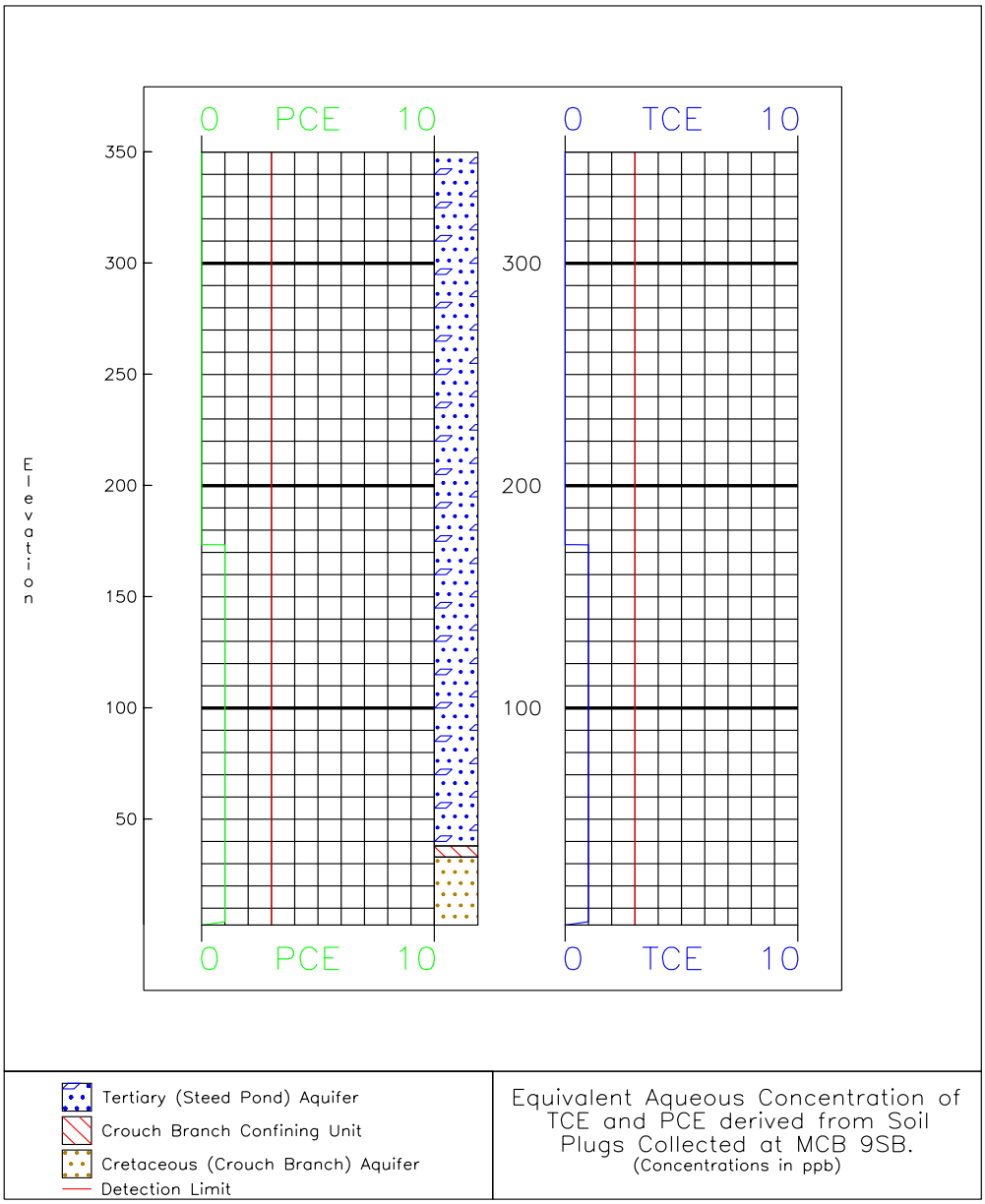


Figure 59: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 9SB, located Upgradient of the Suspected Source Zone.

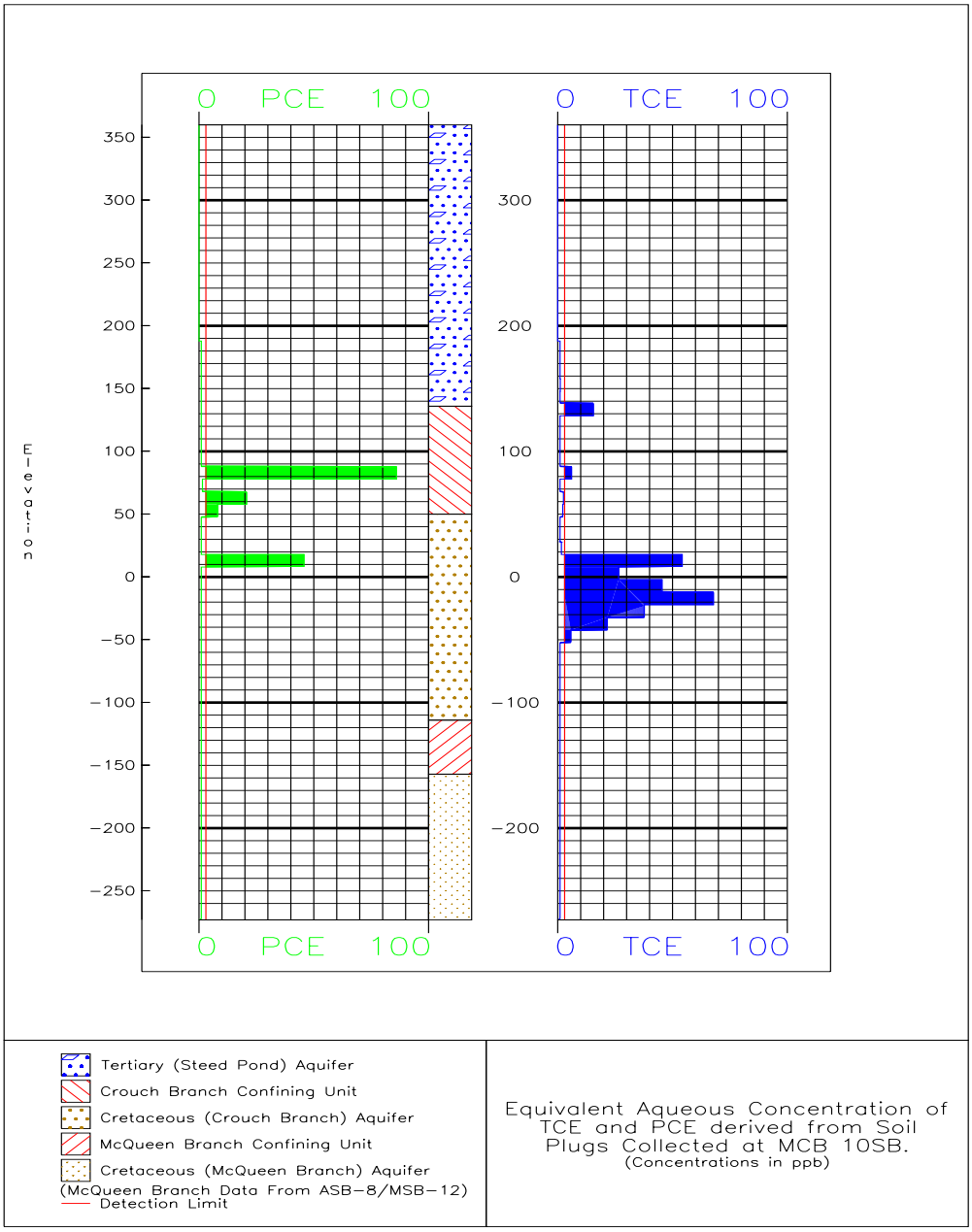


Figure 60: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 10SB, located downgradient from the Suspected Source Zone.

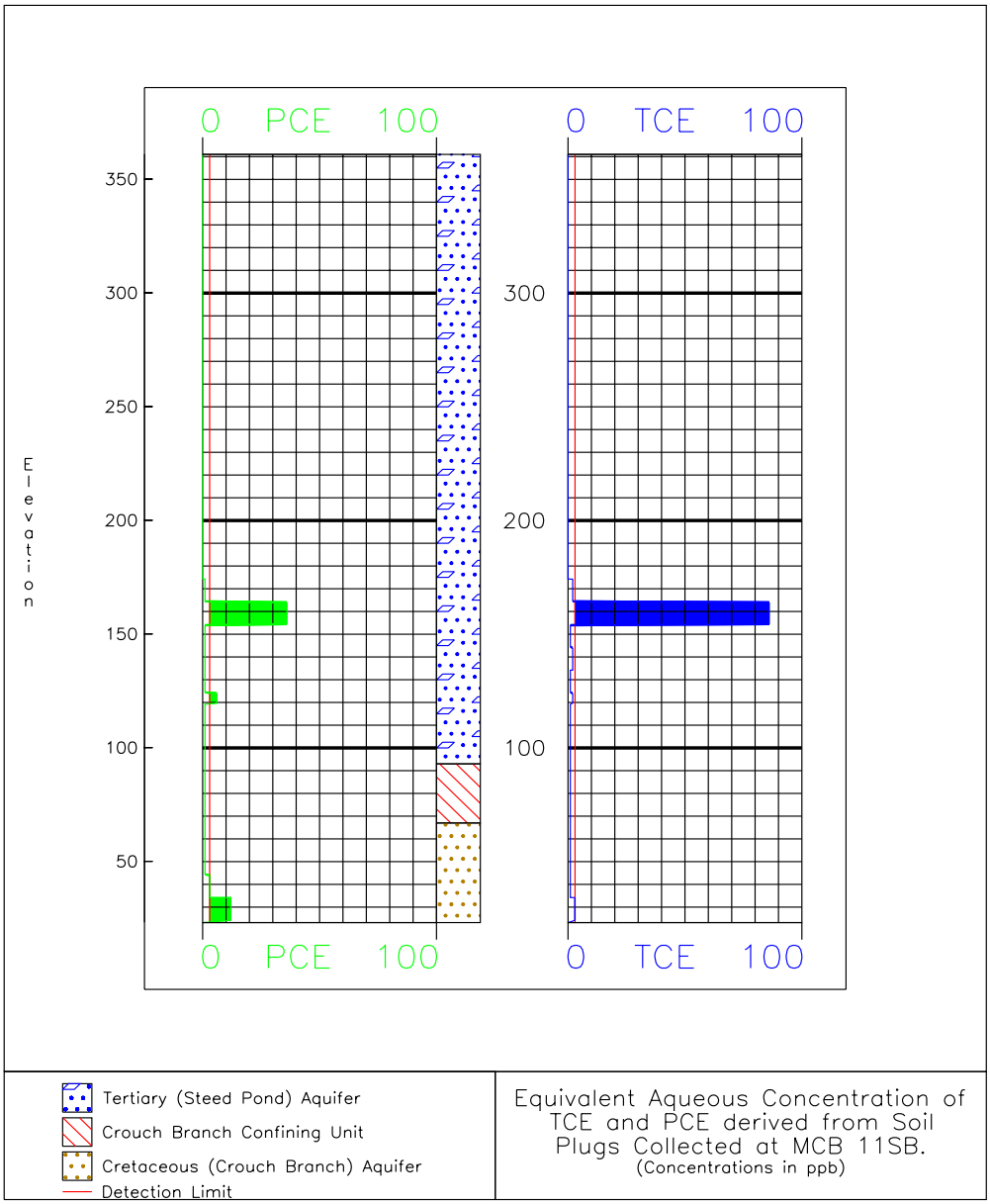


Figure 61: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 11SB, located downgradient from the Suspected Source Zone.

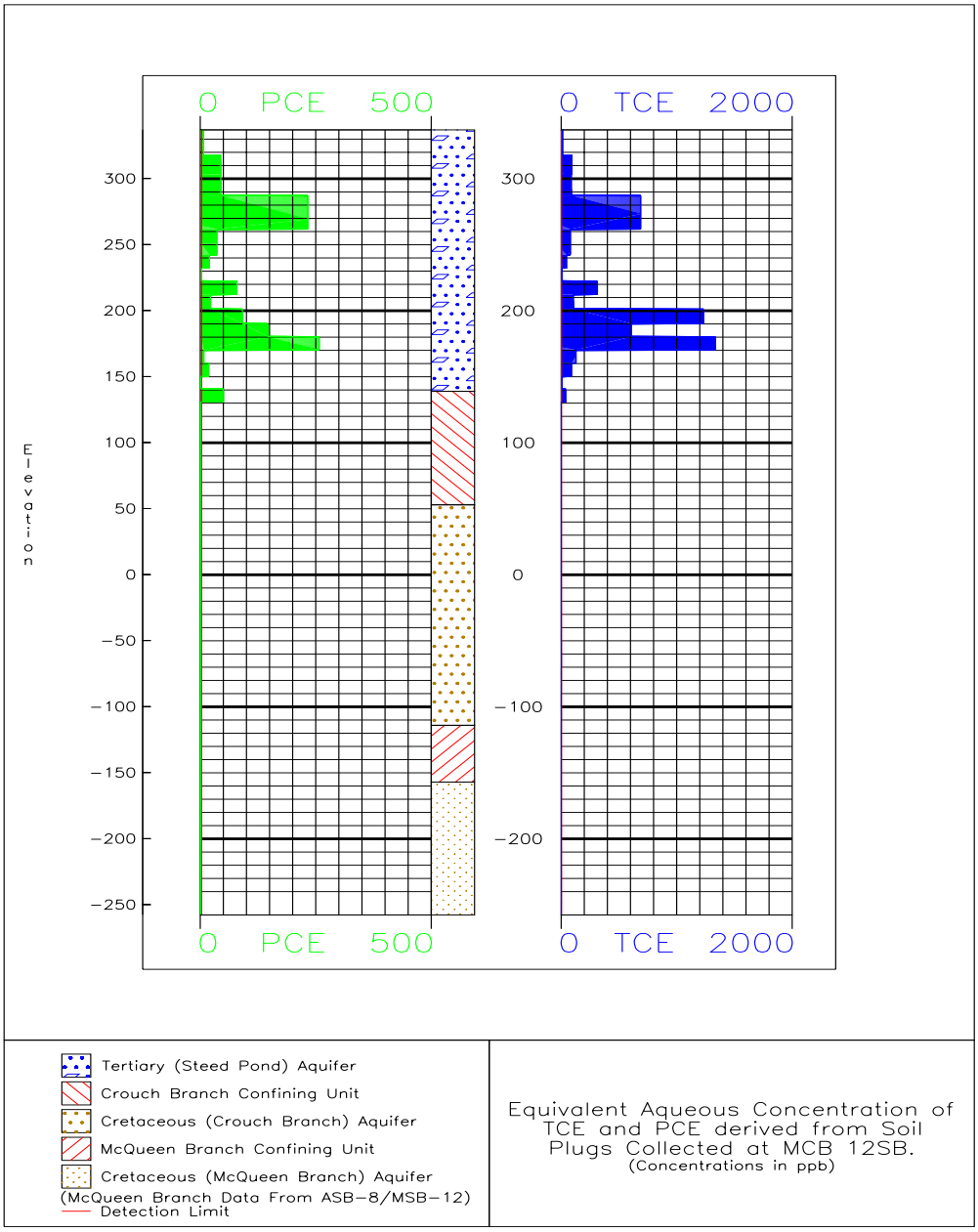


Figure 62: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB 12SB, located downgradient from the Suspected Source Zone.

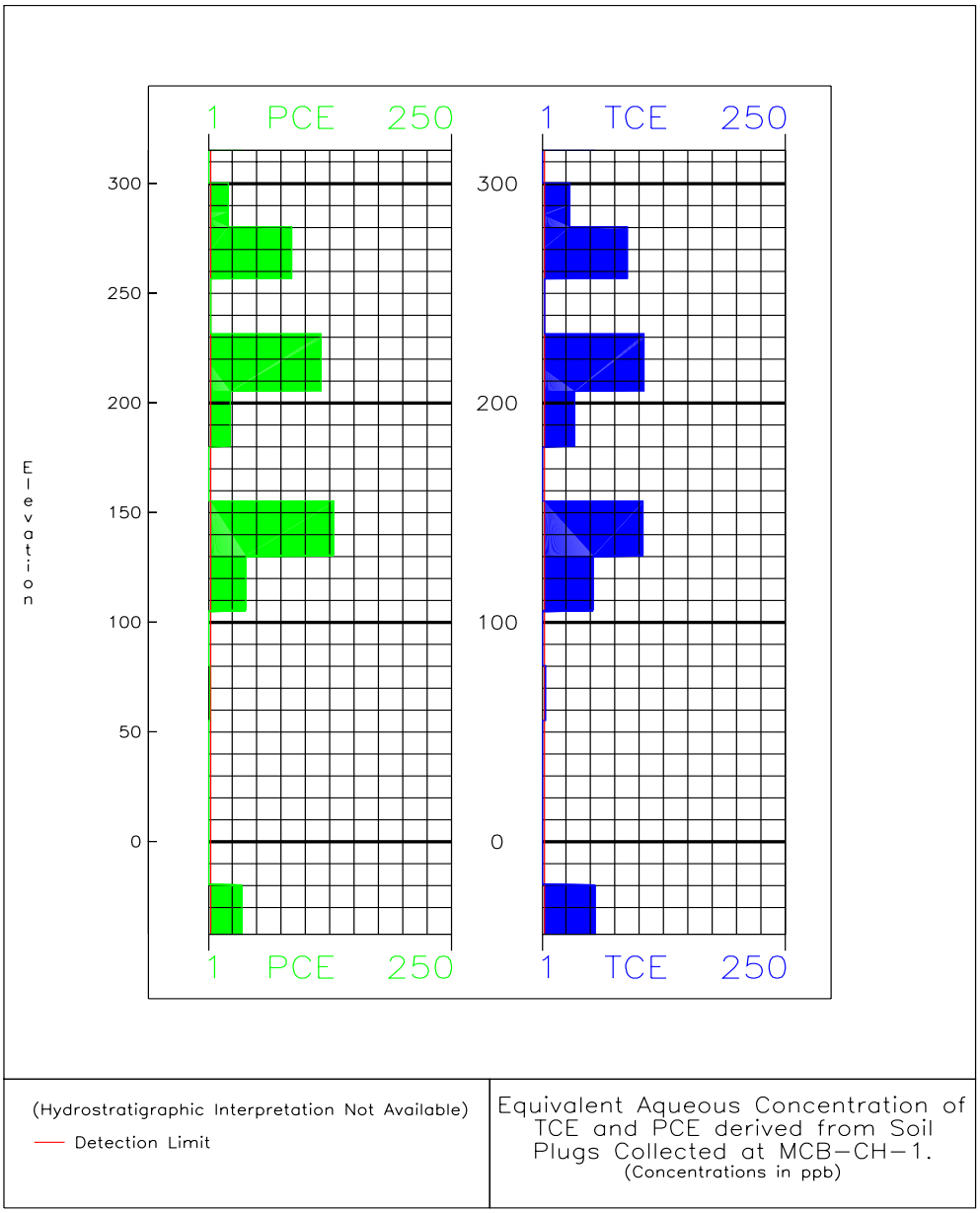


Figure 63: Equivalent Aqueous Concentrations of Trichloroethylene and Tetrachloroethylene derived from Soil Plugs Collected at MCB-CH-1.

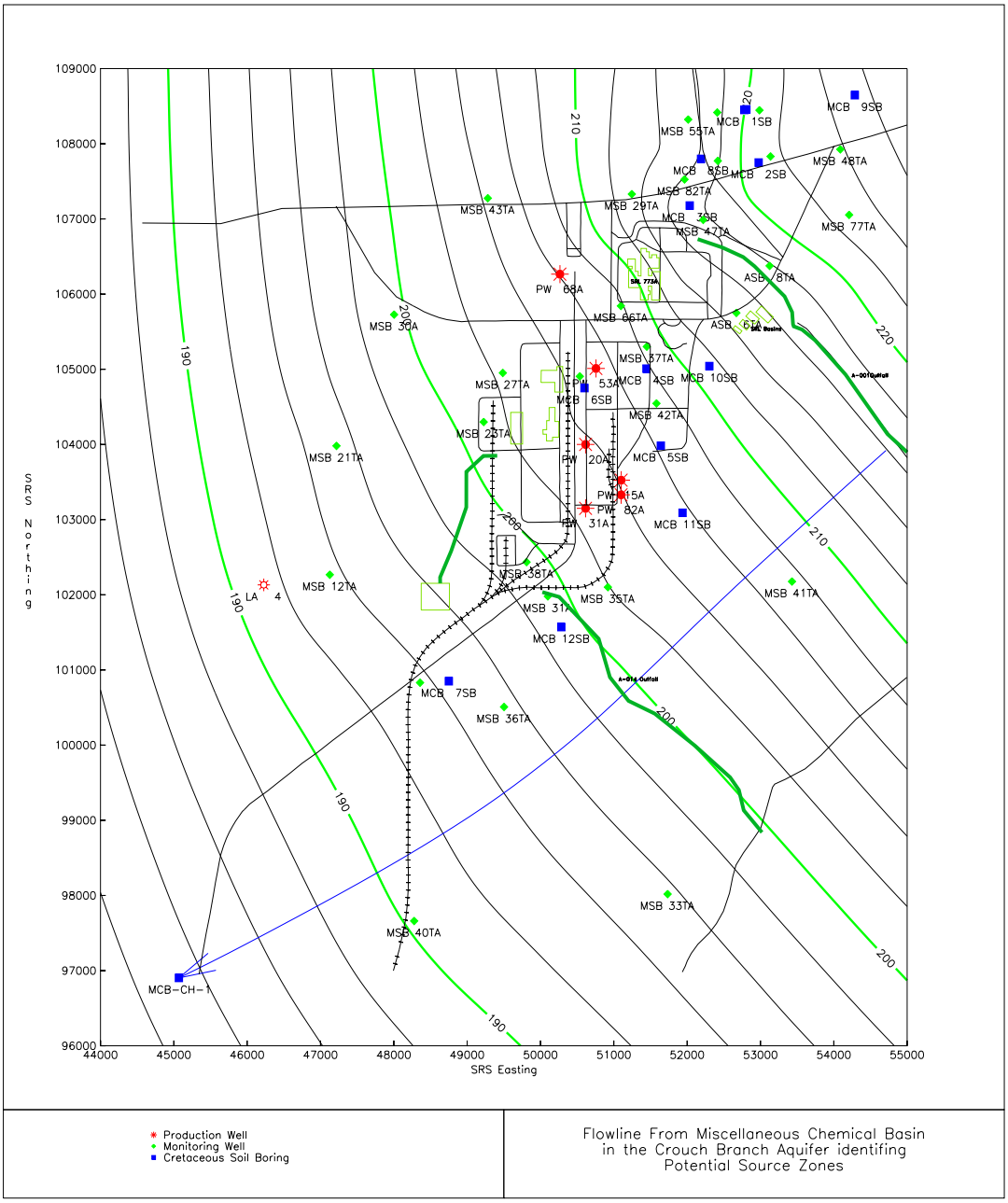


Figure 64: Flowline From Miscellaneous Chemical Basin in the Crouch Branch Aquifer identifying Potential Source Zones.

5 Extent and Distribution of Contamination

As presented in the previous section numerous data sources provide valuable insight on the extent and magnitude of the chlorinated solvent contamination in the Crouch Branch Aquifer. In the subsequent section this data is combined and used to map the extent of the contamination using fundamental principles of groundwater flow, the hydrostratigraphy of A/M Area, and mechanisms of contaminant transport. These considerations are important when mapping the extent and size of the plume in the Crouch Branch Aquifer. Even more important is consideration for the vertical positioning of monitoring wells. Unless considered judiciously one can easily create inaccurate maps with anomalous "bulls-eye" features of high concentrations that do not agree with the conceptual model and source zones. To this extent the distribution of chlorinated solvent contamination in the Crouch Branch Aquifer is determined using the historical data presented along with an appropriate analytical solution to the advective-dispersion equation. The advective-dispersion equation is a differential equation describing solute transport in saturated porous media. This equation is the basis for mathematically describing the migration and fate of a contaminant in an aquifer system. In it's differential form the advective-dispersion equation is difficult to apply and typically serves as the foundation for numerical models simulating contaminant transport. By incorporating appropriate assumptions and simplifications, the advective-dispersion equation has been solved to obtain closed form solutions for several one, two, and even three-dimensional cases. For the case of the Crouch Branch Aquifer a two-dimensional analytical solution is applied to determine the magnitude in regions of limited data. This data was then incorporated with the other data sets to determine the extent and distribution of chlorinated solvents (trichloroethylene) within the aquifer. The applied analytical solution incorporates several site-specific parameters that must be determined in order to assess the extent and magnitude of contamination. Estimates for some of these parameters are available from historical concentrations previously presented and groundwater flow patterns, while others must be determined using more robust techniques. Those parameters that cannot be estimated, are determined using parameter estimation techniques based upon reported groundwater concentrations. The results of this process provides a reasonable estimate of the extent and distribution of chlorinated solvent (trichloroethylene) contamination in the Crouch Branch Aquifer.

5.1 The Advective-Dispersion Equation

Within an aquifer system the migration and distribution of a contaminant is controlled by numerous inter-related processes. These include advection, diffusion, dispersion, adsorption, biodegredation, and chemical reactions (i.e. radioactive decay). Advection is the movement of the contaminant in the porous media with the groundwater at the seepage velocity. Diffusion is a molecular mass-transport process in which contaminants move from areas of higher concentration to areas of lower concentration. Dispersion is a mixing process caused by velocity variations in the porous media that results in the dilution of the contaminant at the leading edge of the contaminant front. Adsorption is a partitioning process where organic contaminants from the soluble phase are adsorbed by the soil matrix, resulting in retarded fronts. Biodegredation represents the transformation and breakdown of certain organic contaminants to non-hazardous forms by microbes in the subsurface. The mathematical relationship governing the influences of these processes and the migration of a chemical contaminant in an aquifer system is derived from the basis of mass conservation. The derivation of these equations are presented in both classical and recent texts on hydrogeology and contaminant transport (Bear, 1972), (Freeze and Cherry, 1979, Appendix X), (Bedient et al., 1994). As presented in the cited literature the advective-dispersion equation is:

$$\left[\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right)+\frac{\partial}{\partial z}\left(D_z\frac{\partial C}{\partial z}\right)\right]-\left[\frac{\partial}{\partial x}\left(\bar{v}_x C\right)+\frac{\partial}{\partial y}\left(\bar{v}_y C\right)+\frac{\partial}{\partial z}\left(\bar{v}_z C\right)\right]=\frac{\partial C}{\partial t} \quad (1)$$

The underlying assumptions in Equation 1 are that the aquifer is homogeneous, isotropic, and saturated

with steady state flow described by Darcy's law. The first bracketed term in Equation 1 accounts for dispersion effects with the second bracketed term accounting for the effects of advection. The term on the right hand side of Equation 1 accounts for time varying effects of the contaminant including adsorption, biodegredation, and other chemical reactions.

For the case of two-dimensional transport migration in a one-dimensional velocity field Equation 1 can be reduced to (Bear, 1972):

$$\left[D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2}\right] - \left[\bar{v}_x \frac{\partial C}{\partial x}\right] = \frac{\partial C}{\partial t} \tag{2}$$

As indicated by Bear, the distribution for any time, t can be obtained by integrating elementary solutions to Equation 1 over the period of injection. For a continuous injection the two-dimensional contaminant distribution is obtained by integrating from time $\theta = 0$ to time $\theta = t$. This is given by (Bear, 1972, Eqn. (10.6.38)):

$$C(x,y,t) = \frac{C_0 Q}{4\pi\sqrt{D_x D_y}} \int_{\theta=0}^{\theta=t} \frac{1}{t-\theta} \exp\left(-\left(\frac{x^2}{4D_x} + \frac{y^2}{4D_y}\right)\right) \frac{1}{t-\theta} + \frac{2xq}{4D_x n} - \frac{q^2}{4D_x n^2}(t-\theta)d\theta \tag{3}$$

The steady-state concentration distribution is obtained by allowing t to approach infinity in Equation 3 and is given by (Bear, 1972)[Eqn. (10.6.39)]:

$$C(x,y) = \frac{C_0 Q}{4\pi\sqrt{D_x D_y}} \exp\left(\frac{qx}{2D_x n}\right) K_0 \left[\sqrt{\frac{q^2}{4D_x n^2}\left(\frac{x^2}{D_x} + \frac{y^2}{D_y}\right)}\right] \tag{4}$$

The solution of the advective-transport equation under these steady-state conditions was initially developed by Bear and has been applied by investigators to assess the extent of contamination in two-dimensional aquifers (Wilson and Miller, 1978). In Equation 4 the function $K_0(x)$ is the modified Bessel Function of the second kind and zero order. This function is defined for all x greater than zero and varies inversely with x such that $K_0(0) = \infty$ and $K_0(\infty) = 0$.

5.2 Application to the Crouch Branch Aquifer

In determining the extent and magnitude of the aqueous concentrations in the Crouch Branch Aquifer, the solution presented in Equation 4 is applied. The flow in the Crouch Branch Aquifer is treated as simple, one-dimensional flow with lateral and transverse migration. The effects and mass removed via the A/M Area production wells are not included in the analysis, thus providing a conservative upper bound on extents and magnitude. The application of Equation 4 involves a coordinate transformation process centered on a conceptual point source region for the Crouch Branch Aquifer and the determination of the transport parameters. The transport parameters are divided into Controlled (Known) Parameters and Estimated (Unknown) parameters. The controlled parameters are determined from the historical concentrations previously presented and groundwater flow patterns. The estimated parameters are determined using robust estimation techniques based upon the measured concentration data. Once these parameters are determined the monitoring well concentration data presented in Table 5 is augmented with the data derived from Equation 4.

5.2.1 Coordinate Transformation

Equation 4 estimates the magnitude of contamination in an aquifer relative to the injection point and the direction of groundwater flow. Application to the Crouch Branch Aquifer requires the development of a coordinate system relative to the source zone with the direction of the abscissa determined by the principle direction of groundwater flow. Since both systems are rectangular the transformation requires

only translation and rotation. The coordinate transformation between SRS Northing and SRS Easting is obtained using the relationship:

$$x_m = (x_{SRS} - x_0)\cos(\theta) + (y_{SRS} - y_0)\sin(\theta) \tag{5}$$
$$y_m = -(x_{SRS} - x_0)\sin(\theta) + (y_{SRS} - y_0)\cos(\theta)$$

In Equation 5 the SRS subscript denotes the coordinates relative to the SRS coordinate system and the m subscript denotes the coordinates relative to the system translated to position (x_0, y_0) and rotated at an angle θ relative to the original system. To translate from the *model* system to the SRS coordinate system the following equations are used.

$$x_{SRS} = x_m\cos(\theta) - y_m\sin(\theta) + x_0 \tag{6}$$
$$y_{SRS} = x_m\sin(\theta) + y_m\cos(\theta) + y_0 \tag{7}$$

Angle of Rotation The rotation angle θ of the *model* coordinate system in Equation 5 and Equation 6 is determined by the principle direction of groundwater flow in the Crouch Branch Aquifer as determined by the potentiometric surface presented in Figure 4.

Center of Coordinate System Based upon the transitional geology associated with a facies change towards sandier sediments of the Crouch Branch Confining Unit and the location of the suspected release zones, the center of the coordinate system was located between well cluster ASB 6 and MSB 47. This position is located upgradient of any known contamination in the Crouch Branch Aquifer and downgradient from possible DNAPL locations in the Steed Pond Aquifer.

5.2.2 Known Locations and Magnitude of Concentration

The numerous data sources previously presented that describe the extent and magnitude of the chlorinated solvent contamination in the Crouch Branch Aquifer were fundamental in mapping the extent of the distribution. This data set included the historical concentrations reported from Crouch Branch monitoring wells presented in Table 5, considerations of "bulk" production well samples presented in Table 4, depth discrete concentrations derived from soil core presented in Table 6, and the depth discrete data collected via the wellbore of production wells 905-20A and 905-53A presented in Table 7.

5.2.3 Estimated Locations and Magnitudes of Concentration

Without consideration for the vertical positioning of the various data sources incorporated, one can easily create inaccurate maps with anomalous "bulls-eye" features of high concentrations that do not agree with the conceptual model and source zones. To minimize these effects during the mapping process the data sets were supplemented with data based upon analytical solutions to Equation 4. These solution were determined using parameter estimation techniques where the unknown parameters of longitudinal and transverse dispersivity were estimated using Levenberg-Marquardt techniques (Press et al., 1992).

5.3 Distribution of Contamination in the Crouch Branch Aquifer

The combined result from these two data sets provide a reasonable estimate of the extent and distribution of chlorinated solvent (trichloroethylene) contamination in the Crouch Branch Aquifer. Based upon this investigation maximum solvent contaminations in the Crouch Branch Aquifer are on the order of 1,000 $\mu g/l$ for trichloroethylene. Figure 65 presents the resulting distribution of trichloroethylene

at an elevation of 30 feet below sea level using this analysis. At this elevation the effects of operating production wells in the Crouch Branch Aquifer are evident as well as local hydraulic conditions. Of particular interest is that portion of the plume that is migrating south of the production well field towards the Miscellaneous Chemical Basin. This portion of the plume results from depth discrete data at the Miscellaneous Chemical Basin. The magnitude of this plume is less than 100 $\mu g/l$ trichloroethylene and reflects early release at the SRTC complex and along the A-01 Outfall. Figure 66 presents a perspective view from the southwest showing the migration from the shallow sediments in the vicinity of the SRTC complex and into the Crouch Branch Aquifer. Although numerous monitoring wells and soil borings are located along this trajectory, all of the monitoring wells are located above the elevation of the plume. Soil boring MCB 7SB may have slightly penetrated the plume at this elevation and soil boring MCB 12SB did indicate concentrations on the order of 1.6 $\mu g/l$ slightly deeper. It is believed that there was some degree of VOC lost during the collection and analysis of samples from borings MCB 7SB and MCB 12SB. The pursuit of additional characterization and monitoring at this elevation, along this flowpath, will allow for the long-term assessment of future migration in the Crouch Branch Aquifer.

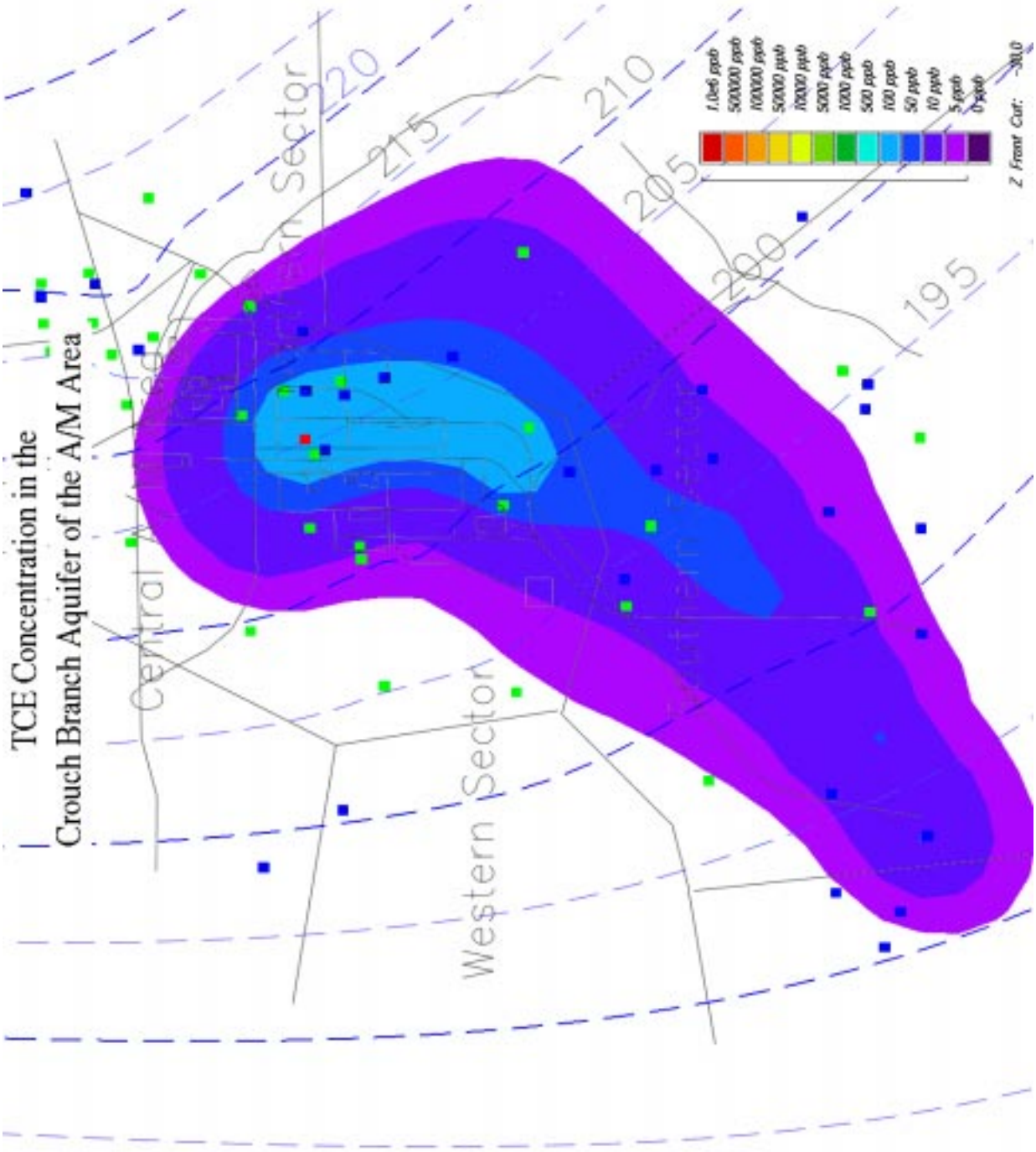


Figure 65: Distribution of Trichloroethylene in the Crouch Branch Aquifer migrating towards the Miscellaneous Chemical Basin.

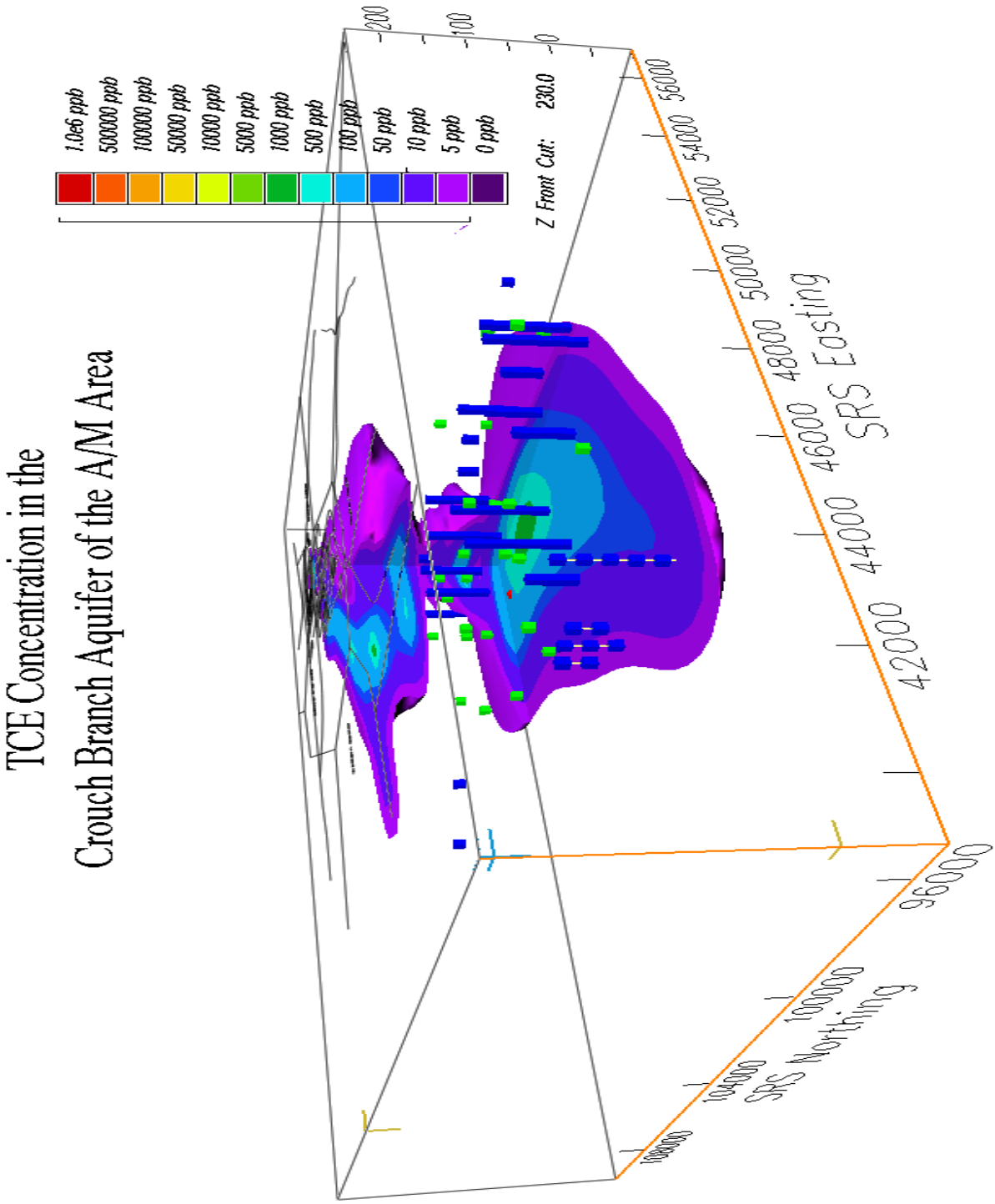


Figure 66: Perspective View from the Southwest showing the Migration of Trichloroethylene From the SRTC Source Zone, into the Crouch Branch Aquifer and towards the Miscellaneous Chemical Basin.

6 Remediation Effecting the Crouch Branch Aquifer

The current strategy for remediation of the Crouch Branch Aquifer incorporates a pump & treat system deployed in the Northern Sector near the SRTC complex. This is complemented with mass removal associated with the operation of A/M Area production wells. The pump & treat system in the Northern Sector provides hydraulic control of the dissolved plume in the up dip equivalent of the Lost Lake aquifer zone per the Part B Permit for the M-Area Hazardous Waste Management Facility. Within the Northern Sector the up dip equivalent of the Lost Lake aquifer zone is referred to as the Steed Pond Aquifer. The pump & treat system in this area is designed to maximize contaminant mass removal prior to prevent migration into the Crouch Branch Aquifer. The Northern Sector pump & treat system incorporates six groundwater recovery wells to remove and contain contaminated groundwater in the Tertiary sediments. The pump and treat system is complemented with mass removal obtained from the operation of the A/M Area production wells. In the current configuration production wells 905-20A and 905-53A are used to supply process water needs in the A/M Area. During periods of operation a large portion of the plume is contained and a significant amount of contaminant mass is removed. The combined effects of these two systems provide an economical and practical remediation strategy for the Crouch Branch Aquifer. The long-term success of the remediation strategy will best be determined by examining future concentrations from select monitoring wells and production wells 905-20A and 905-53A and comparing these values to those historically reported.

6.1 Groundwater Pump & Treat in the Northern Sector

Recognizing the contribution that the shallow contamination in the vicinity of the SRTC complex made to that in the Crouch Branch Aquifer, the original pilot scale air stripper, located in the Central A/M Area, was moved to the Northern Sector in 1990. This air stripper receives contaminated groundwater from recovery well RWM 12 and is designated as the A1 System. The pump & treat program was expanded in 1996 with an additional air stripper and the incorporation of recovery wells RWM 13B and C, RWM 14B and C, and RWM 15B. This system is designated as the A2 system and along with the A1 system, provides remediation within the vicinity of the SRTC complex.

Previous modeling activities evaluated the effectiveness of the pump & treat system (Jackson and Aleman, 1995) with regards to remediation goals in the Tertiary sediments. The previous investigation identified the 5, 15, and 30 year zone of capture in the "Middle Sand" aquifer zone, the Lost Lake aquifer zone, and in the M-Area aquifer zone. The results from this investigation are presented in Figures 67, 68, and 69 for those recovery wells operating in the Northern Sector. These figures represent the zone of capture in the "Middle-Sand" aquifer zone of the Crouch Branch Confining Unit, the Lost Lake aquifer zone, and the M-Area aquifer zone. Within these figures the 0-5 year capture zone is shown in blue, the 5-15 year capture zone is shown in red, and the 15-30 year capture zone is shown in green. The zone of capture in the "Middle-Sand" aquifer zone is as a result of the thinning and disappearance of the "Upper Clay" confining zone of the Crouch Branch Confining Unit towards the northern boundary of the Savannah River Site. This thinning has been identified as a possible facies change of the sediments that make up this unit (Blackhawk Geometrics, 1996). As a result, recovery wells RWM 13B, RWM 14B, and RWM 15B penetrated the layer of the model that represents up dip equivalent of the "Upper Clay" confining zone of the Crouch Branch Confining Unit and provides remediation within the "Middle Sand" zone of the Crouch Branch Confining Unit. To this extent, it is recognized that the "Upper Clay" confining zone of the Crouch Branch Confining Unit has thinned and the effective zone of capture within this model layer actually represents the lower portion of the Steed Pond Aquifer. As shown in Figures 67, 68, and 69, the recovery wells within the Northern Sector provide capture and control within the Steed Pond Aquifer. The combined effects of the natural groundwater flow with the zone of capture of the additional wells minimizes the potential for vertical or lateral migration and spread of groundwater contamination beyond the northern boundary of the site. The greatest impact on plume control and

capture is within the up dip equivalent of the Lost Lake aquifer zone. As discussed by Jackson and Aleman the pumping effects associated with RWM 13B and RWM 15B, should prevent the further spreading of the plume along Tim's Branch in the Lost Lake Aquifer. As determined by the flowline presented in Figure 64 this portion of the plume in the Tertiary sediments may be the source of the plume at the Miscellaneous Chemicals Basin. It is feasible that flowrates at wells RWM 13B and RWM 15B can be decreased and an optimum setting determined based upon plume control and operating cost.

The Northern Sector recovery well system results in plume control and capture within the vicinity of the SRTC complex for the flowrates employed. Continued sampling and examination of historical concentrations at monitoring wells ASB 6TA and MSB 37TA should be an integral part of any long-term assessment of this system with regards to remediation of the Crouch Branch Aquifer. Once the operating conditions of these wells are established the current three-dimensional model should be updated and verified to ensure that simulated results match actual field values and that the flowrates used in this analysis correspond with the operational flowrates. If significant deviations exist in either the model verification or the operational flowrates, the zone of capture for the northern sector should be reexamined.

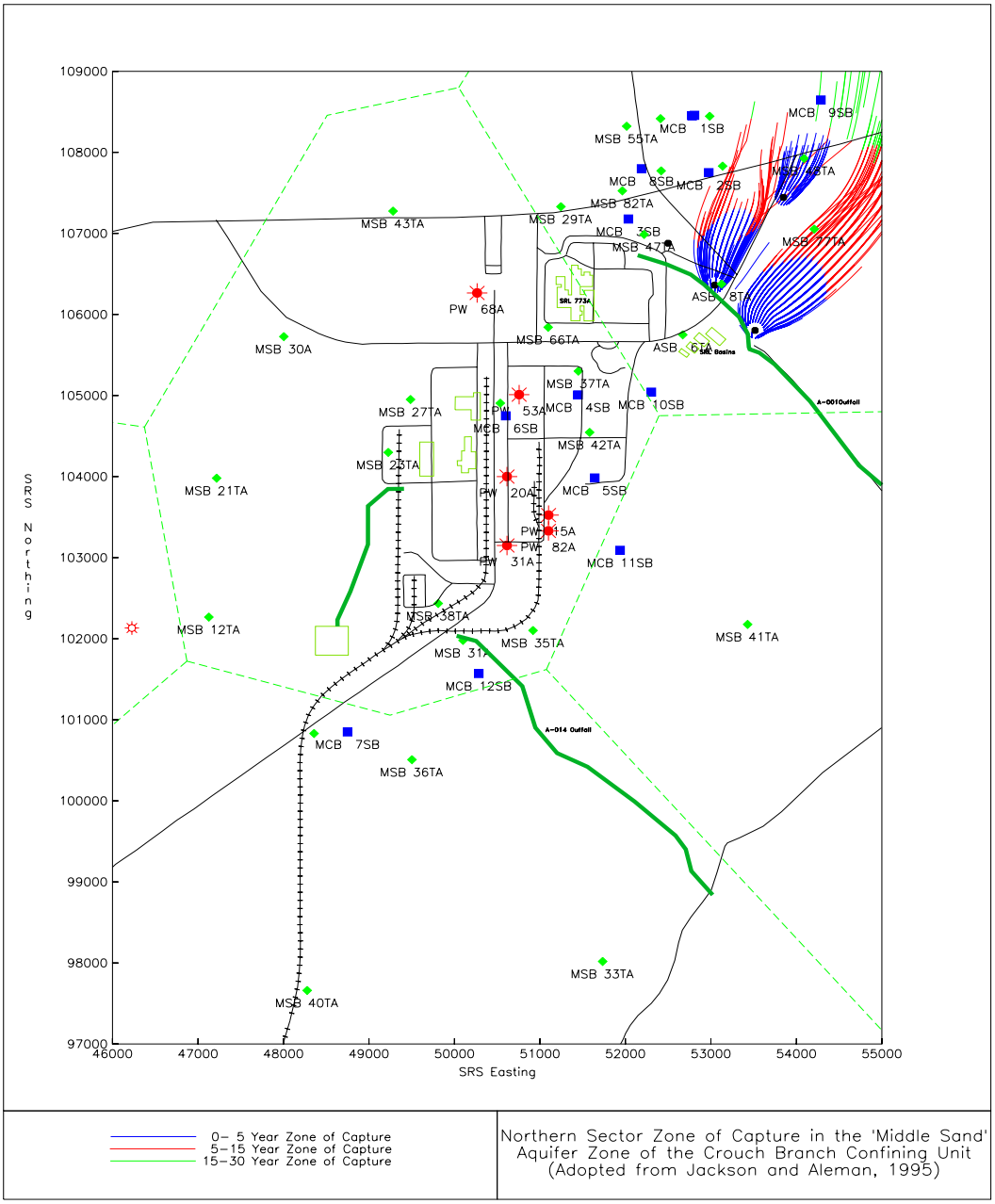


Figure 67: Zone of Capture in the Northern Sector for the "Middle Sand" Aquifer Zone of the Crouch Branch Confining Unit (Adopted from Figure 6, Jackson and Aleman, 1995).

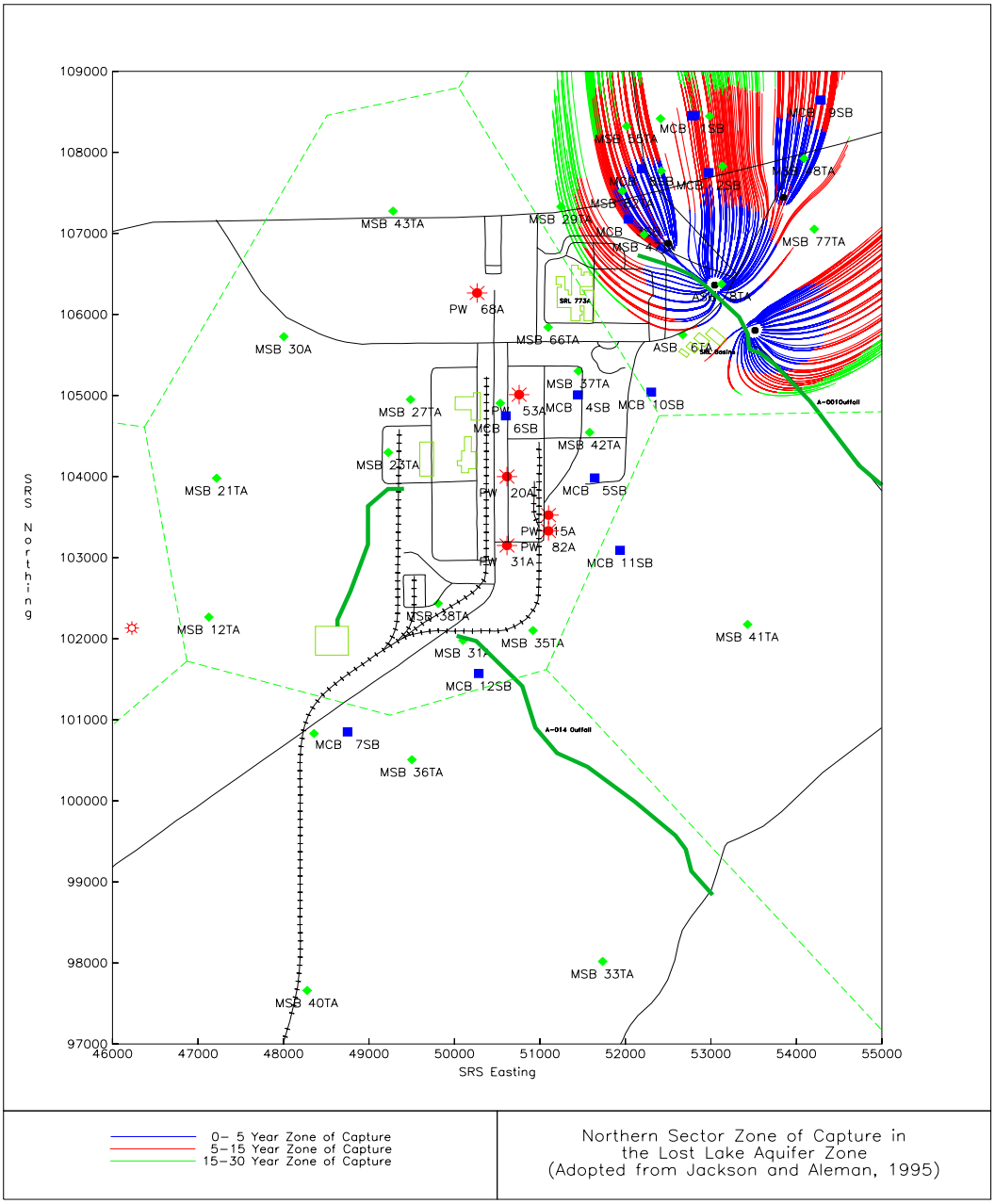


Figure 68: Zone of Capture in the Northern Sector for the Lost Lake Aquifer Zone (Adopted from Figure 7, Jackson and Aleman, 1995).

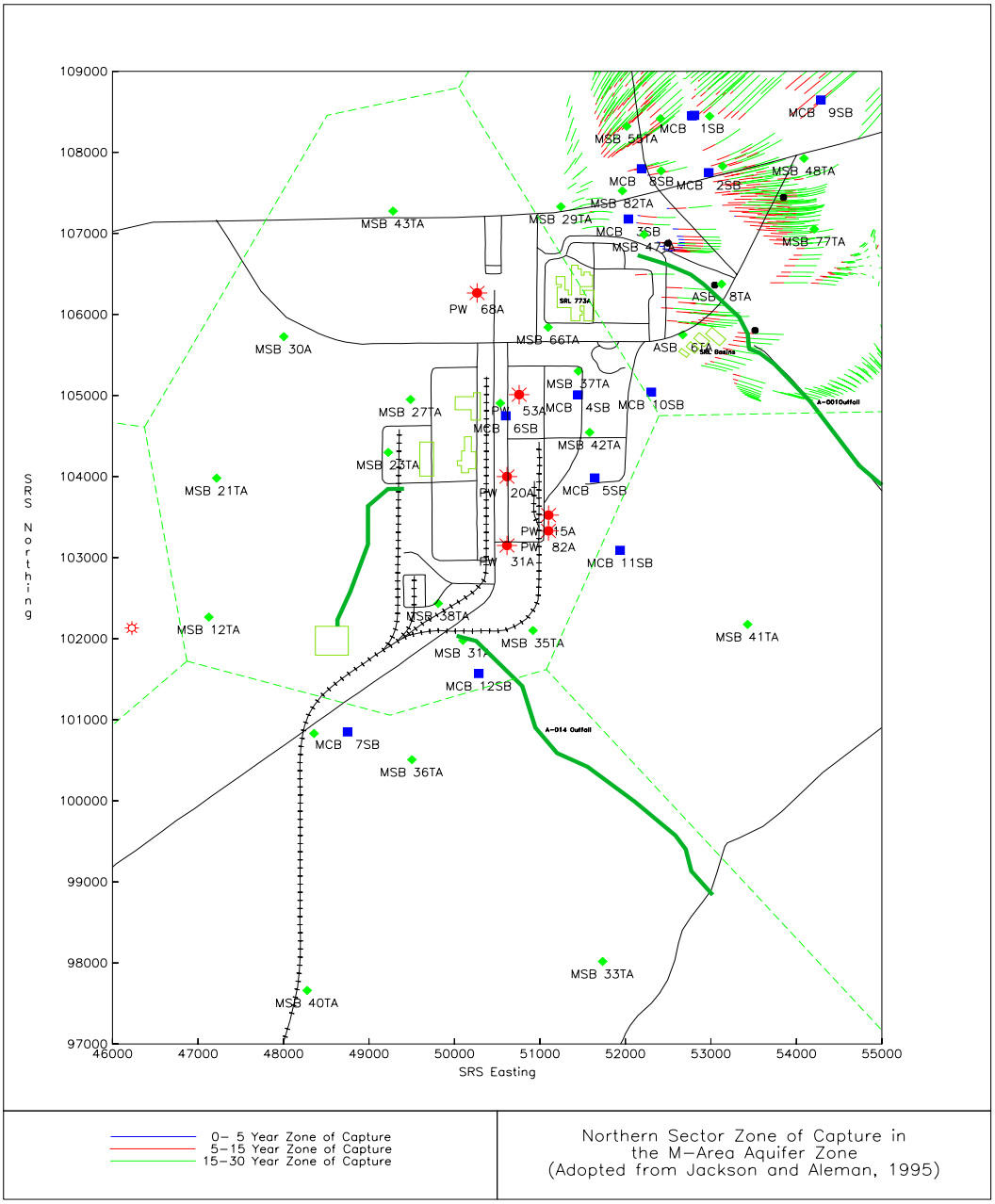


Figure 69: Zone of Capture in the Northern Sector for the M-Area Aquifer Zone (Adopted from Figure 8, Jackson and Aleman, 1995).

6.2 Production Well Mass Removal Estimate

Based upon historical increases in concentrations at the production wells and the volume of water pumped, it is apparent that wells 905-20A, 905-31A, and 905-53A have had a significant effect on controlling the distribution of organic contaminants in the Crouch Branch Aquifer. Prior to the reductions in production demands these wells provided plume containment and control as previous presented (Haselow, 1989). Using the well design information presented in Table 2, the historical concentration data presented in Table 4, and a conservative estimate on well utility, it is possible estimate the amount of contamination ($m_{i,j}$) removed by each of the production wells (i) during the operation period (j) using the following relationship:

$$\begin{aligned} M_T &= \sum_{j=1}^{t}\sum_{i=1}^{N} m_{i,j} \\ &= \sum_{j=1}^{t}\sum_{i=1}^{N} C_{i,j}\eta_{(i,j)}q_i t \end{aligned} \tag{8}$$

In this equation the concentration $C_{i,j}$ is the yearly average groundwater concentration for each well as presented in Table 4, q_i is the design flowrate of the production well presented in Table 2, $\eta_{(i,j)}$ is a well utility factor, and t the time period. The well utility factor identifies the period of operation in a given year and is related to well availability and production demands. Since limited records are available documenting the well availability and production demands, a conservative estimates has been incorporated based upon the limited records, well demand, availability, and process knowledge. Prior to 1988, it is believed that both production wells 905-20A and 905-53A operated at a very high utility. During this period a well utility of 0.8 is used for each well. After this period the wells were informally operated on an alternating sequence with a well utility of 0.5 assumed. The well utility factor for production well 905-31A was assumed to be 0.8 for the operating period between 1982 and 1988. The well utility factor for each production well is presented graphically in Figure 70.

The assumed well utility factor presented in Figure 70 along with historical concentrations presented in Table 2, results in an estimated 5,900 pounds of trichloroethylene and 300 pounds of tetrachloroethylene being removed from production wells 905-20A, 905-31A, and 905-53A between 1982 and 1994. These results are summarized in Table 8. Using the 1994 reported values of 100 $\mu g/l$ and 150 $\mu g/l$ for production wel 905-20A and 905-53A, along with an estimated well utility of 0.5, an estimated 220 pounds of trichloroethylene will be removed per year from production well 905-20A and an estimated 495 pounds will be removed per year from production well 905-53A. Based upon these levels of mass removal, groundwater sampling schedules should be revised to include the collection and analysis of "bulk" water samples from production wells 905-20A and 905-53A. In addition, the production wells should be equipped with a flow recorder so that annual operating periods, i.e. well utility factor, can be determined.

6.3 Influence of Production Wells

As evident from the estimated removal rates presented in previous section, production wells 905-20A and 905-53A have had a significant effect on controlling the distribution of organic contaminants in the Crouch Branch Aquifer. In order to determine the extent and effect these wells have in recovering contaminated groundwater, a numerical model of the Crouch Branch Aquifer has been developed. The primary goal of this model is to assess the effects that production wells 905-20A and 905-53A have had capturing the dissolved trichloroethylene plume that is located in the Crouch Branch Aquifer. The model was used to examine three different scenarios of production well operation.

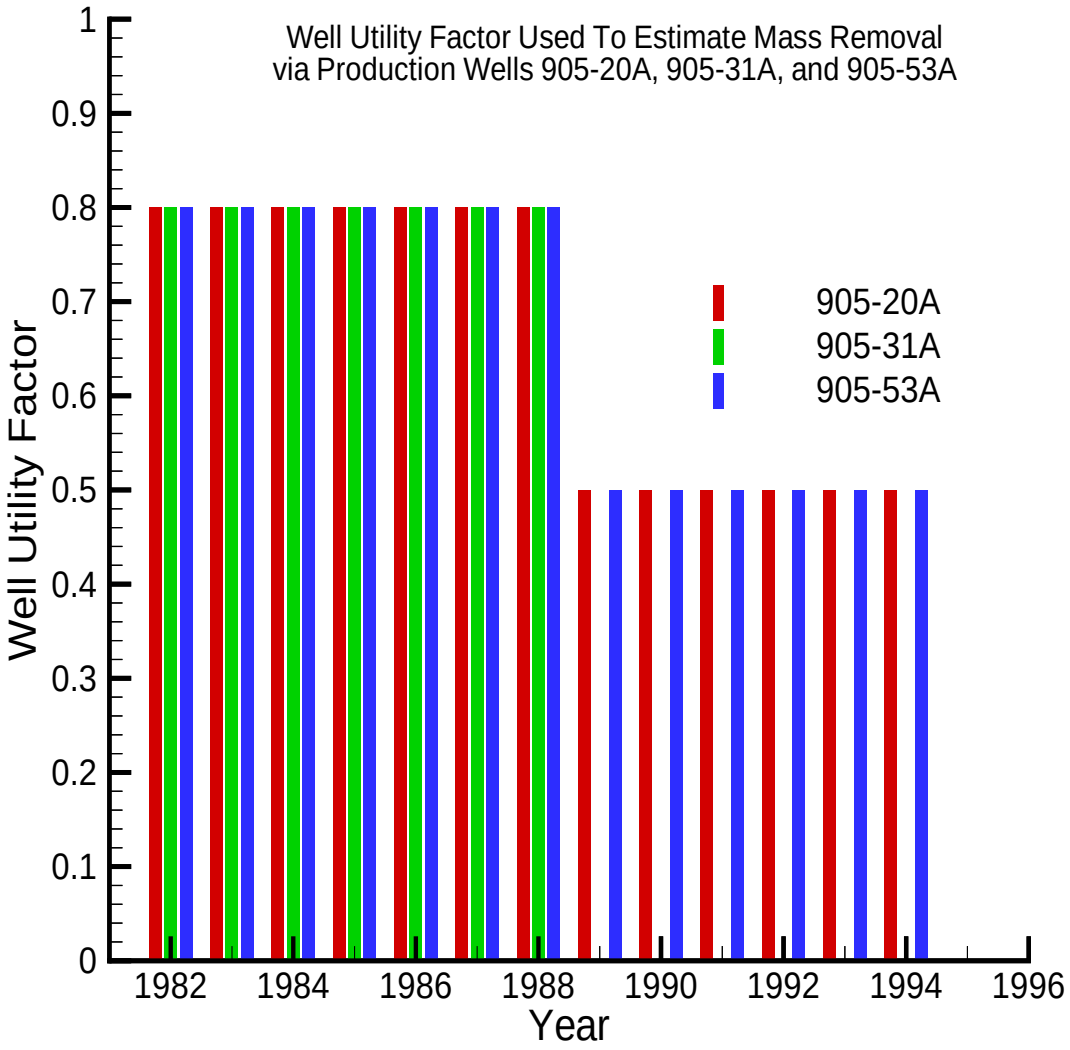


Figure 70: Well Utility Factor Used to Estimate Mass Removal via Production Wells 905-20A, 905-31A, and 905-53A.

Table 8: Summary of Trichloroethylene and Tetrachloroethylene Mass Removed Between 1982 and 1994 from Production Wells 905-20A, 905-31A, and 905-53A.

Well	**Trichloroethylene**	**Tetrachloroethylene**
905-20A	2611.42 lbs.	32.79 lbs.
905-31A	98.33 lbs.	7.02 lbs.
905-53A	3204.68 lbs.	263.38 lbs.
Total	5914.43 lbs.	303.19 lbs.

6.3.1 Model Development

In order to evaluate the zone of capture of the production wells in the Crouch Branch Aquifer, a numerical model simulating the groundwater flow was developed. The development of this groundwater model requires the discretization of the domain in the lateral and vertical directions. This process results in a series of nodes and elements that are combined to represent the aquifers and confining zones within the domain. Appropriate material properties are assigned to the elements to represent the properties of the aquifer and confining zones with appropriately applied boundary conditions. The boundary conditions represent how externally applied stresses, such as pumping wells, streams, and recharge are included into the solution technique. The information regarding the spatial distributions of nodes, element material properties, and boundary conditions are compiled to develop a set of equations representative of the distribution of hydraulic heads throughout the domain. This set of equations is solved and the resultant head values are compared to the observed data. The material properties and boundary condition are adjusted to minimize the difference between the predicted solution and the actual data. The difference between the predicted solution and the actual data is the residual. The process of minimizing the residual by adjusting the material properties, and to a lesser extent the boundary conditions, is referred to as model calibration and is discussed in detail later within this report. This section provides details regarding the horizontal and vertical discretization, and the incorporation of boundary condition data during the development of the model. The model was developed utilizing SRTC's groundwater flow and transport analysis code FACT (Hamm et al., 1997). This code uses a finite element technique to simulate fully three-dimensional groundwater flow and solute transport in subsurface porous media.

Lateral Discretization In performing the assessment of the effect of the production wells on the dissolved plume in the Crouch Branch Aquifer the lateral domain for the model ranges from SRS Easting 33,000 to 59,000 feet in the x-direction, and SRS Northing 75,000 to 113,000 feet in the y-direction. The region is analogous to that of previous numerical models within the A/M Area (Intera Inc., 1993) (Jackson and Aleman, 1995) which aided in the selection and application of external boundary conditions. The region was discretized with a uniform lateral spacing of 100 feet, resulting in a numerical model of 151 nodes in the X-direction and 276 nodes in the Y-direction. The horizontal resolution of 100 feet provides sufficient resolution to adequately simulate the effects of the production wells which produce large quantities of water. The domain encompasses 40.89 square miles and contains the entire A/M Area as well as Upper Three Runs Creek. The aerial domain for the refined model showing this horizontal discretization, relevant surface features, suspected sources of contamination, and topographical data is presented in Figure 71.

Vertical Discretization In order to accurately determine the effects of the "multiple" screen zones associated with the A/M Area production wells, the traditional layer-cake techniques employed in the previous A/M Area regional models (Intera Inc., 1993) (Jackson and Aleman, 1995) were not adequate. To properly determine the effects of each production well additional numerical resolution is required in the Crouch Branch Aquifer. Within each of the the previous models, each model layer represented a specific hydrostratigraphic unit. Although adequate for determining regional flow patterns, these models do not provide the vertical resolution necessary to access the effects of the multiple screen zones associated with the A/M Area production wells. In addition, development of a numerical model with additional vertical resolution will be necessary to support any future contaminant transport simulations associated with the Crouch Branch Aquifer. The model developed includes this resolution and includes those horizons between the top of McQueen Branch Confining Unit and the top of the Crouch Branch Confining Unit. Hydrostratigraphic control for the top and bottom of the domain were incorporated from previous modeling activities (Jackson and Aleman, 1995), supplemented with regional hydrostratigraphic information (Aadland et al., 1995a, Plate 20).

The altitude contour of the top of the McQueen Branch Confining Unit was selected as the bottom of the model domain. The hydrostratigraphic surface incorporated is presented in Figure 72 and was derived from data presented in previous modeling activities (Jackson and Aleman, 1995), supplemented with regional hydrostratigraphic information (Aadland et al., 1995a, Plate 16). The top of the Crouch Branch Confining Unit was selected as the top of the model domain. This surface is presented in Figure 74 and was derived from data presented in previous modeling activities (Jackson and Aleman, 1995), supplemented with regional hydrostratigraphic information (Aadland et al., 1995a, Plate 18). The region between these two surfaces was divided by the top of the Crouch Branch Aquifer represented by the surface presented in Figure 73. Relevant statistical parameters for these surfaces are presented in Table 9. The region of the domain representing the Crouch Branch Aquifer was subdivided into five proportionally thick layers to improve the vertical resolution for particle tracking associated with the production wells and for usage of the model in future contaminant transport simulations. In a similar fashion, the region representing the Crouch Branch Confining Zone was subdivided into two proportionally thick layers. Figure 75 presents the vertical discretization employed in the model.

Hydraulic Parameters Within the vicinity of the A/M Area hydraulic tests have been performed to estimate the hydraulic parameters of the Crouch Branch Aquifer and the Crouch Branch Confining Zone (Siple, 1967) (Geraghty & Miller, 1983b). Additional insight as to the magnitude of these parameters is also available from review of recent modeling activities incorporating these zones (Intera Inc., 1993) (Jackson and Aleman, 1995).

Crouch Branch Aquifer As a result of the clean, well sorted sands that comprise this unit, the hydraulic conductivity of the Crouch Branch Aquifer is expected to range in values from 10^0 to $10^3 ft/day$ (Freeze and Cherry, 1979, Table 2.2). The earliest reported pump test of the Crouch Branch Aquifer in the A/M Area is from activities associated with the installation of production well 905-15A (Siple, 1967). Based upon initial pumping performance a transmissivity of $4,500 ft^2/day$ is cited for the Crouch Branch Aquifer. The transmissivity in this test was determined based upon observed drawdown in the well, which may bias the result. More recently, a pump test was performed using production well 905-20A (Geraghty & Miller, 1983b) and 9 transmissivity values ranging from $75,520$ to $105,910$ gpd/ft were reported. Since this well is screened across two aquifer zones these values represent the combined transmissivity for both the McQueen Branch and the Crouch Branch Aquifers. The reported transmissivity at the pumping well, 905-20A, was $77,850$ gpd/ft. Concluding remarks identified a transmissivity of $79,000$ gpd/ft ($10,500 ft^2/day$) as representative of the hydraulic properties of the *"Tuscaloosa Formation"*, which includes both the McQueen Branch and the Crouch Branch Aquifer Zones.

Recent groundwater modeling activities incorporated a transmissivity of $5,000$ ft^2/day (Jackson and Aleman, 1995). This value was based upon previous modeling activities (Intera Inc., 1993) and is in agreement with reported values for the Crouch Branch Aquifer (Siple, 1967). When combined with the thickness of the aquifer, this transmissivity value results in hydraulic conductivities ranging from 18.8 to 34.3 ft/day. This was the basis for the initial assignment of hydraulic conductivity at each of the elements in the Crouch Branch Aquifer. As discussed in the Calibration and Sensitivity Analysis section of this report it was necessary to increase this value. In order to obtain some degree of vertical heterogeneity in the five elements used to represent the Crouch Branch Aquifer, the hydraulic conductivity at each element was adjusted slightly based on a log-normal distribution of the value determined from the calibrated transmissivity. The anisotropy ratio was set to 10 for all elements in the Crouch Branch Aquifer.

Crouch Branch Confining Unit The 1983 pump test estimated the leakance associated with the Crouch Branch Confining Unit to be 1.1×10^{-3} gpd/ft. Recent groundwater modeling activities (Jackson and Aleman, 1995) explicitly discretized the three zones that make up the Crouch Branch Confining Unit.

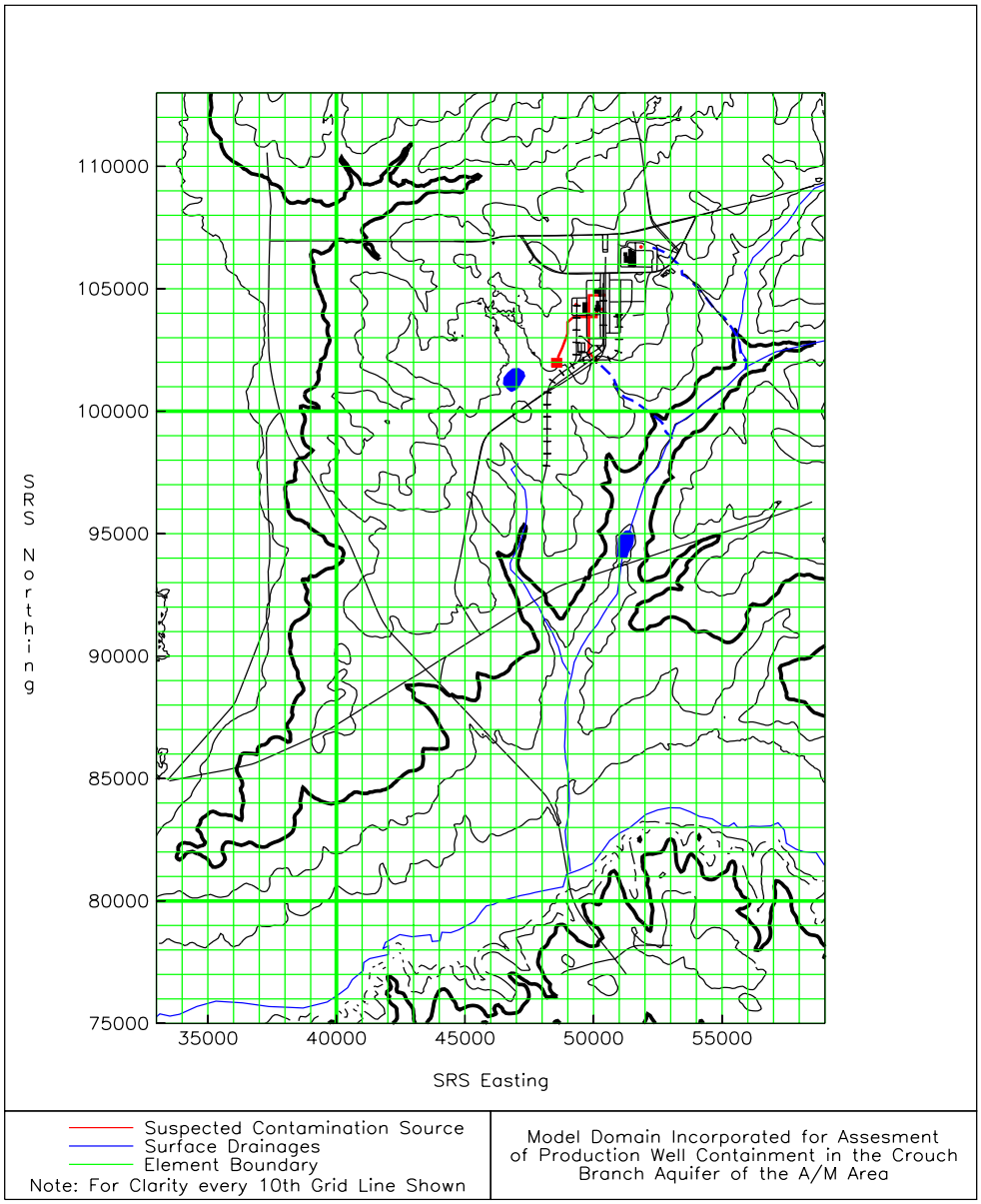


Figure 71: Areal view of the Model Domain Showing Lateral Discretization, Element Boundaries, and Significant Surface Features.

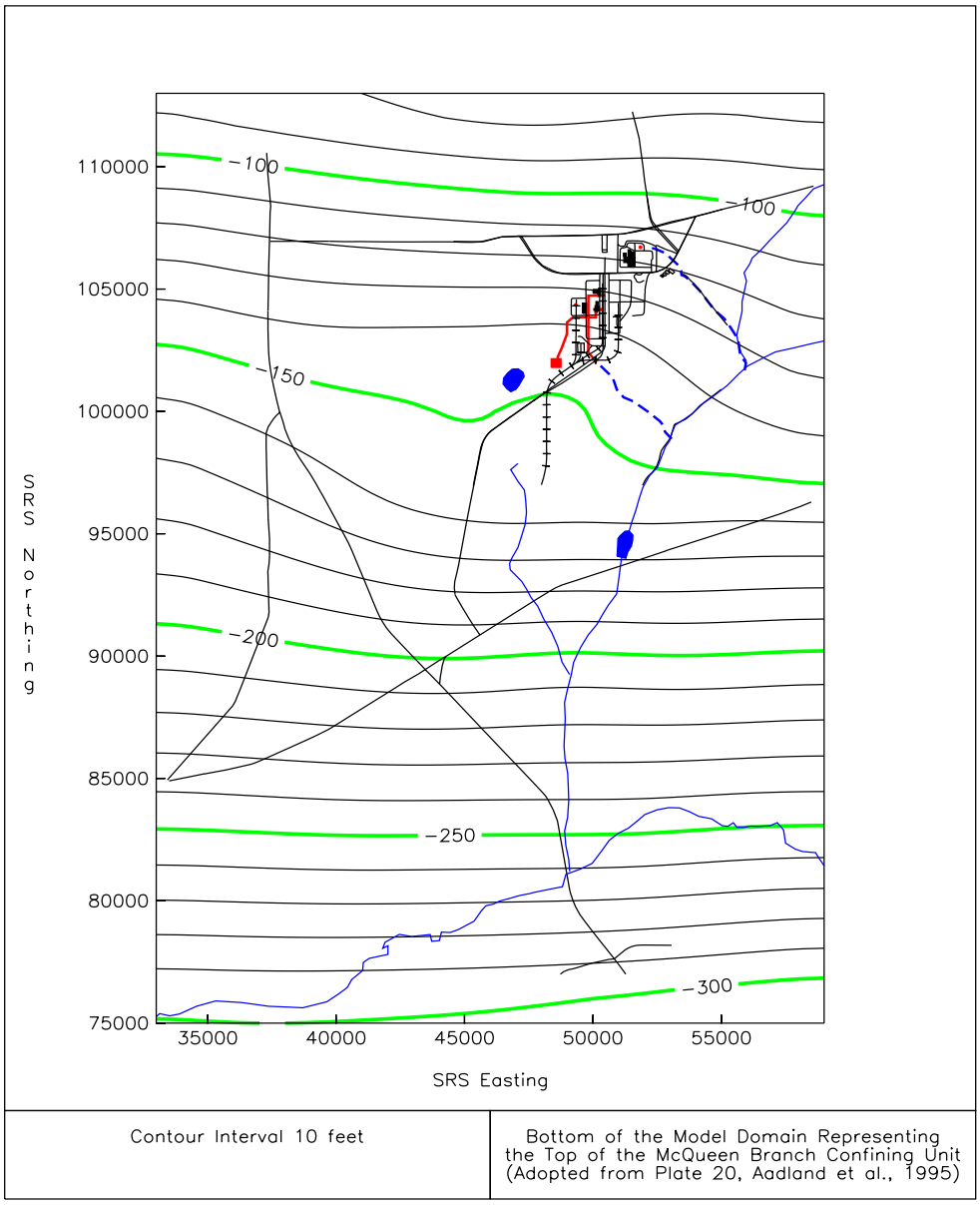


Figure 72: Altitude Contour for the Top of the McQueen Branch Confining Unit used to represent the Bottom of the Model Domain.

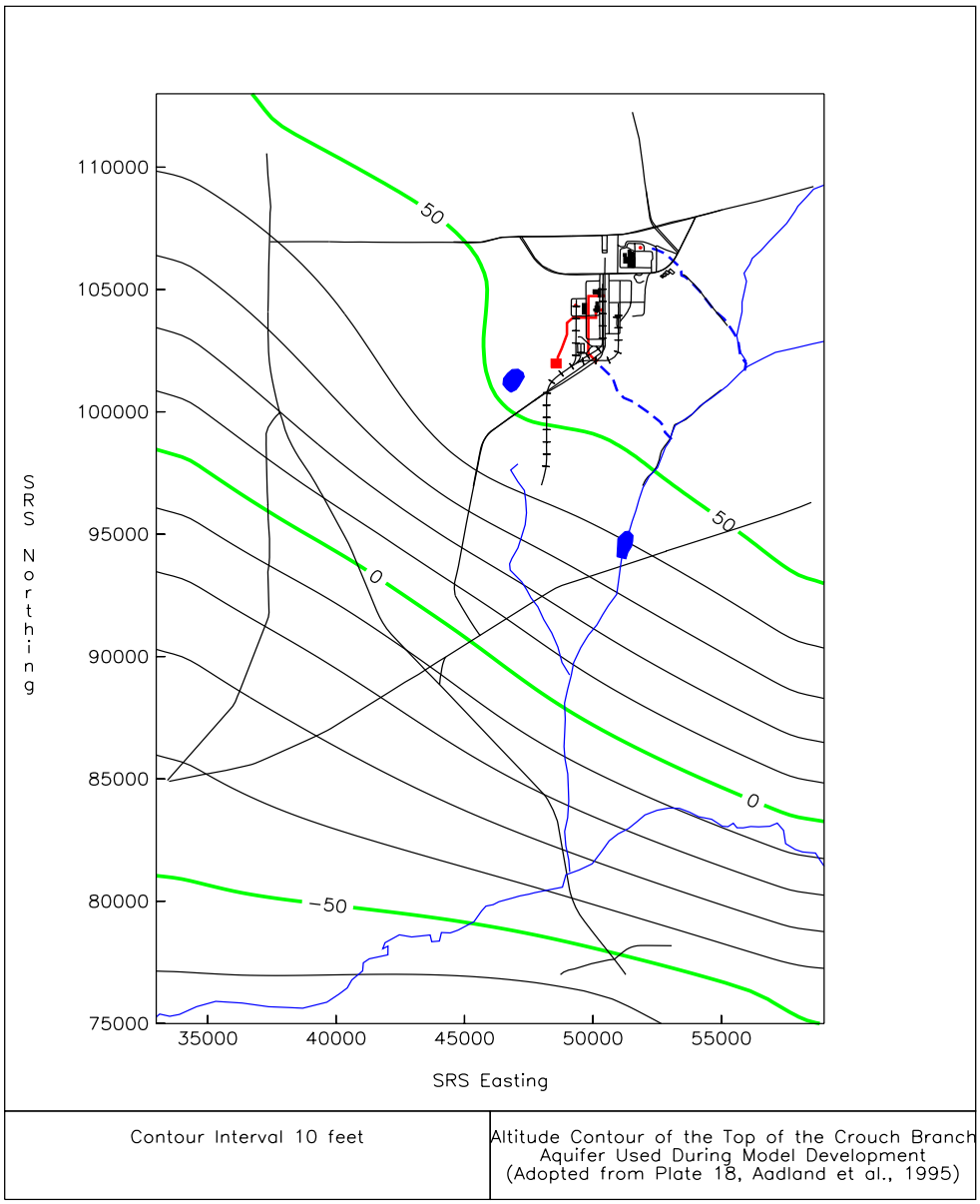


Figure 73: Altitude Contour for the Top of the Crouch Branch Aquifer used in the Model.

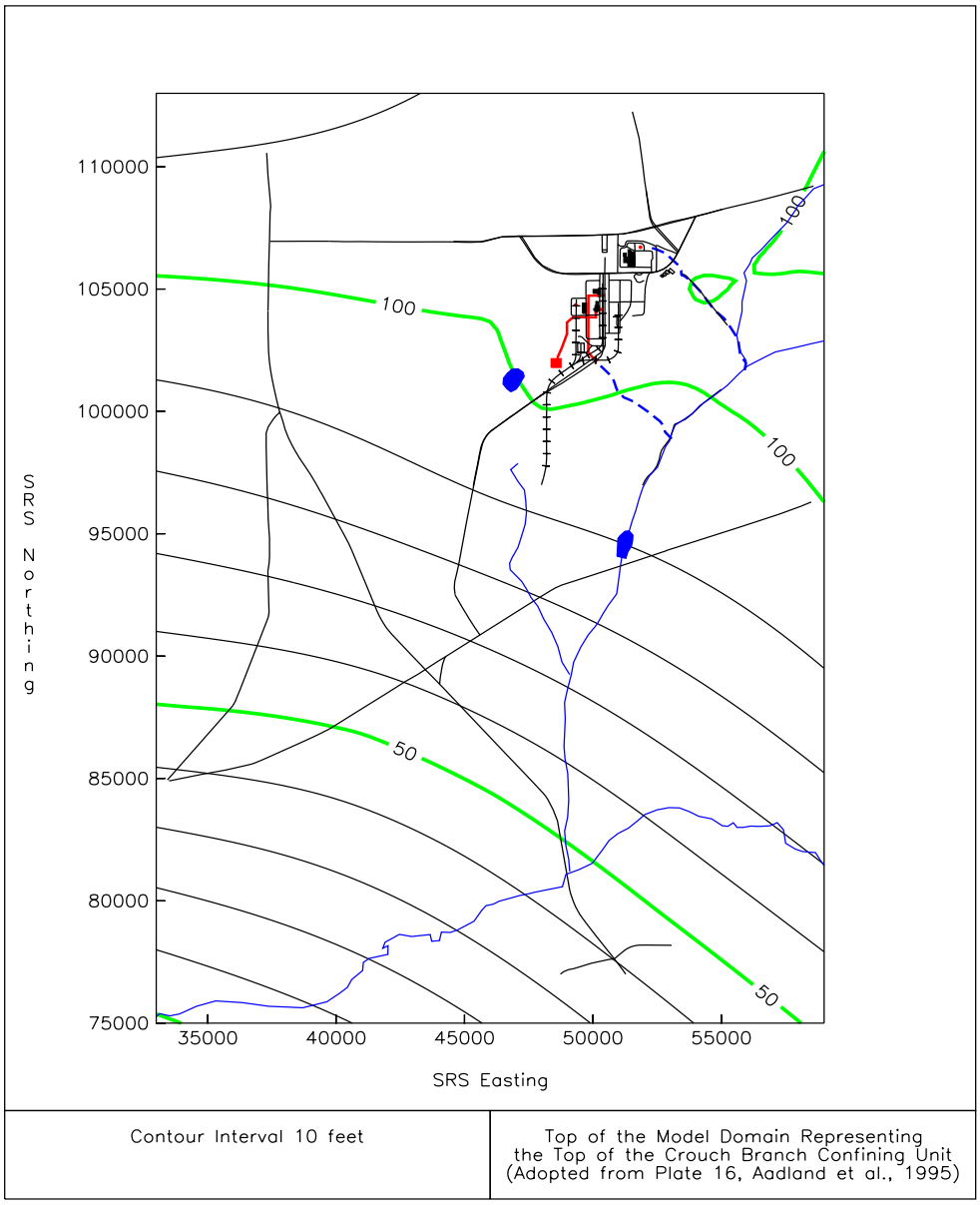


Figure 74: Altitude Contour for the Top of the Crouch Branch Confining Unit used to represent the Top of the Model Domain.

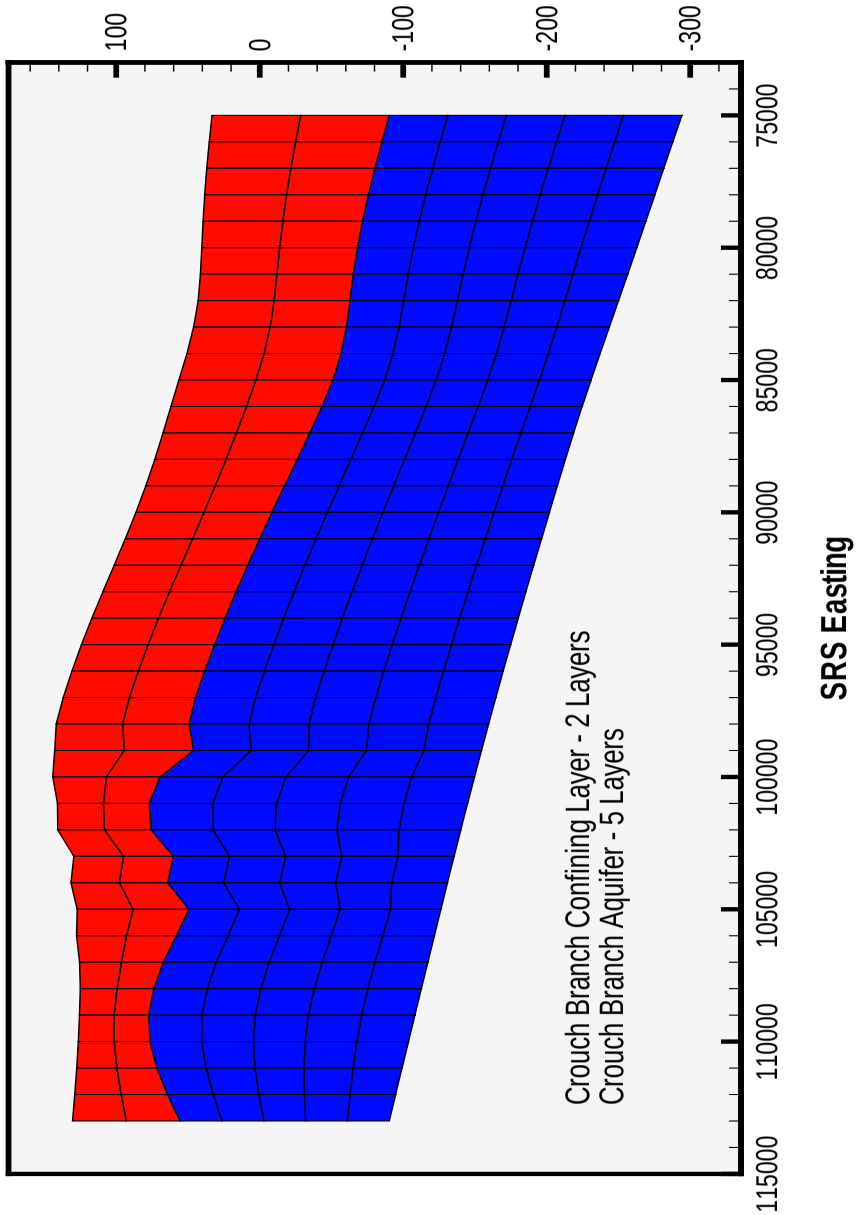


Figure 75: Vertical Discretization Used to Represent the Crouch Branch Confining Unit and the Crouch Branch Aquifer.

Table 9: Statistical Parameters for the Hydrostratigraphic Surfaces used in the vertical Discretization of the Model Domain.

	X-Direction	Y-Direction	Z-Direction
Minimum	33000	75000	-308.87
Maximum	59000	113000	114.97
Range	26000	38000	423.84
Dimensions	261	381	8
Grid spacing	100	100	52.98

Note: Grid Spacing in Z-Direction is an Average Vertical Distance.

Parameter	MBCU	CBA	CBCU
Minimum	-308.87	-65.45	-1.38
Maximum	-75.70	58.73	114.97
Range	233.17	124.19	116.35
Average:	-185.02	9.40	75.17
Standard deviation	65.70	40.28	28.49
Relative deviation	-1.09	13.20	1.16
Coefficient of variation	-0.35	4.28	0.37
Geometric mean	NA	NA	NA
Harmonic mean	-160.34	NA	NA
Skew	-0.19	-0.39	-0.71
Kurtosis	-1.08	-1.33	-0.64

Notes:
MBCU-McQueen Branch Confining Unit
CBA-Crouch Branch Aquifer
CBCU-Crouch Branch Confining Unit

Results from this model had hydraulic conductivity values for the "Upper Clay" zone ranging from $8.0\text{x}10^{-4} - 8.0\text{x}10^{-5}$ ft/day and $2.75\text{x}10^{-3} - 2.75\text{x}10^{-4}$ ft/day for the "Lower Clay" zone. In order to capture the aspects of the facies change associated with the Crouch Branch Confining Unit, the hydraulic conductivity for the entire unit is expected to vary over several orders of magnitude across the model domain. Changes in hydraulic conductivity associated with this facies change is the predominate mechanism that allows the migration of groundwater from the Steed Pond Aquifer into the Crouch Branch Aquifer. In order to incorporate this variation into the numerical model the hydraulic conductivity of this unit was varied over the range of 10^{-5} to 10^{1} ft/day. The distribution was selected so that regions of higher conductivity were located in the northeastern corner of the domain with the hydraulic conductivity decreasing radially towards the southwest. Figure 76 presents the distribution of the hydraulic conductivity for the Crouch Branch Confining Unit that was incorporated into the numerical model. The anisotropy ratio was set to 1 for all elements in the Crouch Branch Confining Unit.

Boundary Conditions The boundary conditions that are incorporated into the model represent how externally applied stresses are included into the solution technique. The boundary conditions are mathematical representations that either specify the dependent variable (head) or the derivative of the dependent variable (fluid flux) at specific locations within the model domain. Three different types of hydrogeologic boundary conditions exist. These types are the specified head condition (Dirichlet condition), specified flux (Neumann condition), and the head-dependent flux conditions (Cauchy or mixed boundary conditions). For the solution of the flow equation, these stresses include pumping and extraction wells, groundwater recharge from precipitation, groundwater supply and discharge from surface streams, and interactions with the remaining hydrologic system at the model boundaries. The operating production wells, 905-20A, 905-53A and 905-68A, were incorporated as steady-state flux conditions based upon the design information previously presented in Table 2.

Specified Head Boundaries on the vertical faces were constrained using the specified head (Dirichlet) condition. The head values were derived from the potentiometric contours in the Crouch Branch Aquifer. The distribution of these heads along the north and south boundaries are presented in Figure 77. As presented in this figure the head in the Crouch Branch Aquifer on the northern boundary varies linearly from 142 feet above mean sea level on the east to almost 250 feet above mean sea level on the west. Along the south boundary the values vary from 164 feet in the west to 174 feet in the east. The distribution of heads along the east and west boundaries are similarly presented in Figure 78. As presented the head in the Crouch Branch Aquifer on the eastern boundary varies from 175 feet above mean sea level on the south to almost 245 feet above mean sea level on the north. Along the western boundary the heads vary from 164 feet in the south to 142 feet in the north.

Specified Flux Boundary conditions of this type were used to control the amount of water entering from the Steed Pond Aquifer and exiting across the McQueen Branch Confining Unit. Distributions of specified flux were derived using potentiometric difference across the appropriate unit combined with a calibrated leakance term.

Leakance across the McQueen Branch Confining Unit The head difference between the McQueen Branch Aquifer and the Crouch Branch Aquifer, previously presented in Figure 7, was used along with a leakance value to control flux. The leakance value was determined from previous modeling efforts (Jackson and Aleman, 1995) and regional hydrogeological investigations (Aadland et al., 1995a). The previous model used a calibrated leakance of $5.0\text{x}10^{-5}1/day$ and simulated the flow based upon observations at the regional P-well clusters. Based upon information presented in recent hydrogeological investigations (Aadland et al., 1995a, Page 90) the leakance value for flow across this unit is slightly lower than that previously incorporated. As presented by Aadland et.al. the leakance of the McQueen Branch Confining Unit is expected to range from $1.04\text{x}10^{-6}$ to $5.57\text{x}10^{-5}1/day$. The current model incorporated

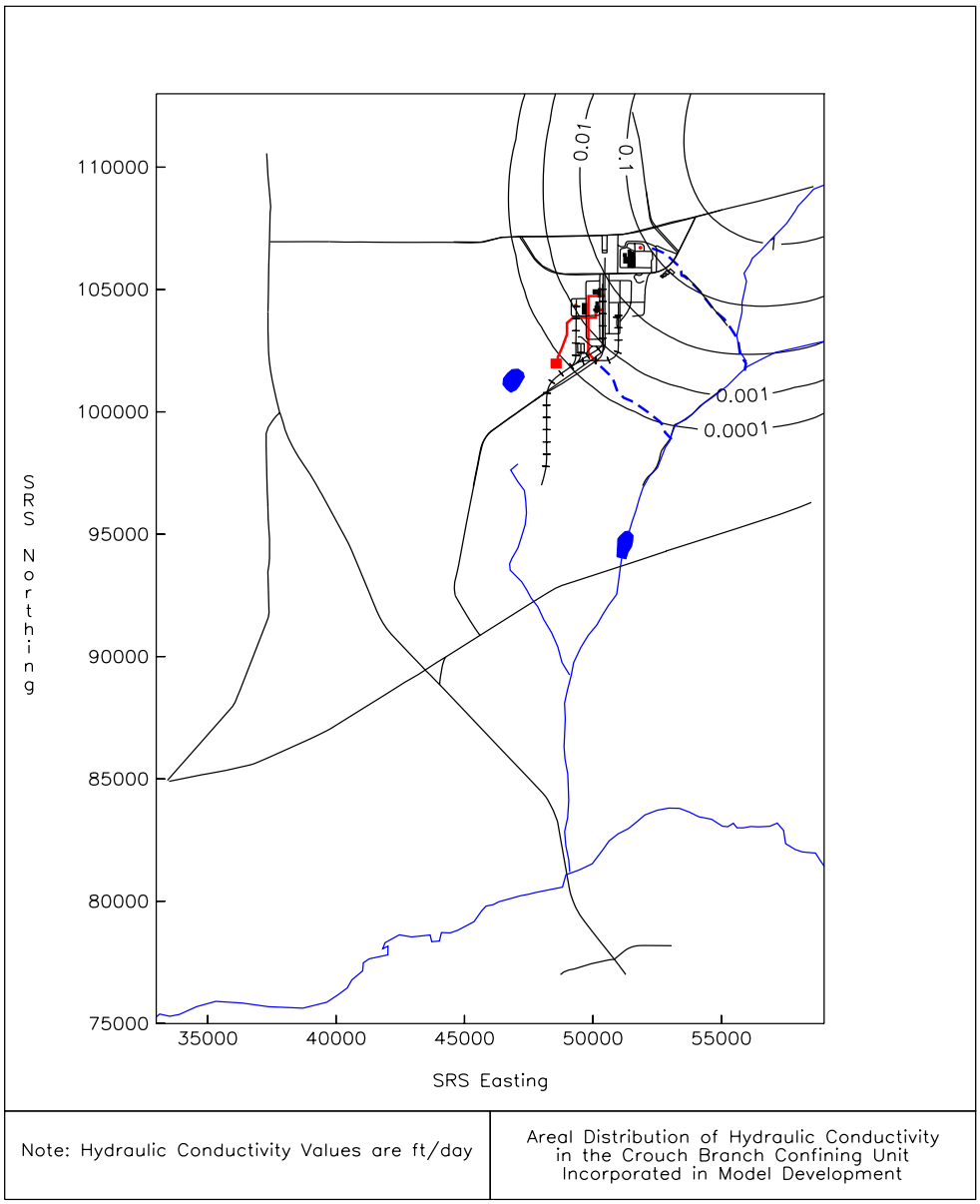


Figure 76: Areal Distribution of Hydraulic Conductivity in the Crouch Branch Confining Unit.

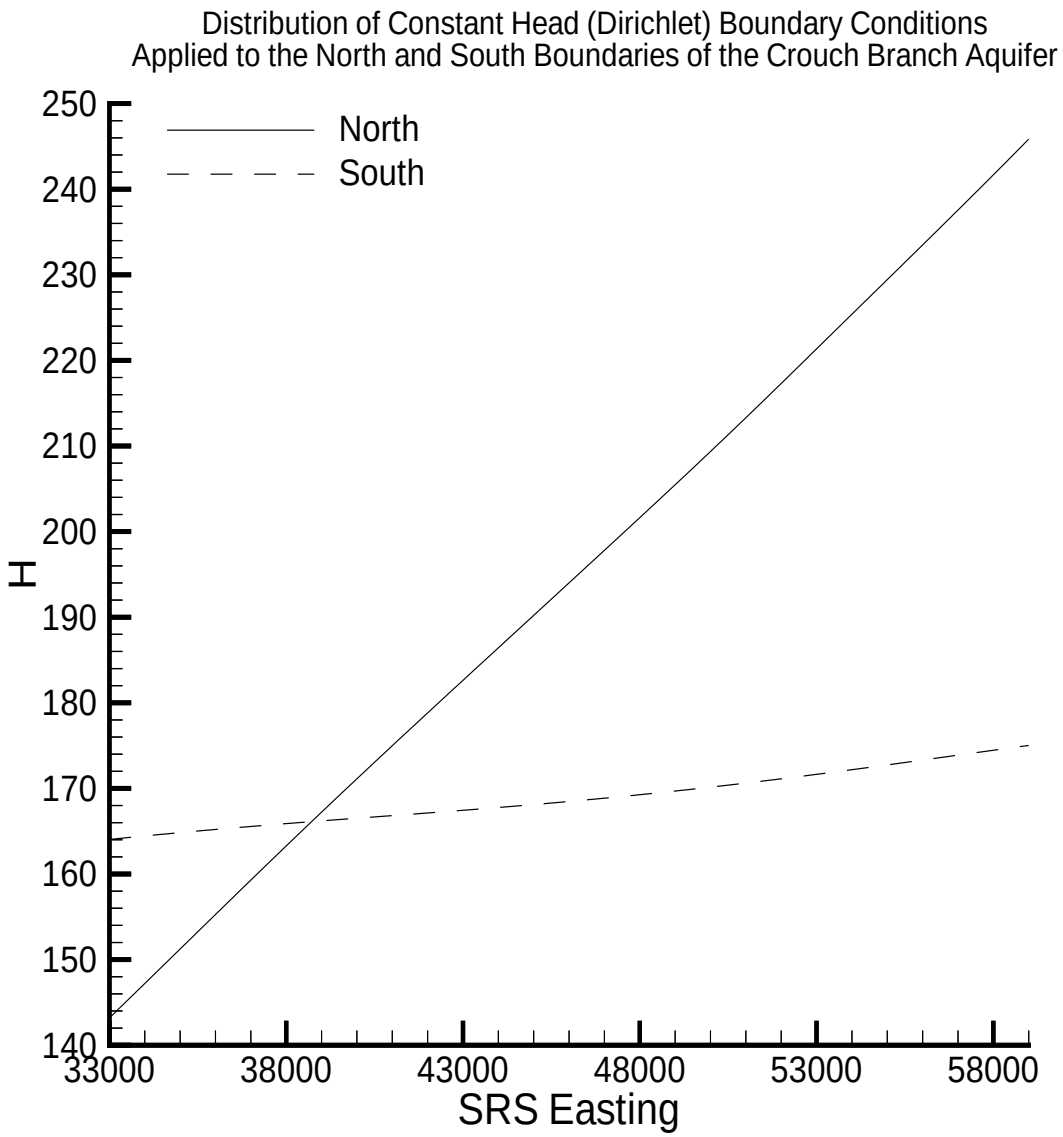


Figure 77: Distribution of Constant Head (Dirichlet) Boundary Conditions Applied to the North and South Boundaries of the Crouch Branch Aquifer.

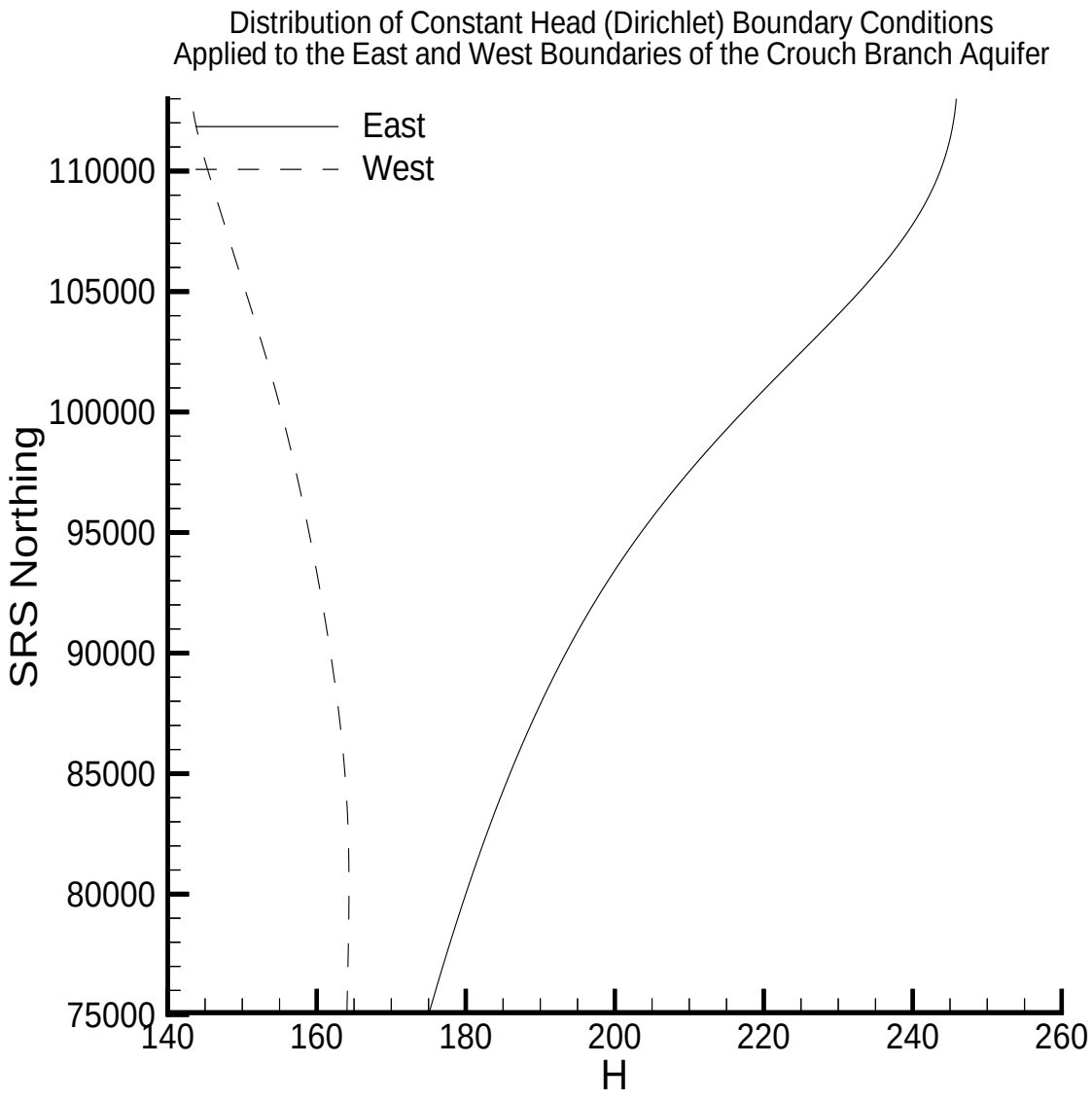


Figure 78: Distribution of Constant Head (Dirichlet) Boundary Conditions Applied to the East and West Boundaries of the Crouch Branch Aquifer.

an average leakance of 1.0×10^{-6} throughout the domain. As presented in the Sensitivity Analysis section the effects of this parameter on model calibration were minimal.

Leakance from the Steed Pond Aquifer In a manner similar to that used for leakance across the McQueen Branch Confining Unit, the flow from the Steed Pond Aquifer to the Crouch Branch Confining Unit was also simulated. This flow was represented using a specified flux distribution. This distribution was derived using head difference data between the Crouch Branch Aquifer and the Steed Pond Aquifer and a calibrated leakance value. The leakance term includes the effects of the interbedded layers of sand, silt, and clay that comprise the Steed Pond Aquifer. The calibrated leakance value incorporated in the model was 6.75×10^{-4} $1/day$. This leakance term couples with the head difference between and aquifers and the hydraulic conductivity of the Crouch Branch Confining Unit to control the amount of water entering the Crouch Branch Aquifer.

Production Wells The operating production wells, 905-20A and 905-53A were incorporated as steady-state flux conditions based upon the design parameters presented in Table 2. Production well 905-68A is located in the Crouch Branch Aquifer [*Upper Tuscaloosa*] and serves as a source of water for the Site's Emergency Response Center. This well operates at 100 *gpm*. Production well 905-31A was not incorporated because it was taken out of service in 1988. The flux values from each operating production well were incorporated into the developed model using FACT's steady state well boundary condition. By specifying the areal and vertical siting information of each screen section with the extraction flux, FACT calculates the appropriate flux values that are to be assigned to each node necessary to simulate the performance of the well. These wells have active screen zones in both the McQueen Branch and the Crouch Branch Aquifers. The total flowrate for each well was normalized by the overall screen length to determine the flowrate per foot of screen. Using this data to calculate extraction flux, each of the screens in the Crouch Branch Aquifer were incorporated into the model. Table 10 summarizes these parameters for the various simulations performed.

Table 10: Summary of Screen Zones and Extraction Fluxes Associated with Production Wells 905-20A, 905-53A, and 905-68A used during Model Calibration and in Various Scenarios.

Model Development and Calibration
(Production Wells 905-20A and 905-53A Operating at 50%)

Well ID	**Screen Zone**		**Length**	**Flux**
905-20A	-76	-26	50	-27504.00
905-53A	-47	-42	5	-7219.80
	-74	-59	15	-21659.40
	-89	-79	10	-14439.60
905-68A	13	33	20	-962.64

Production Wells 905-20A and 905-53A Operating at 100% Capacity.

Well ID	**Screen Zone**		**Length**	**Flux**
905-20A	-76	-26	50	-55008.00
905-53A	-47	-42	5	-14439.60
	-74	-59	15	-43318.80
	-89	-79	10	-28879.20
905-68A	13	33	20	-962.64

Production Wells 905-20A Operating at 100% Capacity.

Well ID	**Screen Zone**		**Length**	**Flux**
905-20A	-76	-26	50	-55008.00
905-53A	-47	-42	5	0.00
	-74	-59	15	0.00
	-89	-79	10	0.00
905-68A	13	33	20	-962.64

Production Wells 905-53A Operating at 100% Capacity.

Well ID	**Screen Zone**		**Length**	**Flux**
905-20A	-76	-26	50	0.00
905-53A	-47	-42	5	-14439.60
	-74	-59	15	-43318.80
	-89	-79	10	-28879.20
905-68A	13	33	20	-962.64

Note: Extraction Fluxes are in ft^3/day.

6.3.2 Calibration, Residual, and Sensitivity Analysis

Calibration During the development of the model the hydraulic conductivity incorporated for the Crouch Branch Aquifer was increased slightly above that used in previous models. This adjustment was necessary in order to prevent mounding of water in the aquifer. As presented in the Sensitivity Analysis section, transmissivity values lower than $7,500\ ft^2/day$ resulted in excessive mounding in the Crouch Branch Aquifer. As a result the model was developed with a transmissivity of $8,125\ ft^2/day$ in this aquifer. When combined with the thickness of the Crouch Branch Aquifer, this transmissivity value results in hydraulic conductivities ranging from 31.4 to 62.6 ft/day. This distribution is presented in Figure 79. The increase in hydraulic conductivity is a direct result of the large variation in hydraulic conductivity incorporated for the Crouch Branch Confining Unit previously presented in Figure 76. The region of high hydraulic conductivity in the northeast was incorporated to simulate the facies change in this region. This has the effect of allowing more water into the Crouch Branch Aquifer than previous simulations. Unfortunately a direct correlation between the TDEM data used to identify this facies change and hydraulic conductivity is unavailable. As a result, the qualitative effects of this facies change were quantitatively included as presented.

Residual Analysis Residual analysis involves the comparison of observed conditions (targets) to simulated conditions. The difference between the simulated and the observed condition is the residual. Residual analysis provides a quantitative method for the adequacy of the model. In performing a residual analysis numerous statistical parameters are examined with respect to the residuals during model development and calibration. These parameters are the root mean square of the residual (RMS), the average value of the the residual, the average absolute value of the residual and the location and maximum value of the residual. Individual residuals for the monitoring wells in the Crouch Branch Aquifer are presented in Table 11 for the calibration parameters previously presented. Figure 11 presents a summary of the residuals as well as a scatter plot of the residuals. The calibrated RMS residual was 2.85 feet with a maximum difference of -6.65 feet which occured at monitoring well MSB 47TA. Examination of the scatter plot shows a slight bias for under prediction for observations greater than 212 feet. This represents that region of the model associated with the facies change of the Crouch Branch Confining Unit. Several techniques exist to resolve this slight bias, including increasing the leakance term associated with the Crouch Branch Aquifer and/or expanding the region of the facies change associated with the sediments representing the Crouch Branch Confining Unit. Both of which result in more flow to the Crouch Branch which would require an additional increase in transmissivity of the aquifer. Although initially considered viable, decreasing the transmissivity of the Crouch Branch Aquifer does not result in the desired effect. Assignment of localized values of transmissivity may provide the decrease in residual to reduce the maximum residual reported. Currently insufficient data exists to justify these local adjustments.

Complementing the quantitative residual analysis is a qualitative comparison of the mapped potentiometric surfaces with those predicted by the model. Often time is the case where the quantitative residual analysis shows excellent calibration, only to have groundwater migration in the wrong direction. The results of this comparison are presented in Figure 81. As shown in this figure there is excellent agreement between the mapped potentiometric surfaces and those simulated. The only significant regions of discrepancy are near Steed's Pond and along Road B between Road A and Road C. These discrepancies are associated with the limited availability of data in these regions. Within the A/M Area the simulated conditions are in agreement with the mapped conditions. In this area the general direction of groundwater flow in the Crouch Branch Aquifer is towards the interior of the site.

Sensitivity Analysis A sensitivity analysis results in quantitative relationships between model results and the input hydraulic properties and/or boundary conditions of the aquifers and confining zones. Examination of the sensitivity of calibration residuals and model conclusions to the model inputs is a

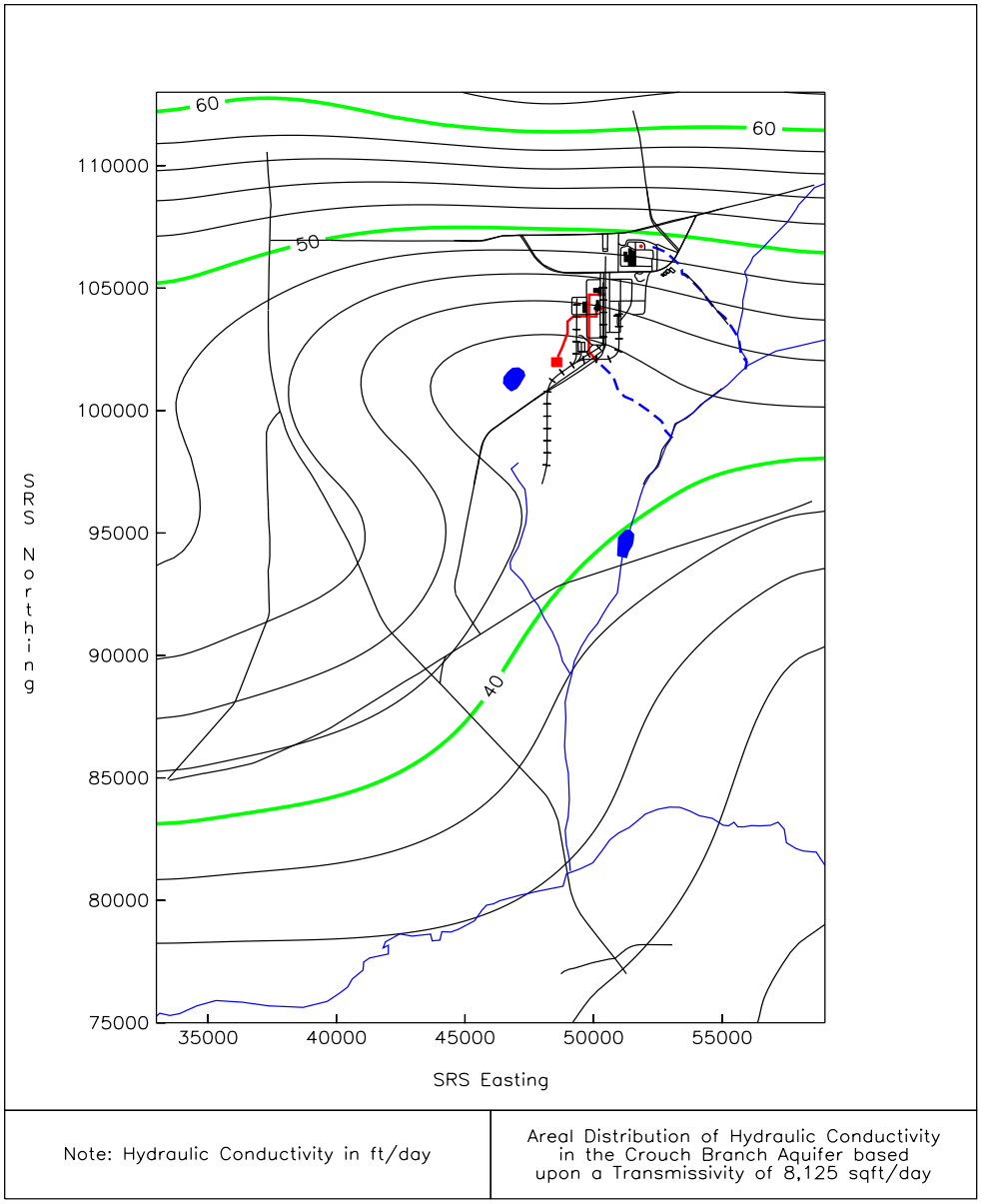


Figure 79: Areal Distribution of Hydraulic Conductivity in the Crouch Branch Aquifer based upon a Transmissivity of $8,125 ft^2/day$.

Table 11: Statistical Parameters for Monitoring Well Targets in the Crouch Branch Aquifer.

Well ID	Easting	Northing	Screen Zone		Observed	Simulated	Residual
ASB 6TA	52671.30	105749.50	34.50	40.00	215.54	210.94	-4.60
ASB 8TA	53124.70	106375.80	19.40	24.60	217.07	213.61	-3.46
MSB 12TA	47127.30	102266.70	-112.80	-102.80	193.71	191.98	-1.73
MSB 12TB	47133.00	102260.10	-5.50	14.50	193.66	192.00	-1.66
MSB 21TA	47218.20	103980.90	17.30	22.60	195.22	193.31	-1.91
MSB 23TA	49225.80	104298.80	60.40	65.40	202.75	198.56	-4.19
MSB 23TR	49036.00	104278.50	35.90	40.80	200.05	197.89	-2.16
MSB 27TA	49486.50	104951.40	50.60	55.90	202.32	200.22	-2.10
MSB 29TA	51245.70	107330.40	58.60	63.90	213.52	208.44	-5.08
MSB 30A	48004.10	105727.40	26.90	36.90	199.56	196.68	-2.88
MSB 31A	50100.20	101979.30	12.00	22.00	199.13	198.89	-0.24
MSB 33TA	51734.00	98018.20	18.10	23.40	195.69	197.93	2.24
MSB 34TA	50536.60	104905.80	-101.90	-91.90	202.57	201.50	-1.07
MSB 34TB	50537.90	104891.60	65.80	75.80	203.88	202.41	-1.47
MSB 35TA	50919.60	102101.60	32.90	38.20	201.94	201.08	-0.86
MSB 36TA	49503.00	100507.70	48.40	53.40	195.53	196.03	0.50
MSB 37A	51439.80	105295.00	68.10	73.70	208.58	205.66	-2.92
MSB 37TA	51449.80	105301.30	29.80	35.10	208.38	205.45	-2.93
MSB 38TA	49810.40	102434.90	26.70	32.00	199.23	198.47	-0.76
MSB 39TA	48357.70	100830.60	44.40	49.70	193.63	193.85	0.22
MSB 40TA	48277.20	97660.40	23.70	29.00	190.29	190.81	0.52
MSB 41TA	53429.70	102176.50	21.40	26.70	207.45	208.14	0.69
MSB 42TA	51581.70	104545.60	40.50	45.80	206.93	204.92	-2.01
MSB 43TA	49281.80	107275.80	35.00	40.30	204.28	201.93	-2.35
MSB 47TA	52219.00	106987.70	50.10	55.10	217.95	211.30	-6.65
MSB 54TA	52985.80	108446.30	75.30	80.90	220.81	216.23	-4.58
MSB 55TA	52014.70	108322.80	86.20	91.60	215.37	212.52	-2.85
MSB 66TA	51096.70	105842.60	30.80	35.50	207.63	205.29	-2.34
MSB 69TA	52418.40	107772.50	74.60	80.30	216.86	213.22	-3.64
MSB 77TA	54208.90	107053.80	77.60	82.90	222.84	218.76	-4.08
MSB 82TA	51964.20	107525.70	88.40	93.80	215.72	211.22	-4.50
MSB 83TA	52410.90	108416.30	70.20	75.70	216.87	214.08	-2.79
MSB 85TA	53137.20	107831.20	82.80	88.20	222.33	215.93	-6.40
IDP 3A	37781.10	85104.30	-86.70	-81.30	167.95	167.40	-0.55
P 28A	55487.90	79275.20	-57.60	-46.80	176.85	177.47	0.62
P 28TD	55500.20	79293.50	-223.10	-212.20	176.84	177.47	0.63
P 28TE	55514.80	79296.40	-133.90	-123.10	176.91	177.49	0.58
P 29A	42751.60	86466.50	-48.10	-37.30	171.14	172.81	1.67
P 30TC	57117.50	98976.30	-105.20	-94.50	209.48	210.48	1.00
P 30TD	57121.60	98991.20	4.50	15.30	209.69	210.52	0.83

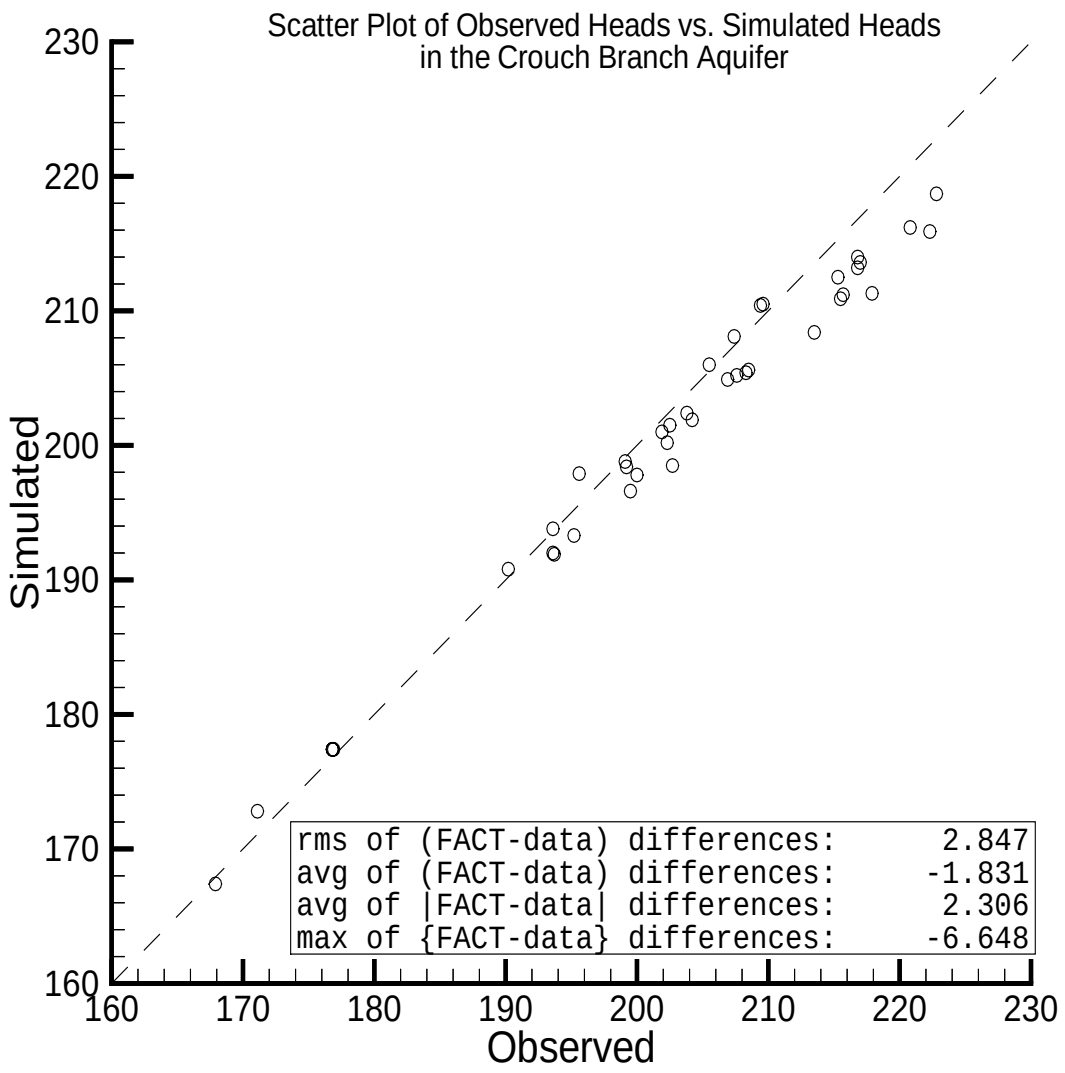


Figure 80: Scatter Plot of the Observed Heads vs. the Simulated Heads for the Monitoring Wells in the Crouch Branch Aquifer.

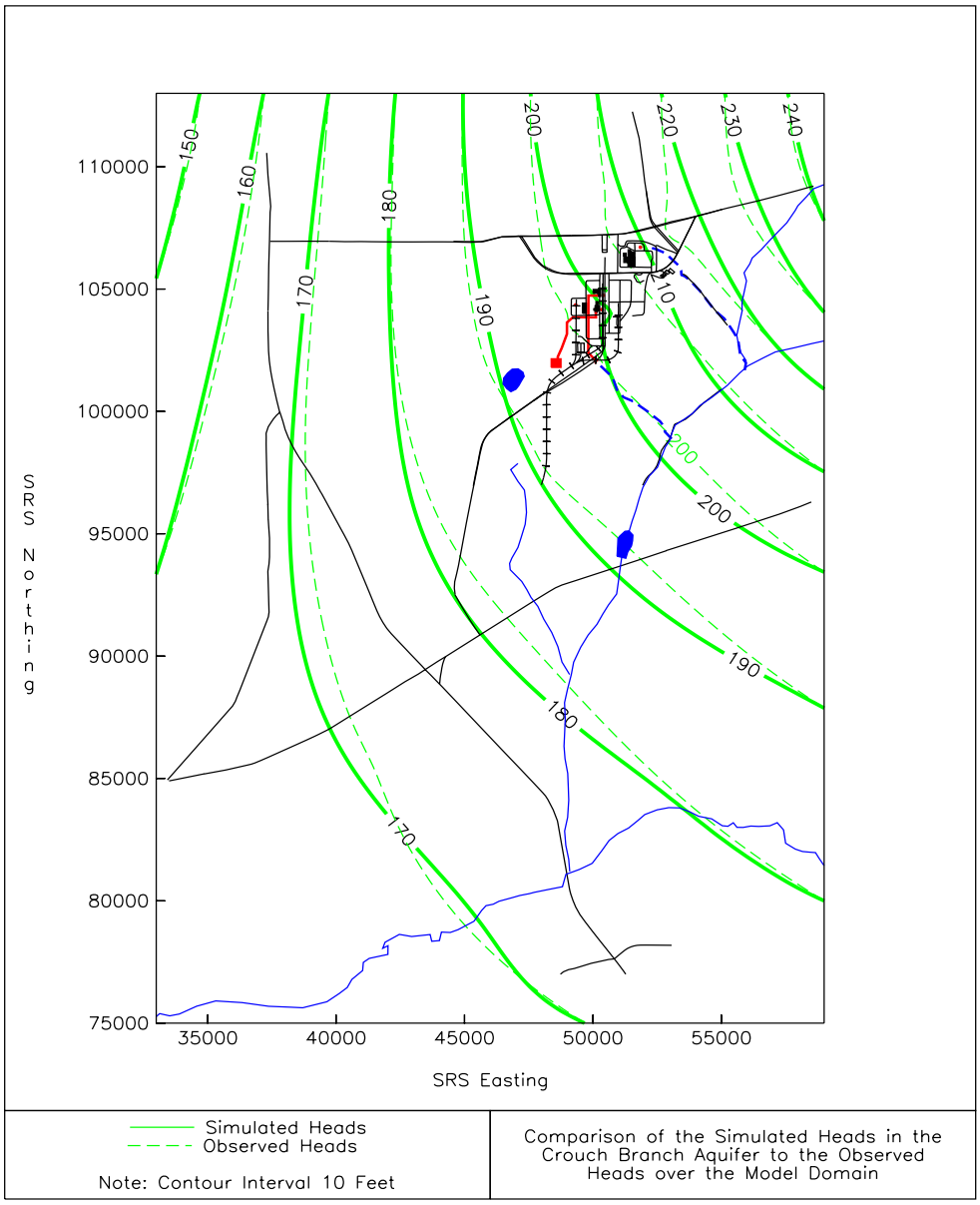


Figure 81: Comparison of the Simulated Heads in the Crouch Branch Aquifer to the Observed Heads over the Model Domain.

method for assessing the adequacy of the model with respect to the intended function. The sensitivity analysis is performed by systematically varying specific properties (model inputs) over an accepted range. The goal of the sensitivity analysis is to identify those parameters that have the greatest impact on the degree of calibration and on the conclusions of the modeling analysis. The process of performing a sensitivity analysis is straight forward. First those model inputs are identified that should have the most significant effect on the calibration and subsequent conclusions. These parameters are then systematically varied over a specified range and executed within the model. The results of various simulations are then examined to determine the effect of each parameter on the models calibration.

Leakance of the McQueen Branch Confining Unit The leakance, K_v/t, associated with the McQueen Branch Confining Unit was varied over several orders of magnitude to assess the influence of this parameter on the model calibration. This parameter controls the magnitude of vertical flow across the McQueen Branch Confining Unit. During the sensitivity analysis the leakance parameter was varied over the range from 1.0x10^{-8} to 1.0x10^{-1} $1/day$. The leakance value of 1.0x10^{-8} $1/day$ approaches a no-flow condition while the upper limit of 1.0x10^{-1} $1/day$ approaches conditions similar to the Dirichlet or constant head. The results of this analysis are presented in Figure 82. As presented in this figure the magnitude of the leakance has a minimal effect on either the RMS or the maximum residual for leakance values less than 10^{-4}. For leakance value greater than this the RMS residual decreases slightly and then increases along with the maximum residual. The leakance value of 1.0x10^{-6} $1/day$ was incorporated in the model and is in the region where neither the RMS or the maximum residual is effected. This value is in agreement with previous modeling investigations and hydrogeologic investigations.

Crouch Branch Aquifer The transmissivity, K_h/t, of the Crouch Branch Aquifer was varied to determine the effect of this parameter on model calibration. In this analysis the transmissivity was varied systematically over the range of 500 to 50,000 ft^2/day with the RMS and maximum residual examined. The transmissivity effects the rate at which water flows through the Crouch Branch Aquifer directly effecting travel times. Mounding occurs when the value is to low, and groundwater velocities become large when the value is to high. Selection of high transmissivity values will over estimate capture zones. The results of this analysis are presented in Figure 83. As presented in this figure the selection of the transmissivity value has an effect on both the RMS and maximum residual for transmissivity values less than 7,500 ft^2/day. The calibrated transmissivity value of 8,125 ft^2/day incorporated in the model is at the limit of changes associated with the RMS and maximum residual and as previously discussed is slightly higher than the value used in previous modeling activities. It is feasible that the transmissivity value may be even higher than that incorporated. This is based upon a cursory review of historical heads for monitoring wells around the operating production wells. During the course of this review there were no significant fluctuations observed in water elevations that could be attributed with operation of the production wells. This could indicate a higher transmissivity value than that incorporated.

Leakance From the Steed Pond to the Crouch Branch Confining Unit The leakance, K_v/t, associated with the Crouch Branch Confining Unit was varied over several orders of magnitude to assess the influence of this parameter on the model calibration. This parameter is one of the most important parameters in the model as it controls the groundwater flow from the Tertiary to the Cretaceous sediments. During the sensitivity analysis the leakance parameter was varied over the range from 1.0x10^{-8} to 1.0x10^{-1} $1/day$. The results of this analysis are presented in Figure 84. As presented in this figure the magnitude of this parameter has a dramatic effect on both the RMS and the maximum residual for values less than 10^{-4}. In this region the RMS residual reaches a minimum value. A leakance value of 6.75x10^{-4} $1/day$ was incorporated in the model.

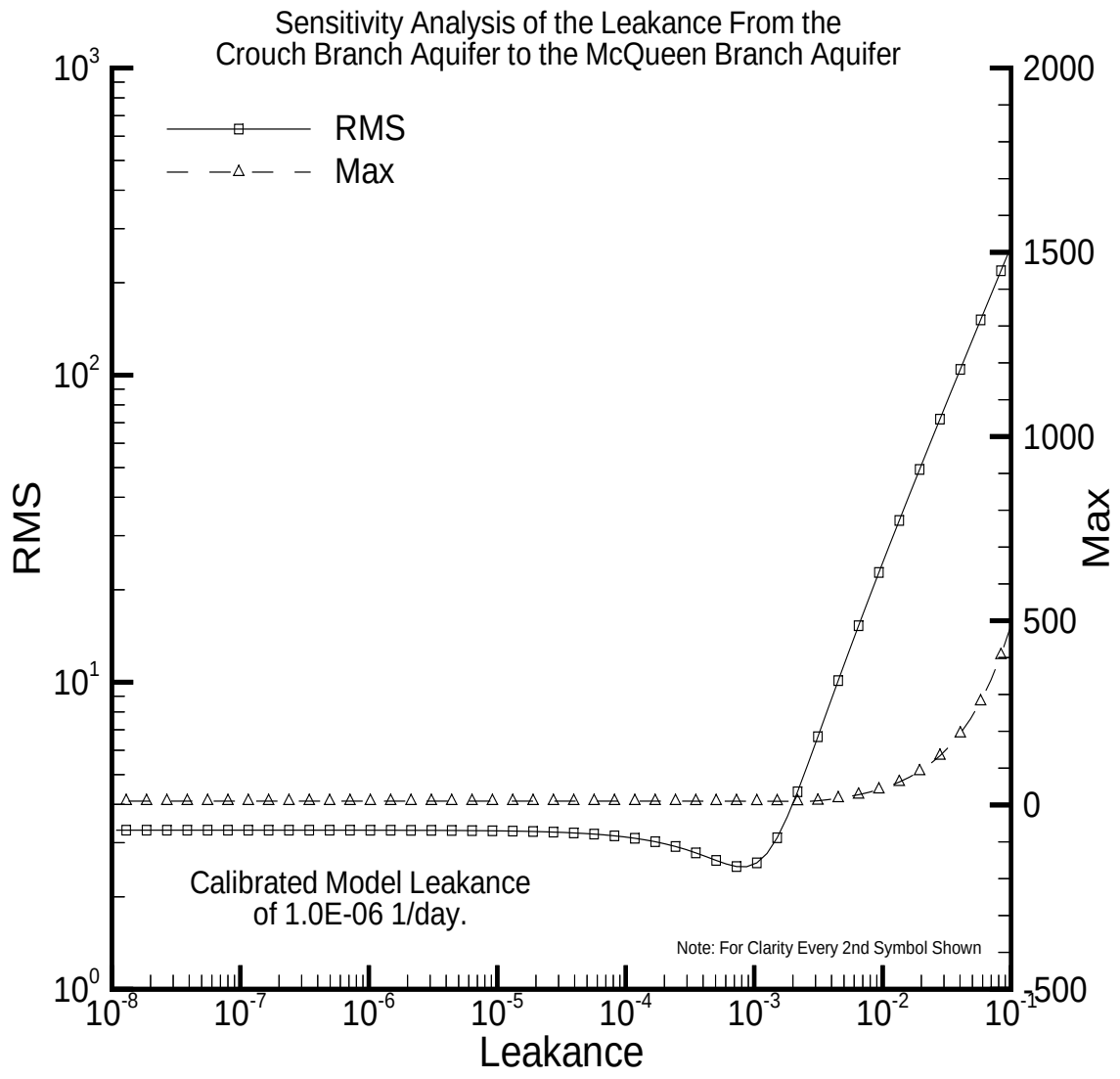


Figure 82: RMS and Maximum Residuals as a Result of the Sensitivity Analysis of the Leakance from the Crouch Branch Aquifer to the McQueen Branch Aquifer.

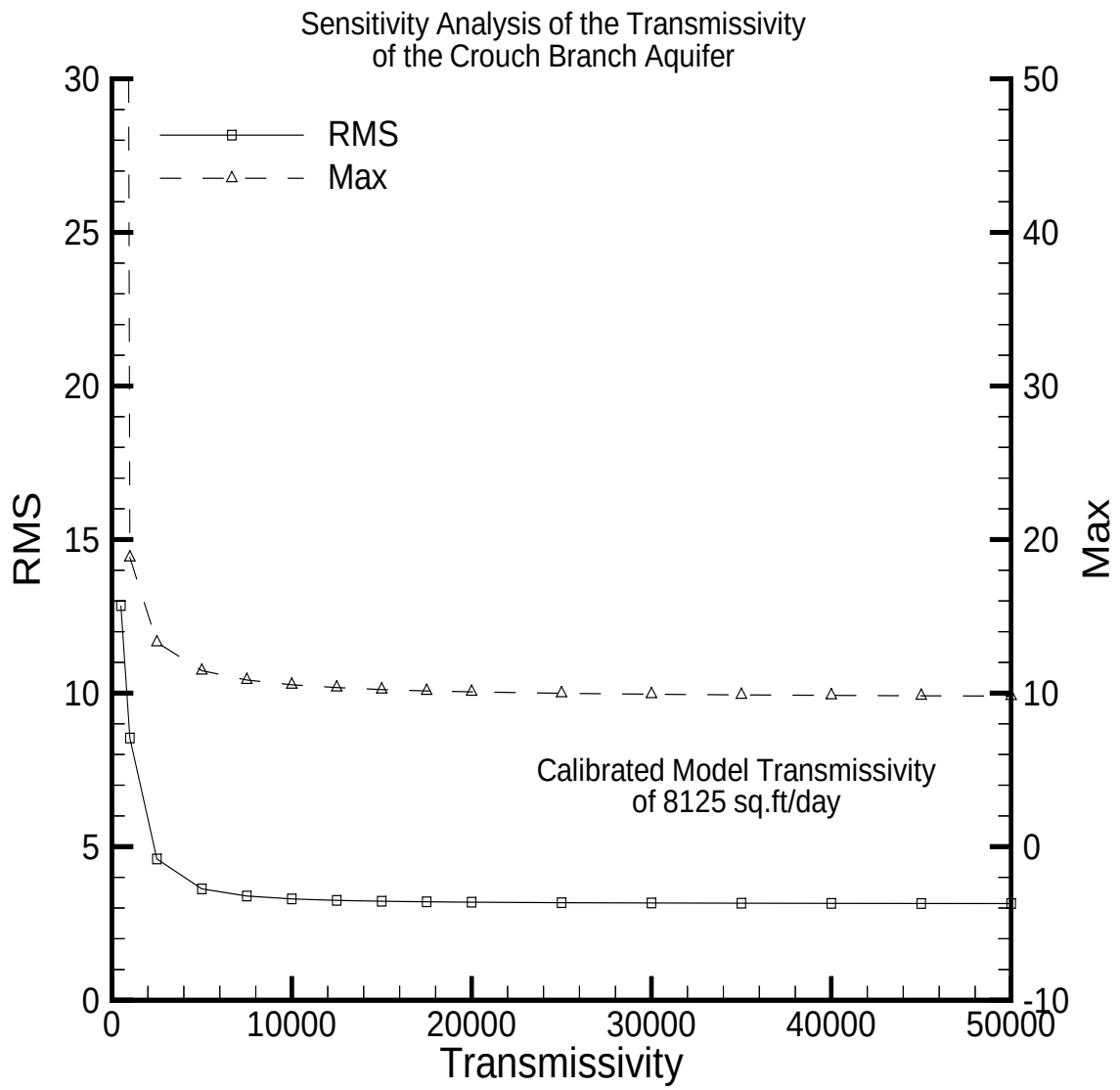


Figure 83: RMS and Maximum Residuals as a Result of the Sensitivity Analysis of the Transmissivity of the Crouch Branch Aquifer.

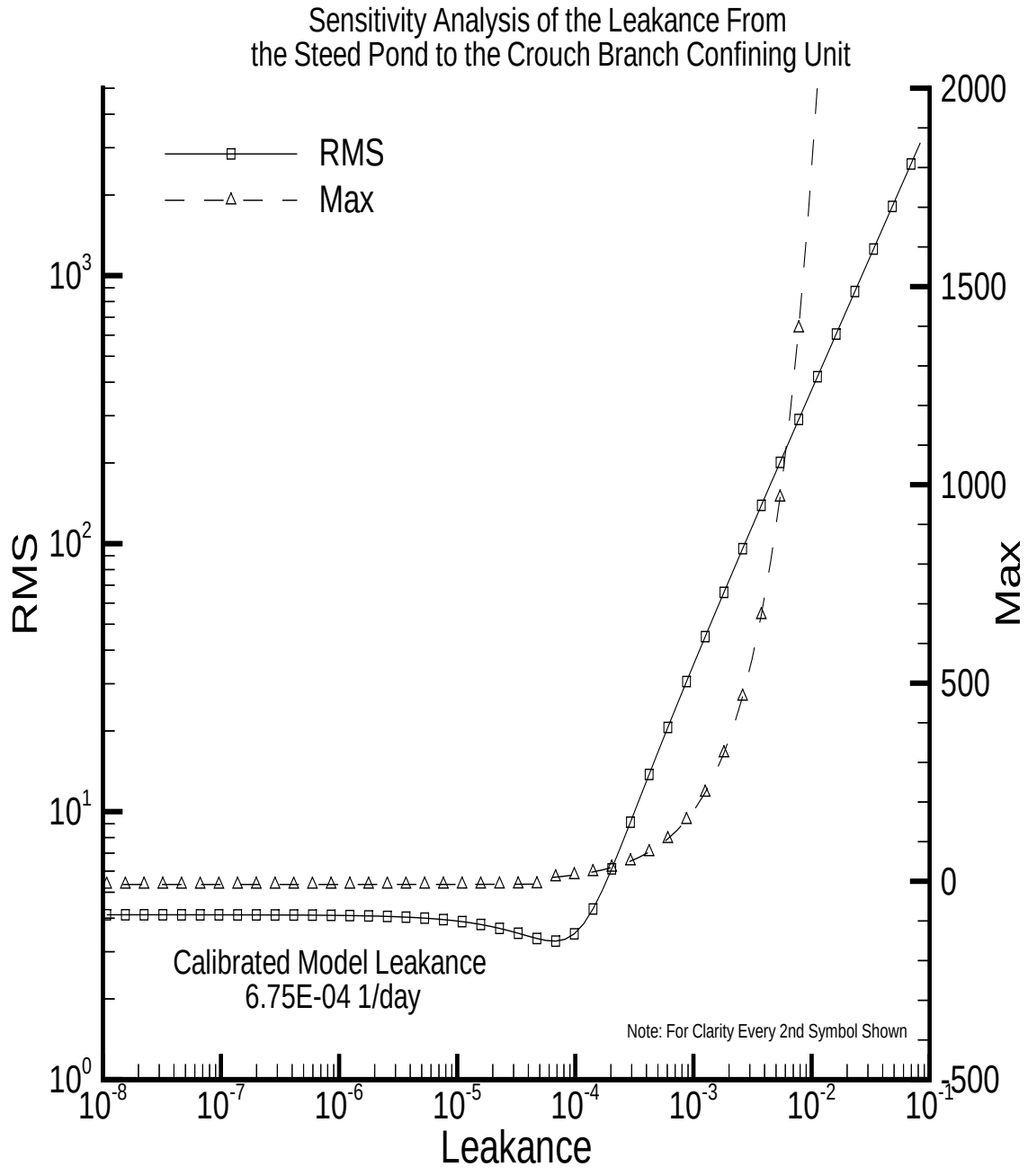


Figure 84: RMS and Maximum Residuals as a Result of the Sensitivity Analysis of the Leakance from the Steed Pond to the Crouch Branch Confining Unit.

6.3.3 Predictive Simulations

The pumping effects associated with production wells 905-20A, 905-53A, and 905-68A were incorporated into the developed model using FACT's steady state well boundary condition. By specifying the areal and vertical siting information of each screen section with the extraction flux, FACT calculates the appropriate flux values that are to be assigned to each node necessary to simulate the performance of the well. Since the production wells are screened in both the Crouch Branch and the McQueen Branch Aquifers the extraction flux from each aquifer was estimated assuming a uniform distribution per length of screen. The capture zone for each system was analyzed using reverse particle tracking techniques to identify the 0-5, 5-15, and 15-30 year capture zones. The purpose of the analysis is to identify regions where the production wells provide plume control and containment within the Crouch Branch Aquifer and to provide an insight on any additional remediation needs. Since production wells 905-15A and 905-30A are no longer active they were not included in the simulation and production well 905-82A is located outside the vertical domain in the McQueen Branch Aquifer.

Particle tracking is completed by simulating the backward paths of a distribution of particles emanating from a region encompassing each of the production wells. The analysis employs a Runge-Kutta (Press et al., 1992) integration algorithm for the calculation of particle tracks. This technique creates particle tracks by moving in a series of increments in the direction opposite of the local velocity field. This method allows determination of the hydrologic control of a plume and estimation of the region of water that is recovered by the network during a specific time period. For this analysis, the particle tracking method incorporated advection transport only and does not account for mechanical dispersion, retardation, or bioremediation. The analysis investigated several different scenarios of production well operation. These scenarios include:

1. The operation of production well 905-20A at 500 gpm and the operation of production well 905-53A at 750 gpm.
2. The operation of production well 905-20A at 1000 gpm and the operation of production well 905-53A at 1500 gpm.
3. The operation of production well 905-20A at 1000 gpm.
4. The operation of production well 905-53A at 1500 gpm.

Scenario #1 represents the pumping conditions used in the development of the numerical model. By allocating 50% of the design flowrates from 905-20A and 905-53A, simulations representing current operating conditions can be performed without resorting to transient calibration techniques. Scenario #2 serves to identify the zone of capture associated with historical production well operations. Scenarios #3 and #4 serve to identify the zone of capture associated with the current mode of operation in which only one of the two wells are operated to provide service water needs in the A/M Area. Consideration of the information from these two scenarios will be useful in the event that water demands in A/M Area decrease even more. It is noted that the various scenarios are designated by the capacity of the well at the wellhead. In each scenario these values are portioned from both the McQueen Branch and the Crouch Branch Aquifers as previously discussed. All model simulations used the appropriate flux values previously presented in Table 10.

Capture Zone of 905-20A and 905-53A at 50% Capacity The current model of the Crouch Branch Aquifer was developed and calibrated based upon the operation of production wells 905-20A and 905-53A at 50% of their design capacity. The current operating scheme for these wells is to have one well operating with the other in a standby mode. Simulations at 50% of design capacity are the most accurate scenario to represent this scheme without resorting to transient calibration techniques. The simulated heads resulting from this scenario were previously presented in Figure 81 along with the observed heads.

Figure 85 presents the zone of capture in the Crouch Branch Aquifer that is associated with this mode of operation.

Capture Zone of 905-20A and 905-53A at 100% Capacity In addition to the capture zone representing current operational conditions, capture zones were also developed based upon production well 905-20A and 905-53A operating jointly at 100% of capacity. The results of this operating mode is presented in Figure 86 along with the simulated heads. As shown in this figure the effective capture zone is much larger than that presented in Figure 85 and is a direct result of the increase in extraction flux.

Capture Zone of 905-20A at 100% Capacity The capture zone associated with operation of production well 905-20A at 100% of design capacity is presented in Figure 87.

Capture Zone of 905-53A at 100% Capacity The capture zone associated with operation of production well 905-53A at 100% of design capacity is presented in Figure 88.

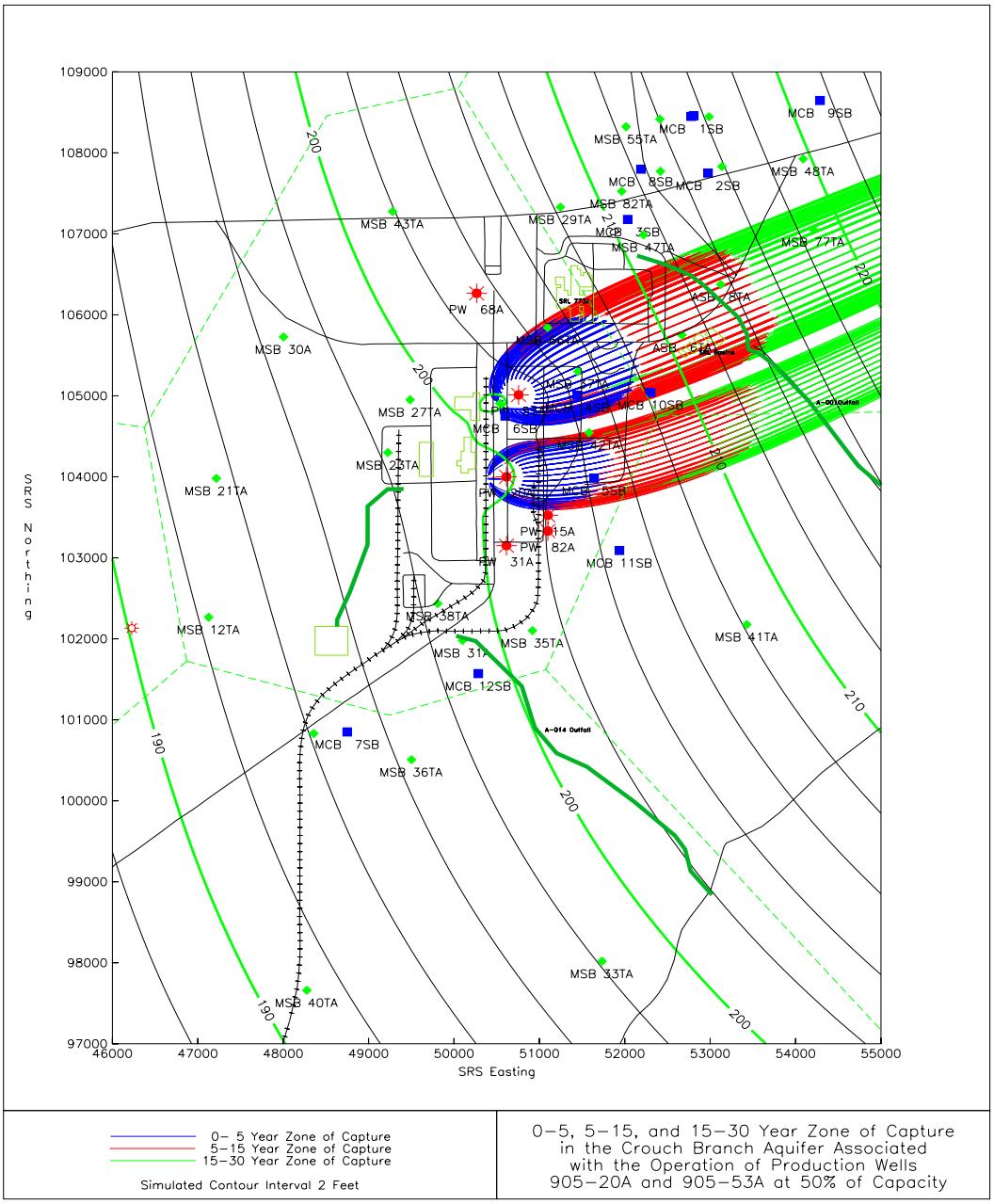
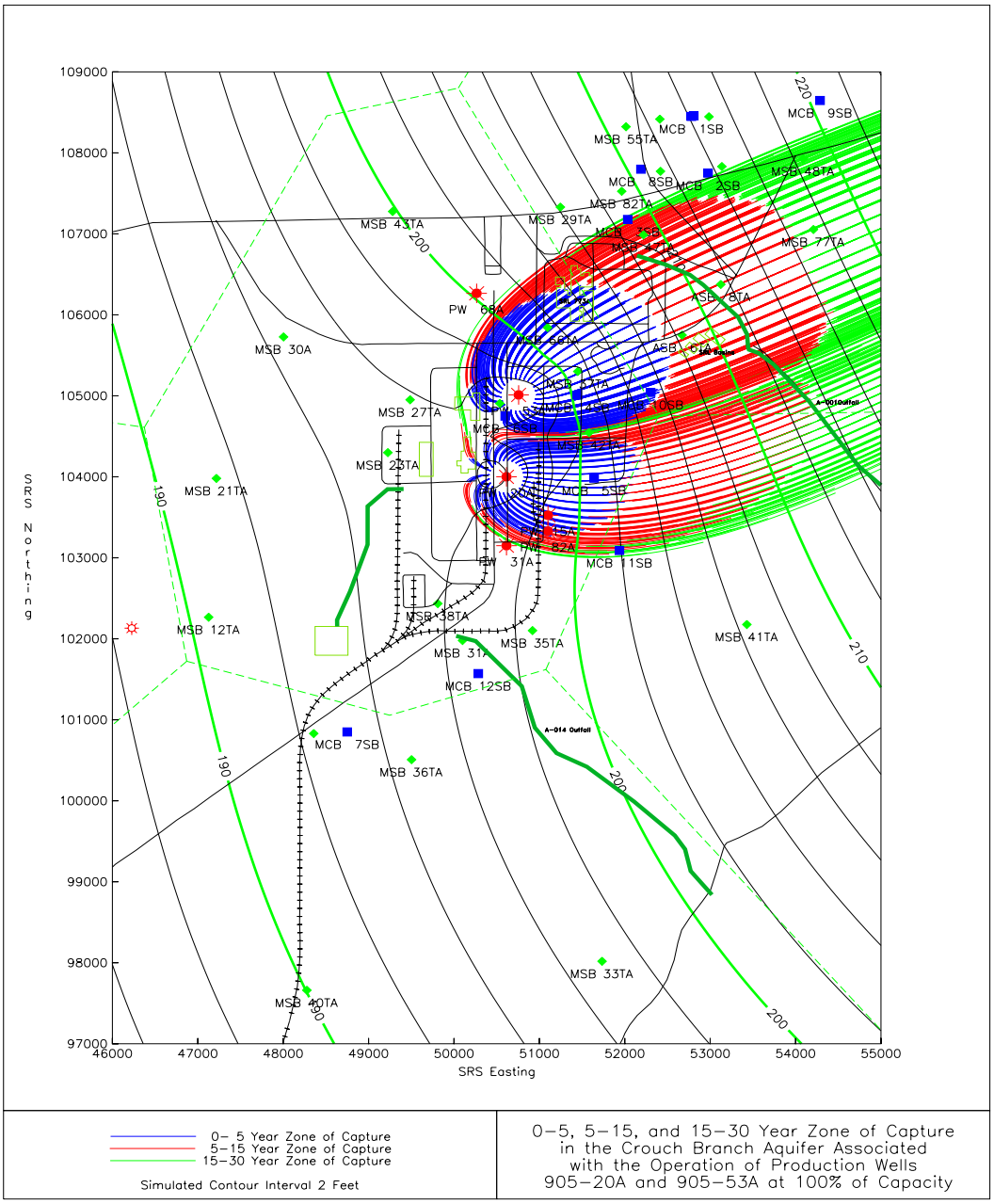


Figure 85: 0-5, 5-15, and 15-30 Year Zone of Capture in the Crouch Branch Aquifer Associated with the Operation of Both Production Well 905-20A and 905-53A at 50% of Capacity.



0– 5 Year Zone of Capture
5–15 Year Zone of Capture
15–30 Year Zone of Capture
Simulated Contour Interval 2 Feet

0–5, 5–15, and 15–30 Year Zone of Capture in the Crouch Branch Aquifer Associated with the Operation of Production Wells 905–20A and 905–53A at 100% of Capacity

Figure 86: 0-5, 5-15, and 15-30 Year Zone of Capture in the Crouch Branch Aquifer Associated with the Operation of Both Production Well 905-20A and 905-53A at 100% of Capacity.

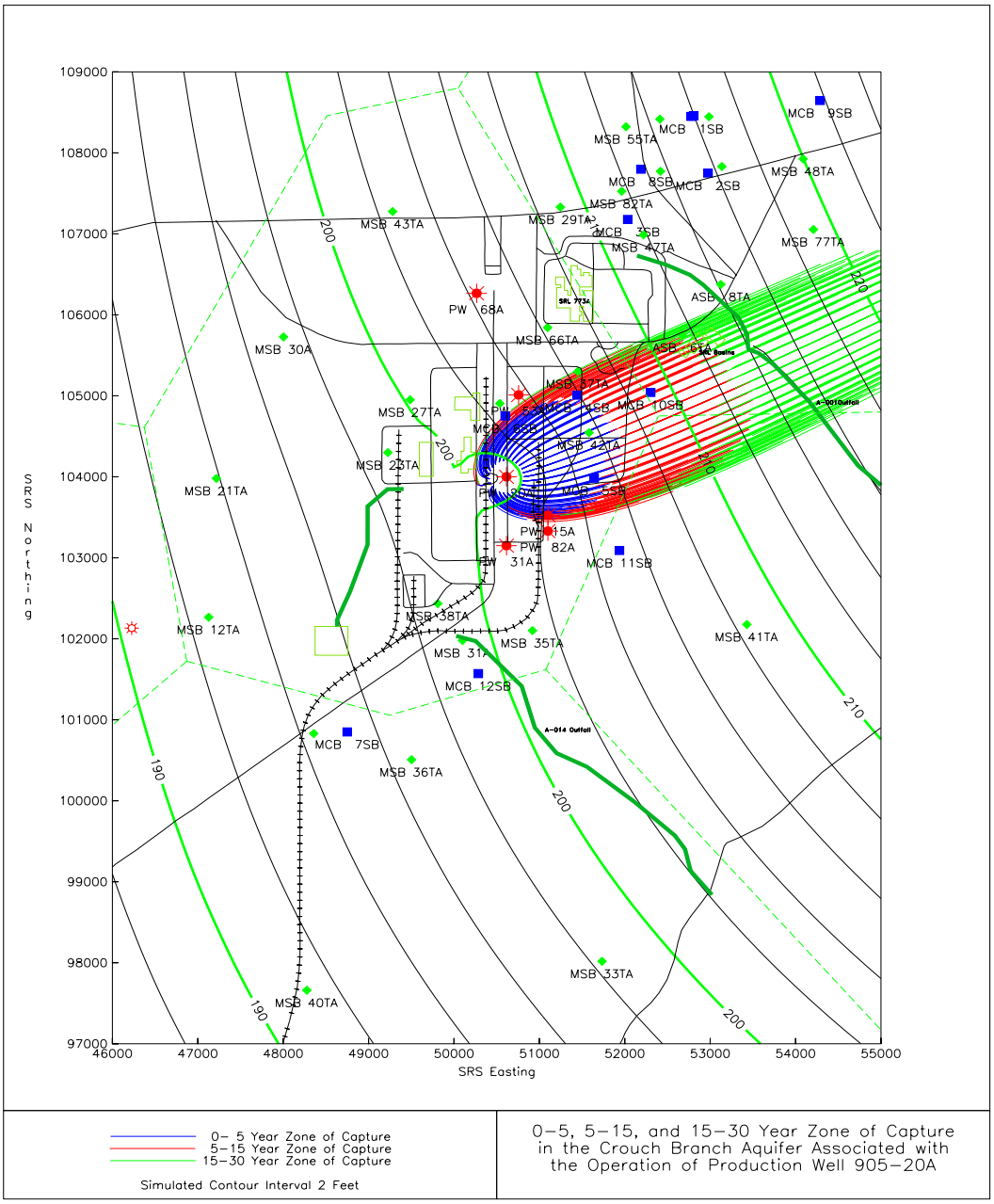


Figure 87: 0-5, 5-15, and 15-30 Year Zone of Capture in the Crouch Branch Aquifer Associated with the Operation of Production Well 905-20A at 100% of Capacity.

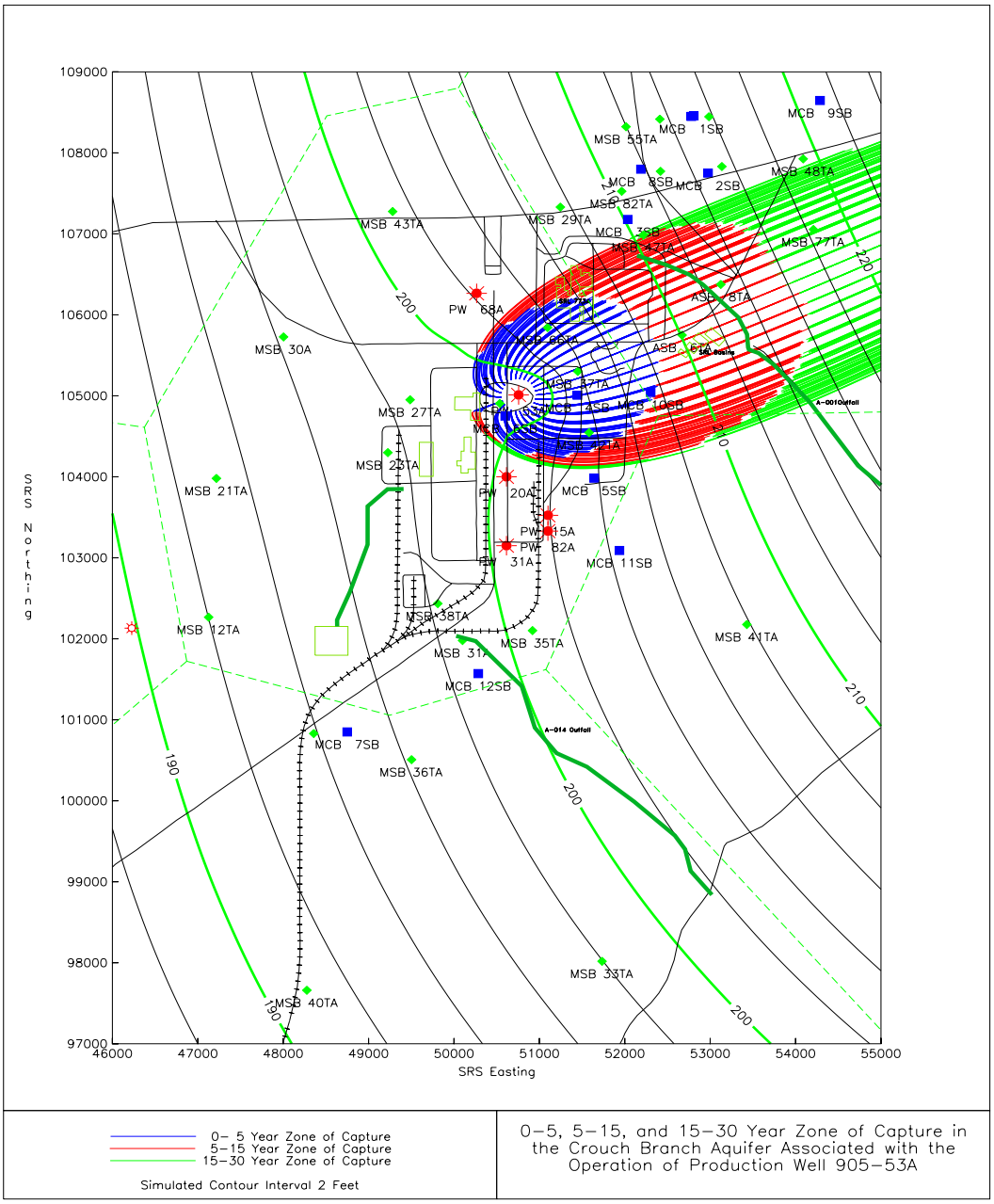


Figure 88: 0-5, 5-15, and 15-30 Year Zone of Capture in the Crouch Branch Aquifer Associated with the Operation of Production Well 905-53A at 100% of Capacity.

7 Results and Discussion

In this section the current distribution of contamination in the Crouch Branch Aquifer is compared with the capture zones obtained by operation of the A/M Area production wells. Prior to the reductions in production well demand that occured in the late 1980's and early 1990's, the wells operating at a high capacity. Figure 89 presents the zone of capture associated with this mode of operation with the 1996 distribution of trichloroethylene in the Crouch Branch Aquifer. As shown in this figure, operation of these production wells at 100% of capacity would result in the containment of a significant portion of the dissolved plume in Crouch Branch Aquifer. As indicated by this figure, historically these wells would have captured a significant portion of the plume that is greater that 100 $\mu g/l$ trichloroethylene. Figure 91 presents that portion of the containment provided from operations of production well 905-53A at 100% of capacity. In a similar manner, Figure 90 presents that portion of the plume captured and contained by only the operation of production well 905-20A at 100% of capacity. From these figures, of the two operating production wells, well 905-53A has a greater contribution to the containment and capture of the plume in the Crouch Branch Aquifer. Unless water supply demands increase in the near term, production well 905-53A should be used as the primary source for process water in the A/M Area. This is based upon the larger amount of screen which is located in the Crouch Branch Aquifer and the fortuitous positioning of the well with respect to the source zone. The current operating mode involves alternating between operation of 905-20A and 905-53A. The effects of this mode of operation is presented in Figure 92.

As evident by the soil core samples reported at the Miscellaneous Chemical Basin a portion of the plume in the Crouch Branch Aquifer is migrating past the effective zone of capture towards the interior of the site with the eventual outcrop in the Crackerneck Swamp and the Savannah River southwest of the A/M Area. As interpreted from the depth discrete samples soil samples reported at the Miscellaneous Chemical Basin the concentration level of this plume is on the order of 50 $\mu g/l$. The plume represents the leading edge of the plume in the Crouch Branch Aquifer is a result of early releases near the SRTC complex and along the A-01 Outfall. The pump & treat operations deployed in the Northern Sector are adequately addressing the source zone remediation in this area. The installation of additional characterization and monitoring at the elevation of the plume along the flowpath towards the Miscellaneous Chemical Basin will allow for the long-term assessment of these systems and future migration in the Crouch Branch Aquifer.

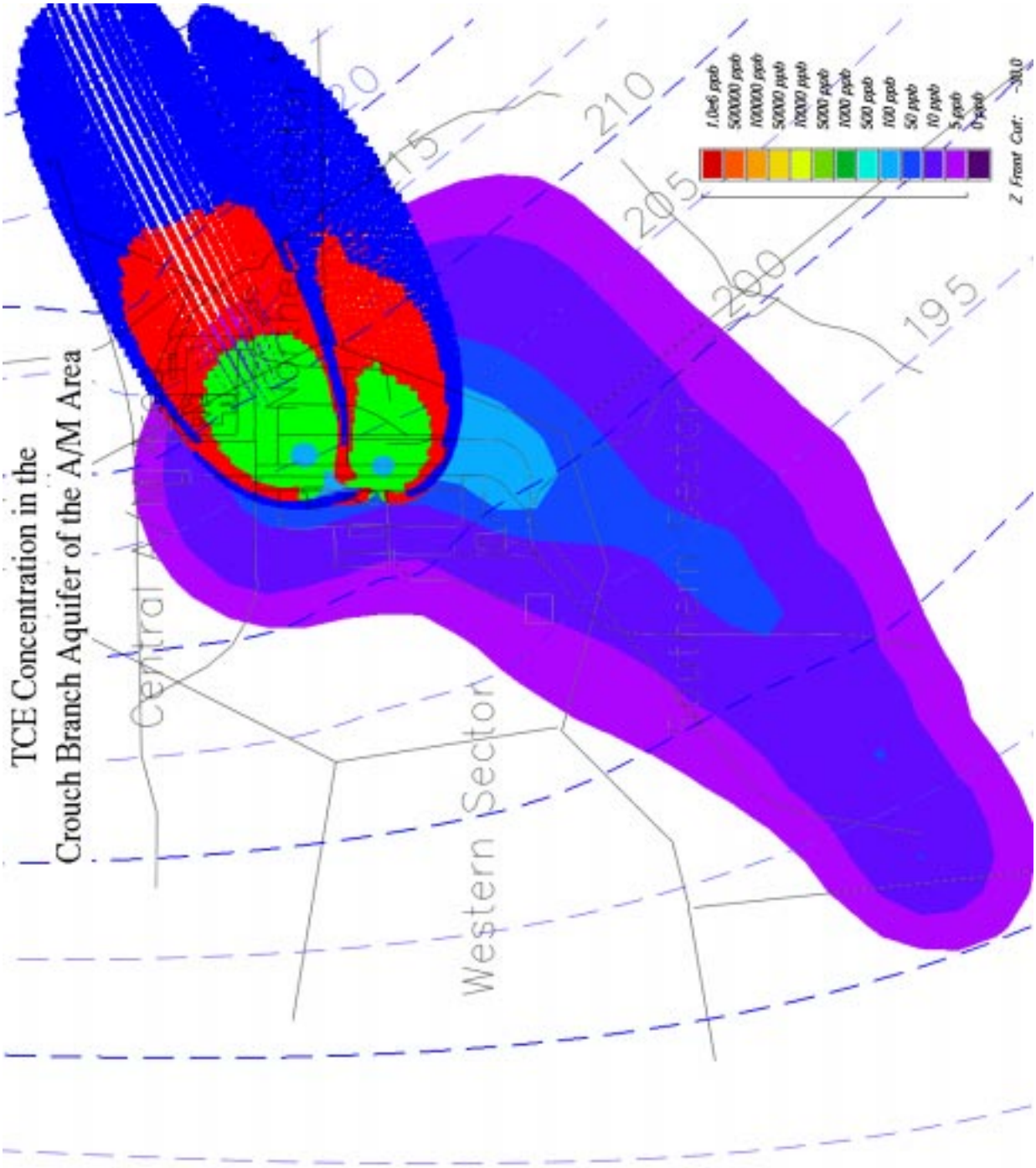


Figure 89: Distribution of Trichloroethylene in the Crouch Branch Aquifer along with the Zone of Capture Associated with Operation of Production Wells 905-20A and 905-53A at 100% of Capacity.

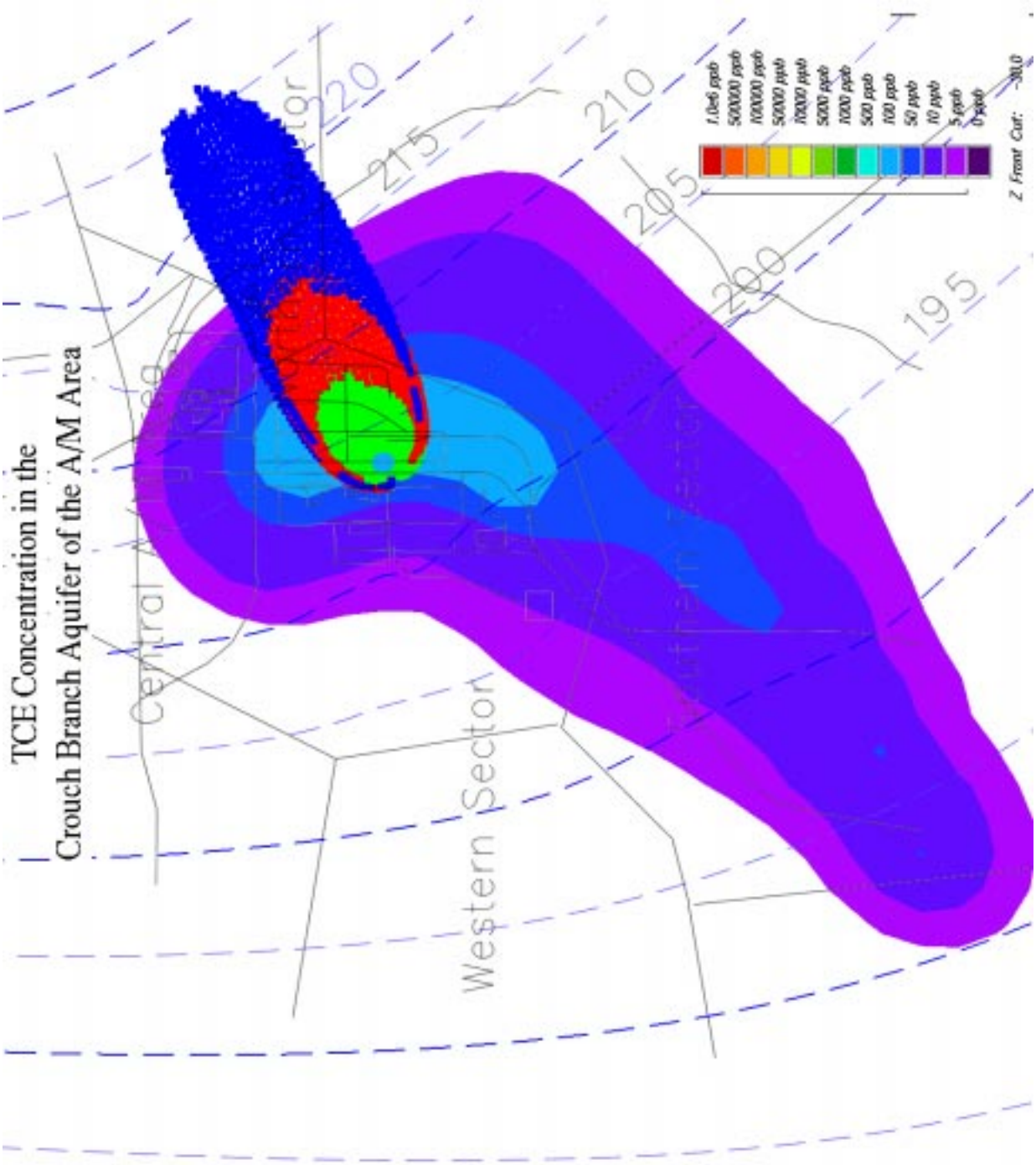


Figure 90: Distribution of Trichloroethylene in the Crouch Branch Aquifer along with the Zone of Capture Associated with Operation of Production Wells 905-20A at 100% of Capacity.

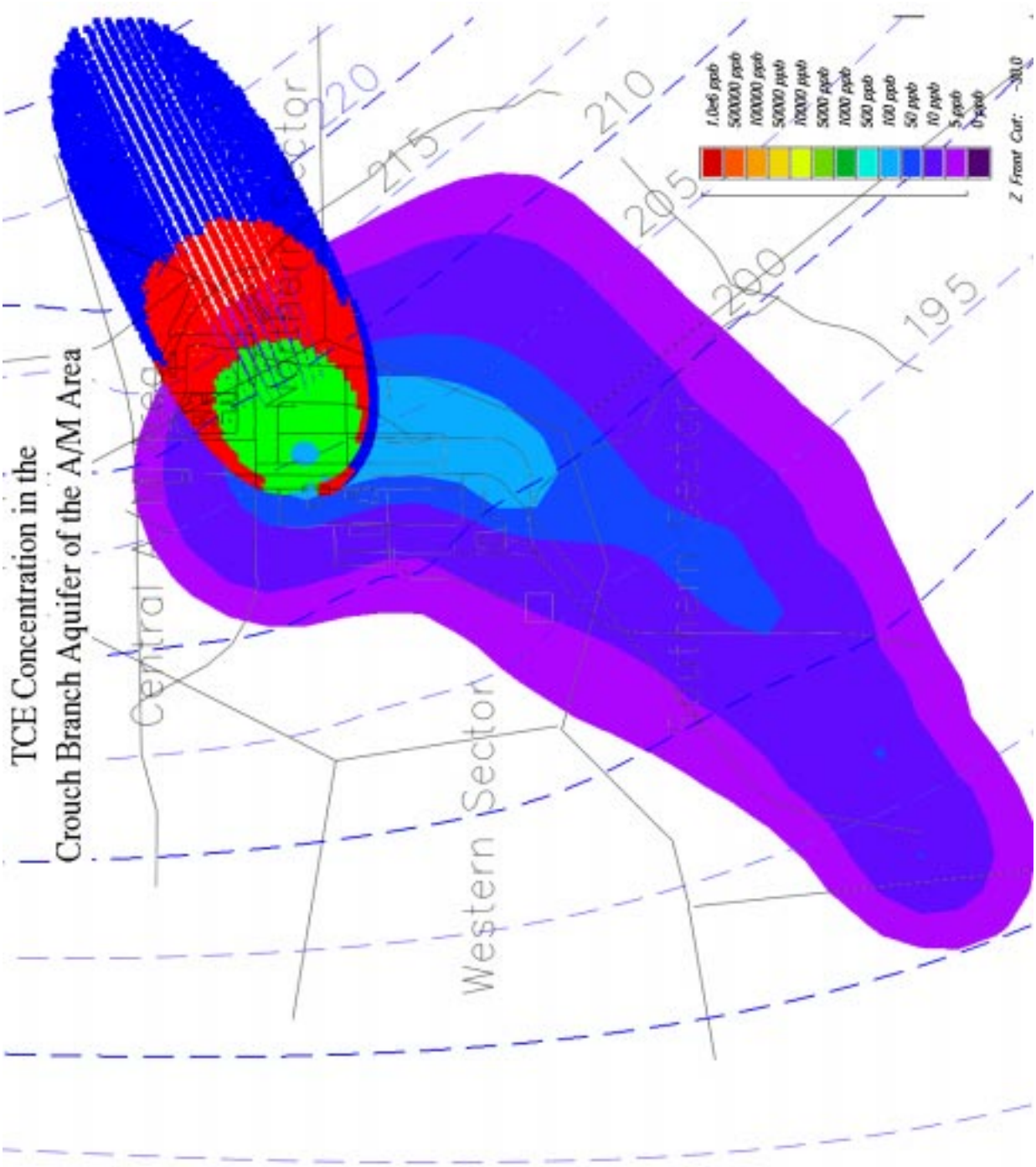


Figure 91: Distribution of Trichloroethylene in the Crouch Branch Aquifer along with the Zone of Capture Associated with Operation of Production Well 905-53A at 100% of Capacity.

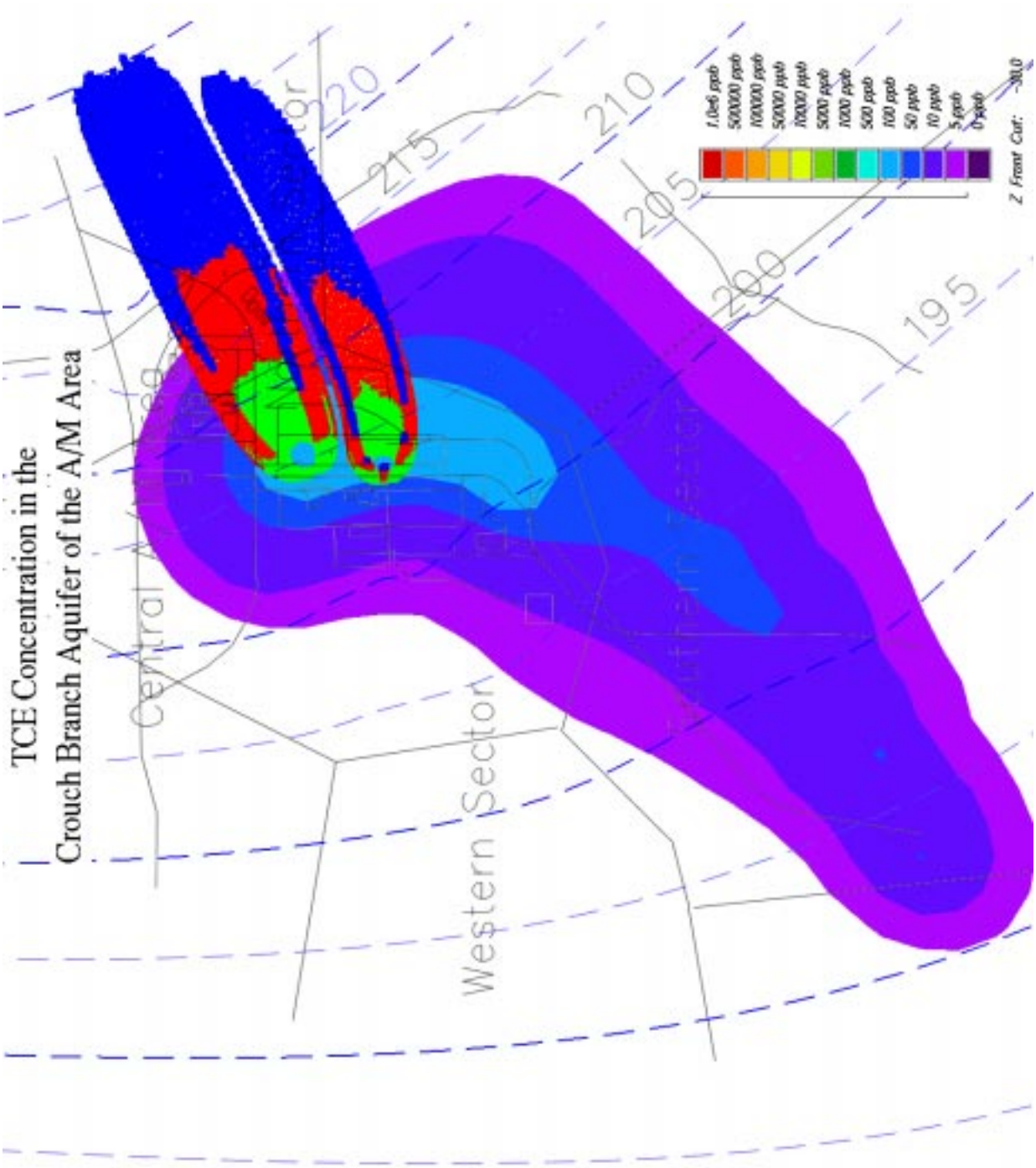


Figure 92: Distribution of Trichloroethylene in the Crouch Branch Aquifer along with the Zone of Capture Associated with Operation of Production Wells 905-20A and 905-53A at 50% of Capacity.

8 Conclusions

As a result of historical releases of chlorinated solvents near the vicinity of the SRTC complex, a plume of dissolved contamination has migrated from the release area into the Crouch Branch Aquifer. This migration is a result of the transitional geology beneath the SRTC complex that has been identified with a facies change in the Crouch Branch Confining Unit. Data from numerous monitoring wells and soil cores throughout the A/M Area indicates that a dissolved plume is migrating from the source area in the Northern Sector southwesterly towards the interior of the Savannah River Site. The plume is located along a distinct horizon in the Crouch Branch Aquifer which is below several of the monitoring wells, resulting in historical reporting of non-detect values. The distribution of chlorinated solvent contamination in the Crouch Branch Aquifer was determined using available data along with an analytical solution to the advective-dispersion equation. These results provide a reasonable estimate of the extent and distribution of chlorinated solvent (primarily trichloroethylene) contamination in the Crouch Branch Aquifer. The distribution of contaminants are controlled by local hydraulic conditions, transitional geology near the source zone, and the effects of the A/M Area production wells. During operational periods these wells have provided a significant amount of containment and control for the aqueous plume. Since 1981 an estimated 6,200 pounds of organic solvents have been removed via operation of the A/M Area production wells. Even though the production wells have had a dramatic effect on the distribution of chlorinated solvents in the Crouch Branch Aquifer, designs aspects have resulted in some downward migration via the wellbore of idle production wells. This has resulted in a small amount of chlorinated solvent migrating into the lower section of the Crouch Branch Aquifer and into the deeper McQueen Branch Aquifer during idle periods. Recent investigations have characterized the magnitude of solvent migration during these idle periods. Modifications and well abandonments were performed to preclude additional migration during idle periods.

Current remediation strategies for the Crouch Branch Aquifer incorporate a pump & treat remediation system in the Northern Sector source zone complemented with mass removal aspects provided by active A/M Area production wells. The long-term effectiveness of this pump & treat system with respect to the Crouch Branch Aquifer will be determined from future concentrations at downgradient monitoring wells and from "bulk" samples collected at production wells. Historical operation of the A/M Area production wells have managed to capture and contain a significant portion of the dissolved plume located in the Crouch Branch Aquifer. Utilization of these wells as process water supply has resulted in the containment of the majority of the plume in the Crouch Branch Aquifer that is greater than 100 $\mu g/l$ trichloroethylene. A portion of the plume has passed south of the zone of capture offered by the production wells and has reached the vicinity of the Miscellaneous Chemical Basin. The magnitude of this plume is less than 100 $\mu g/l$ trichloroethylene and reflects early releases at the SRTC complex and along the A-01 Outfall. Additional characterization and monitoring at the elevation of the plume along this flowpath will allow for the long-term assessment of future migration in the Crouch Branch Aquifer. The continued operation of production wells on an alternating frequency couples with source zone remediation in the Northern Sector provides a cost-effectiveness remediation strategy for the Crouch Branch Aquifer. Any direct remediation within the Crouch Branch Aquifer should target the elevation of the plume and not the entire vertical extent of the aquifer.

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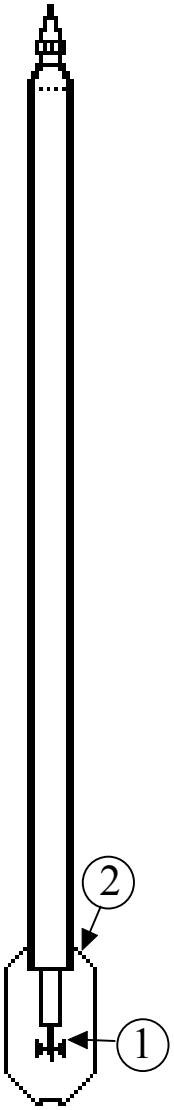
WSRC (1994). A/M Area Crouch Branch (Cretaceous) Aquifer Characterization - Phase II: Soil Coring Report (U). Technical Report WSRC-RP-94-1107, Westinghouse Savannah River Company, Aiken, South Carolina 29808.

WSRC (1997). Extent of A/M Area Vadose Zone Contamination, Monitoring, and Corrective Action (U). Technical Report WSRC-RP-97-0109, Westinghouse Savannah River Company, Aiken, South Carolina 29808.

A Product Description for 9710 Logging Tool

9710 Logging Tool

Product Description



Background Information

Continuous velocity flowmeter logs are used to measure the fluid flow rates in open and cased wells. Logs can be run in the up or down direction; with or without the well producing water. Century's 9710 flowmeter uses a magnetic coupling between the sensing device and the electronics so that borehole fluids can not enter the tool and injected oil is no longer necessary. Internally, a 256-pulse-per-revolution optical encoder records the impeller turns minimizing statistical problems of other tools. With this low friction design, logging speeds of two feet per minute can be achieved for low flow rates of less than 0.32 liters per second (5 gallons per minute). The tool is configured with either a 8.9 cm (3.5 in) or 11.4 cm (4.5 in.) shroud.

Features

Properties Measured (see diagram)

① Flow Propeller
Offset: 134.6 cm. (53 in.)

② Propeller Guard Cage

Tool Specifications

Length: 152.4 cm (60 in.)

Temperature: 75 C (167 F)

Tool Diameter: 4.1 cm (1.63 in.)

Pressure: 176 kg/cm2 (2500 psi)

Weight: 7.3 kg (16 lbs.)

Logging Speed: 15-18 m/min. (60 ft/min.)

Sensor Response Ranges

Sensor	Response Limits	Accuracy
Flow	0.6 to 60.96 m/min. (2 to 200 ft/min.)	+/- 5%

Accessories

Recommended

8.9 cm (3.5 in.) cage shroud (part # 299711)
7.62 cm (3.0 in.) propellor (part # 299961)
11.4 cm (4.5 in.) cage shroud (part # 299701)
10.16 cm (4.0 in.) propellor (part # 299951)

Part # 299501
Sales Kit # 1450

Specifications subject to change without notice

Document Numbers:
Product Description #238.001
User Guide #320.000
Repair Authorization Form #107.000

Probes

Century Geophysical Corp.
7517 East Pine,
Tulsa, OK 74115 USA
(918) 838-9811

Fax: (918) 838-1532
Fax Back: (918) 838-0652
BBS: (918) 838-0649
E-mail: century@ionet.net
http://www.century-geo.com

Primary Calibration Of The Tool

Primary Calibration	Standard	Response Limits
Up or Down Flow	34.8 m/min. (10 ft/min.)	40-60 cps
	152.4 m/min. (50 ft/min.)	250-300 cps

Default Calibrations

The following parameters are sensors and responses are set-up to electronic bench testing specifications. Therefore, these "default" calibration numbers may be used to log the tool. The sensors are the following:

NONE

In the calibration file, if the default values of 0 cps equals 0 engineering units are not changed, the tool will then automatically use the default values in the tool module for that tool.

Notes On Logging The 9710 Tool

Usual application for the tool is with a submersible pump installed in the well above the upper-most screened interval. An access pipe is then lowered past the pump for logging the flowmeter through the production zone.

The recommended logging for the tool is to make two consecutive runs of the tool in the downward direction against the upward flow of the well. With the well pumping, the spinner rate will increase through a producing zone. Scaling the log should be such that maximum deflection should equal 100% of the fluid volume. Stationary checks can also be made at specific depths, recommended locations would be at the 100% and 0% flow points, and through the zone of interest.

In some open hole situations with multiple aquifers, there will be a difference between formation head pressures. This will cause flow within the well. The flow meter can be run in both the downwards and upwards directions. Logging in the down direction, the blade rotation will increase through the flow area, while logging in the upwards direction, the blade will slow down through the zone. Combining these two plots will show the zone of flow.

Tool calibration is dependent on pitch and size of the spinner blades, hole size, and viscosity of the fluids measured. Therefore, downhole calibration of the tool is recommended. This is done by logging the tool through an unscreened cased portion of the well at widely different cable speeds with the well producing. Since the tool response is linear, a graph of line speed vs. response can be made. Also, using the Compu-Log system, a two-point calibration can be done so that recorded logs in feet or meters per minute can be achieved. These calibrated logs will then show both the contribution of line speed in feet or meters per minute, and fluid contribution. A run at 9.14 m/min. (30 ft/min.) would then show a continuous 9.14 m/min. (30 ft/min.) response through a zone with NO Flow. Additionally, a zone that shows 27.43 m/min. (90 ft/min.) would be getting 1/3 of its response due to line speed and 2/3 of its response from the well fluids.

Century GEOPHYSICAL CORP.

7517 East Pine,
Tulsa, OK 74115 USA
(918) 838-9811

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Fax Back: (918) 838-0652
BBS: (918) 838-0649
E-mail: century@ionet.net
http://www.century-geo.com

B Data Sheet for Kemmerer Sample Bottle

C Manufacturer Data for Production Well Packers

905-53A: Baski Serial #18367/6655.1,18368/5566.2

905-20A: Baski Serial #18369/5581.2,18370/5581.1

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BASKI, Inc.
1586 South Robb Way
Denver, Colorado, 80232
Phone: 1-303-789-1200 or 1-800-55-BASKI

D Manufacturer Data for Production Well Check Valves

E Analytical Reports from Production Well Samples

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================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\001F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  02:55 PM            Vial Number     :
Sample Name      : 0 ppb (blank)                  Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\001F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.034         182783          45821  BV     0.059     94.9739
      2     2.593           1843            444  VB     0.062      0.9578
      3     3.281           5125            436  PV     0.150      2.6631
      4     7.330            809            116  BV     0.094      0.4202
      5    19.732           1896             91  BV     0.267      0.9850

Total area = 192456

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\001R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  02:55 PM            Vial Number     :
Sample Name      : 0 ppb (blank)                  Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\001R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.010            317             137  BB     0.034    100.0000

Total area = 317

================================================================================

================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\002F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
```

```
Acquired on      : 27 May 96  03:24 PM           Vial Number     :
Sample Name      : 3 ppb std                     Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\002F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.065         211955          47017  BV     0.067      8.2621
      2     2.626           1981            560  PV     0.055      0.0772
      3     3.314           9071           1834  BV     0.074      0.3536
      4     3.510           6898           1364  VB     0.077      0.2689
      5     4.763            795            149  BB     0.075      0.0310
      6     5.280         164936          20925  BV     0.122      6.4293
      7     5.661         854913         108799  VB     0.123     33.3248
      8     7.390         299776          35688  BB     0.129     11.6854
      9    12.558        1014483         141704  BB     0.112     39.5449
     10    19.747            586             35  VB     0.214      0.0229

Total area = 2565394

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================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\002R0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  03:24 PM           Vial Number     :
Sample Name      : 3 ppb std                     Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\002R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.041            346            129  BB     0.044      1.5690
      2     2.343          21725           2077  BB     0.132     98.4310

Total area = 22071

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\003F0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  03:52 PM           Vial Number     :
```

```
Sample Name      : 5 ppb std                      Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\003F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.064         208652          46308  BV     0.067      6.0028
      2     2.624           1708            498  PV     0.054      0.0491
      3     2.839            592            164  PV     0.057      0.0170
      4     3.312          14152           2901  BV     0.074      0.4071
      5     3.509          10605           2116  VB     0.076      0.3051
      6     4.766           1192            214  BB     0.082      0.0343
      7     5.277         250077          31605  BV     0.123      7.1946
      8     5.659        1225676         153444  VB     0.125     35.2623
      9     7.387         444888          51877  BB     0.132     12.7993
     10    12.555        1318344         181935  BB     0.114     37.9283

Total area = 3475887

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\003R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  03:52 PM            Vial Number     :
Sample Name      : 5 ppb std                      Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\003R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.040            361            134  BB     0.041      1.0757
      2     2.326          33238           4181  BB     0.102     98.9243

Total area = 33600

================================================================================
================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\004F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  04:21 PM            Vial Number     :
Sample Name      : 10 ppb std                     Injection Number: 1
```

```
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\004F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.064         205657          45700  BV     0.066      3.3328
      2     2.622           1291            404  PV     0.052      0.0209
      3     2.838            857            206  PV     0.066      0.0139
      4     2.973           1073            229  VV     0.067      0.0174
      5     3.310          27522           5093  VV     0.080      0.4460
      6     3.507          24972           4237  VV     0.086      0.4047
      7     4.761          12962            408  VB     0.388      0.2101
      8     5.275         459852          57759  BV     0.123      7.4521
      9     5.657        2249720         275092  VB     0.128     36.4579
     10     7.383         818007          93789  BB     0.134     13.2562
     11    12.552        2368815         318962  PB     0.116     38.3879

Total area = 6170728

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\004R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  04:21 PM            Vial Number     :
Sample Name      : 10 ppb std                     Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\004R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.041            353            129  BB     0.043      0.5394
      2     2.307          65048          11752  BV     0.073     99.4606

Total area = 65401

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\005F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  04:49 PM            Vial Number     :
Sample Name      : 50 ppb std                     Injection Number: 1
```

```
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\005F0101.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.064	205378	45484	BV	0.067	0.8484
2	2.623	1311	411	VV	0.051	0.0054
3	2.838	1104	274	PV	0.065	0.0046
4	2.971	5210	1207	VV	0.067	0.0215
5	3.310	76187	16041	PV	0.072	0.3147
6	3.506	79744	15512	VB	0.077	0.3294
7	4.762	8522	1492	VB	0.089	0.0352
8	5.275	1736979	216231	BV	0.124	7.1751
9	5.657	9078406	1121146	VB	0.123	37.5012
10	7.382	3049180	341205	BV	0.136	12.5956
11	8.550	6370	354	VB	0.228	0.0263
12	11.912	1434	161	BV	0.125	0.0059
13	12.165	1006	172	VV	0.098	0.0042
14	12.271	1414	234	VV	0.093	0.0058
15	12.551	9953381	1402070	VV	0.106	41.1155
16	15.186	1848	179	VB	0.139	0.0076
17	18.998	110	17	BV	0.112	0.0005
18	19.941	731	16	PBA	0.766	0.0030

```
Total area = 2.42083E+007

==============================================================================
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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\005R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  04:49 PM            Vial Number     :
Sample Name      : 50 ppb std                     Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\005R0101.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.040	355	131	BB	0.045	0.1093
2	2.286	319294	84547	BV	0.063	98.3904
3	3.281	786	171	VB	0.065	0.2421
4	3.476	1170	321	BB	0.058	0.3605
5	5.251	1021	151	BB	0.089	0.3146
6	7.353	876	129	BB	0.093	0.2700
7	12.523	1016	166	BB	0.083	0.3132

Total area = 324518

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==========
Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\006F0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 05:18 PM Vial Number :
Sample Name : 100 ppb std Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\006F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.063	197198	44535	BV	0.066	0.3285
2	2.622	1952	598	PV	0.053	0.0033
3	2.838	878	216	PV	0.065	0.0015
4	2.969	13330	2996	VB	0.068	0.0222
5	3.307	132996	27866	BV	0.073	0.2215
6	3.503	146442	28029	VB	0.078	0.2439
7	4.578	839	199	BV	0.068	0.0014
8	4.760	16710	2884	VB	0.090	0.0278
9	5.273	3264581	409054	BV	0.123	5.4379
10	5.672	2.44007E+007	3778397	VV	0.093	40.6448
11	7.377	5513584	625375	PV	0.133	9.1841
12	8.550	9920	570	VB	0.226	0.0165
13	11.909	2229	305	BV	0.111	0.0037
14	12.163	1532	307	PV	0.083	0.0026
15	12.267	2579	413	VV	0.097	0.0043
16	12.575	2.62295E+007	3778134	VB	0.106	43.6911
17	15.188	1140	194	BV	0.095	0.0019
18	17.996	9577	552	BV	0.225	0.0160
19	18.476	25671	1238	VV	0.276	0.0428
20	18.853	22980	1461	VV	0.213	0.0383
21	19.114	21059	1699	VV	0.175	0.0351
22	19.351	14391	1451	VV	0.146	0.0240
23	19.554	3508	432	VV	0.122	0.0058
24	19.943	689	312	PBA	0.037	0.0011

Total area = 6.00341E+007

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Area Percent Report
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```
Data File Name   : C:\HPCHEM\3\DATA\053096J\006R0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  05:18 PM          Vial Number     :
Sample Name      : 100 ppb std                  Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\006R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.040           331            126  BB     0.043      0.0519
      2     2.281        626027         174680  BV     0.054     98.1695
      3     3.278          2056            374  VV     0.077      0.3224
      4     3.474          2870            711  VB     0.061      0.4501
      5     5.252          2194            312  BB     0.107      0.3441
      6     7.349          1983            275  BB     0.095      0.3110
      7    12.519          2239            347  BB     0.094      0.3511

Total area = 637700

================================================================================
================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\007F0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  05:46 PM          Vial Number     :
Sample Name      : 250 ppb std                  Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\007F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.063        196539          44461  BV     0.065      0.1805
      2     2.312          2593            574  VV     0.069      0.0024
      3     2.622          2410            703  PV     0.055      0.0022
      4     2.837          2355            549  PV     0.067      0.0022
      5     2.968         38005           8291  VV     0.070      0.0349
      6     3.306        276358          57803  PV     0.073      0.2538
      7     3.502        328571          62020  VB     0.079      0.3018
      8     4.573          2092            498  BV     0.066      0.0019
      9     4.760         39966           6759  VV     0.092      0.0367
     10     5.272       7843546        1022670  PV     0.116      7.2035
     11     5.722   4.39499E+007        3779432  VV     0.145     40.3638
     12     7.375   1.38482E+007        1769251  VV     0.114     12.7183
     13     8.546         36666           1495  VB     0.312      0.0337
     14    11.910          5551            812  BV     0.105      0.0051
```

15	12.164	4426	828	PV	0.082	0.0041
16	12.268	6862	1141	VV	0.091	0.0063
17	12.615	4.22876E+007	3778399	VV	0.137	38.8371
18	15.188	9895	839	VB	0.165	0.0091
19	19.127	1557	102	BV	0.190	0.0014
20	19.352	1367	166	VB	0.118	0.0013

Total area = 1.08884E+008

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================================================================================
================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\007R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  05:46 PM            Vial Number     :
Sample Name      : 250 ppb std                    Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 2 in C:\HPCHEM\3\DATA\053096J\007R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.278	1594188	461821	BV	0.054	98.0996
2	3.277	4439	870	VV	0.075	0.2731
3	3.473	7477	1831	VB	0.063	0.4601
4	5.250	5648	809	BB	0.108	0.3476
5	5.628	1192	165	BB	0.111	0.0734
6	7.347	5416	752	BB	0.111	0.3333
7	12.519	6711	1061	BB	0.098	0.4129

Total area = 1625071

```
================================================================================
================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\008F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  06:15 PM            Vial Number     :
Sample Name      : 500 ppb std                    Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 1 in C:\HPCHEM\3\DATA\053096J\008F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %

1	2.063	195715	44074	BV	0.065	0.1320
2	2.311	4168	957	VV	0.067	0.0028
3	2.622	2908	837	PV	0.055	0.0020
4	2.836	4104	944	PV	0.068	0.0028
5	2.967	73544	15608	VV	0.072	0.0496
6	3.305	454663	94830	VV	0.073	0.3067
7	3.501	556508	102917	VV	0.080	0.3754
8	4.573	5677	1031	PV	0.085	0.0038
9	4.759	73278	11942	VV	0.094	0.0494
10	5.272	1.58217E+007	2348984	VV	0.097	10.6729
11	5.742	5.33927E+007	3779757	VV	0.174	36.0173
12	7.409	3.06017E+007	3778922	VV	0.103	20.6431
13	8.549	91489	2707	VB	0.424	0.0617
14	11.910	13344	1468	BV	0.133	0.0090
15	12.164	9126	1562	VV	0.088	0.0062
16	12.269	13011	2082	VV	0.094	0.0088
17	12.624	4.68656E+007	3778763	VV	0.154	31.6143
18	15.188	39806	1797	VB	0.281	0.0269
19	19.120	15056	341	BV	0.548	0.0102
20	19.355	7802	390	VB	0.257	0.0053

Total area = 1.48242E+008

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\008R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 06:15 PM Vial Number :
Sample Name : 500 ppb std Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\008R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.278	3020383	884619	BV	0.055	98.2513
2	3.276	7777	1559	VV	0.072	0.2530
3	3.472	13846	3366	VB	0.062	0.4504
4	5.248	10539	1494	BV	0.108	0.3428
5	5.627	2166	299	VB	0.113	0.0705
6	7.346	9509	1321	BB	0.111	0.3093
7	12.519	9923	1574	BB	0.100	0.3228

Total area = 3074142

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Area Percent Report

```
Data File Name   : C:\HPCHEM\3\DATA\053096J\009F0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  06:43 PM          Vial Number     :
Sample Name      : 1000 ppb std                 Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 1 in C:\HPCHEM\3\DATA\053096J\009F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.062	196104	44685	BV	0.065	0.1000
2	2.312	8691	1916	VV	0.069	0.0044
3	2.625	28006	7807	PV	0.056	0.0143
4	2.835	5194	1232	VV	0.067	0.0026
5	2.966	131637	27762	VV	0.072	0.0671
6	3.305	758809	157866	VV	0.073	0.3870
7	3.500	942968	176116	VV	0.080	0.4810
8	4.572	9442	1739	PV	0.084	0.0048
9	4.759	126938	20892	VV	0.094	0.0647
10	5.318	3.39295E+007	3779472	VV	0.113	17.3060
11	5.765	6.40322E+007	3779910	VV	0.208	32.6601
12	7.435	4.17845E+007	3779717	VV	0.140	21.3125
13	8.550	134056	4240	VV	0.396	0.0684
14	11.910	20396	2594	BV	0.117	0.0104
15	12.164	16364	2815	VV	0.087	0.0083
16	12.269	23767	3811	VV	0.094	0.0121
17	12.638	5.37647E+007	3778719	VV	0.176	27.4231
18	15.189	110278	3462	VV	0.396	0.0562
19	18.053	2818	193	BV	0.189	0.0014
20	19.130	20172	446	VV	0.552	0.0103
21	19.356	9966	468	VV	0.269	0.0051

Total area = 1.96057E+008

Area Percent Report

```
Data File Name   : C:\HPCHEM\3\DATA\053096J\009R0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  06:43 PM          Vial Number     :
Sample Name      : 1000 ppb std                 Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 2 in C:\HPCHEM\3\DATA\053096J\009R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.038	337	128	BB	0.041	0.0054
2	2.280	6169943	1805062	BV	0.056	98.3574
3	3.276	14382	2922	VV	0.071	0.2293
4	3.472	27053	6443	VB	0.063	0.4313
5	5.248	20389	2875	BV	0.111	0.3250
6	5.626	4322	574	VB	0.116	0.0689
7	7.344	18371	2545	BB	0.112	0.2929
8	12.518	18190	2894	BB	0.098	0.2900

Total area = 6272986

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\010F0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 07:12 PM Vial Number :
Sample Name : 0 ppb (blank) Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\010F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.062	211375	46227	BV	0.067	85.9810
2	2.622	1727	449	VV	0.058	0.7025
3	2.840	2942	645	PV	0.071	1.1968
4	3.308	15300	1882	VV	0.112	6.2234
5	5.272	949	127	BB	0.093	0.3858
6	5.650	1775	231	BB	0.106	0.7220
7	7.377	2691	341	BV	0.120	1.0947
8	12.547	4769	708	BB	0.104	1.9397
9	19.116	2708	150	BV	0.223	1.1016
10	19.350	1604	183	VB	0.124	0.6524

Total area = 245840

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\010R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 07:12 PM Vial Number :

```
Sample Name      : 0 ppb (blank)                 Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\010R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.692            907             71  BB     0.162    100.0000

Total area = 907

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================================================================================
                                Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\011F0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  07:40 PM           Vial Number     :
Sample Name      : PW1B                          Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\011F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.062         186953          42622  BV     0.065     13.9782
      2     2.391           6368            699  VV     0.127      0.4761
      3     2.619           3932            626  VV     0.088      0.2940
      4     3.044           9762            578  PV     0.215      0.7299
      5     3.433           5286            156  VB     0.408      0.3952
      6     4.759           1256            225  BB     0.084      0.0939
      7     7.381         444060          51993  BB     0.131     33.2015
      8    11.158            972            126  BB     0.115      0.0727
      9    12.550          77329          11310  BV     0.105      5.7817
     10    13.087          13020            876  VV     0.219      0.9735
     11    13.506           7381            526  VV     0.203      0.5518
     12    14.170           8870            671  VV     0.182      0.6632
     13    14.727         138035           9323  VV     0.213     10.3206
     14    15.154          29191           1933  VV     0.209      2.1825
     15    15.473           5421            505  VV     0.156      0.4053
     16    16.166          26974           2352  VV     0.168      2.0168
     17    16.722          80915           7064  VV     0.169      6.0498
     18    17.174           5392            672  VV     0.123      0.4032
     19    17.619         152162          15586  PV     0.150     11.3769
     20    17.829          21121           4133  VV     0.085      1.5792
     21    17.980          74366           6737  VV     0.159      5.5602
     22    18.515           9164           1135  VV     0.117      0.6852
     23    18.746           8932            863  VV     0.156      0.6679
```

24	19.080	6393	841	PV	0.117	0.4780
25	19.348	7022	1040	VV	0.100	0.5250
26	19.728	3901	497	VV	0.118	0.2917
27	19.913	3290	607	PBA	0.092	0.2460

Total area = 1337467

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\011R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  07:40 PM            Vial Number     :
Sample Name      : PW1B                           Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 2 in C:\HPCHEM\3\DATA\053096J\011R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.037	265461	94099	BB	0.044	100.0000

Total area = 265461

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\012F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  08:09 PM            Vial Number     :
Sample Name      : PW2B                           Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 1 in C:\HPCHEM\3\DATA\053096J\012F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.062	182398	41969	BV	0.064	13.7262
2	2.386	4863	587	VV	0.113	0.3659
3	2.620	3265	503	VV	0.088	0.2457
4	3.026	9919	589	PV	0.215	0.7464
5	3.430	4296	106	VB	0.480	0.3233
6	7.382	437518	51426	BB	0.130	32.9250
7	11.164	1387	126	BB	0.152	0.1044
8	12.552	100592	14741	BV	0.105	7.5700

9	13.088	12275	814	VV	0.220	0.9238
10	13.510	7937	515	VV	0.217	0.5973
11	14.172	10505	691	VV	0.204	0.7906
12	14.728	130846	8852	VV	0.213	9.8467
13	15.153	25516	1737	VV	0.202	1.9202
14	15.486	3966	409	VV	0.138	0.2985
15	16.169	26556	2178	VV	0.176	1.9985
16	16.723	79209	6709	VV	0.173	5.9608
17	17.175	5527	655	VV	0.128	0.4159
18	17.621	145363	14946	PV	0.149	10.9392
19	17.832	22076	4086	VV	0.090	1.6613
20	17.982	78609	6586	VV	0.169	5.9157
21	18.516	6758	948	VV	0.106	0.5085
22	18.757	11337	916	VV	0.179	0.8531
23	19.074	5726	750	VV	0.116	0.4309
24	19.351	6290	1013	PV	0.093	0.4734
25	19.522	1285	167	VV	0.122	0.0967
26	19.739	1821	361	PV	0.085	0.1370
27	19.911	2990	538	PBA	0.095	0.2250

Total area = 1328832

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\012R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 08:09 PM Vial Number :
Sample Name : PW2B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\012R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.037	318695	113403	BB	0.044	100.0000

Total area = 318695

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\013F0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 08:37 PM Vial Number :
Sample Name : PW3B Injection Number: 1

Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\013F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.061	177300	40973	BV	0.064	10.5712
2	2.389	5894	747	VV	0.111	0.3514
3	2.618	3047	482	VV	0.087	0.1817
4	3.029	15252	910	PV	0.204	0.9094
5	3.180	5161	771	VV	0.089	0.3077
6	3.417	12206	784	VV	0.192	0.7277
7	4.340	37301	484	VV	0.986	2.2240
8	4.759	3545	317	VB	0.152	0.2114
9	7.382	453334	52827	BV	0.132	27.0292
10	8.555	665	49	VB	0.200	0.0396
11	11.160	1102	172	BB	0.109	0.0657
12	12.553	106027	15582	BV	0.106	6.3216
13	13.088	17563	1196	VV	0.221	1.0472
14	13.512	10619	748	VV	0.207	0.6331
15	14.172	13794	905	VV	0.209	0.8225
16	14.728	189636	12737	VV	0.215	11.3067
17	15.155	38277	2596	VV	0.204	2.2822
18	15.480	6846	687	VV	0.143	0.4082
19	16.169	39922	3122	PV	0.183	2.3802
20	16.724	118400	9946	VV	0.175	7.0594
21	17.177	8524	1045	VV	0.124	0.5082
22	17.619	204020	20794	PV	0.151	12.1643
23	17.836	35164	6235	VV	0.081	2.0966
24	17.981	117503	9639	VV	0.172	7.0059
25	18.517	11450	1603	VV	0.106	0.6827
26	18.757	17562	1447	VV	0.177	1.0471
27	19.075	8619	1149	VV	0.114	0.5139
28	19.351	8414	1452	PV	0.089	0.5016
29	19.736	5567	737	VV	0.114	0.3319
30	19.914	4487	749	PBA	0.100	0.2675

Total area = 1677203

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\013R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 08:37 PM Vial Number :
Sample Name : PW3B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH

Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\013R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.037	345434	123850	BB	0.044	100.0000

Total area = 345434

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\014F0101.D
Operator : Jackson/Nichols
Instrument : DATA3
Acquired on : 27 May 96 09:05 PM
Vial Number :
Sample Name : PW4B
Injection Number: 1
Run Time Bar Code:
Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\014F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.062	188493	43057	BV	0.065	8.7855
2	2.386	7116	950	VV	0.100	0.3317
3	2.617	3235	479	VV	0.094	0.1508
4	3.040	14174	946	PV	0.194	0.6607
5	3.174	6192	876	VV	0.096	0.2886
6	3.415	11726	826	VV	0.186	0.5465
7	4.347	42289	573	VV	0.937	1.9711
8	4.761	11041	1251	VB	0.126	0.5146
9	7.384	815028	93511	BV	0.134	37.9877
10	8.558	1741	131	VB	0.183	0.0811
11	11.165	2325	188	BB	0.187	0.1084
12	12.553	39694	5944	BV	0.104	1.8501
13	13.089	18865	1344	VV	0.208	0.8793
14	13.514	11662	832	VV	0.207	0.5436
15	14.174	15611	1118	VV	0.191	0.7276
16	14.729	220757	14696	VV	0.217	10.2893
17	15.162	44524	3071	VV	0.205	2.0752
18	15.448	11253	1063	VV	0.156	0.5245
19	16.169	49219	3801	PV	0.185	2.2941
20	16.725	137508	11515	VV	0.175	6.4091
21	17.178	10184	1241	VV	0.125	0.4747
22	17.619	239116	24123	PV	0.152	11.1449
23	17.837	41888	7489	VV	0.081	1.9524
24	17.982	135441	11198	VV	0.171	6.3128
25	18.519	14346	1958	VV	0.108	0.6686
26	18.756	20918	1784	VV	0.172	0.9750

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     27    19.076          10034           1352  VV     0.113      0.4677
     28    19.352           9679           1688  PV     0.088      0.4511
     29    19.740           6326            887  VV     0.110      0.2949
     30    19.914           5121            873  PBA    0.098      0.2387

Total area = 2145507

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\014R0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  09:05 PM           Vial Number     :
Sample Name      : PW4B                          Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\014R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.036          15007           5440  BV     0.044    100.0000

Total area = 15007

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==============================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\015F0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  09:33 PM           Vial Number     :
Sample Name      : PW5B                          Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\015F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.061         179119          41276  BV     0.064     10.8263
      2     2.392           5644            698  VV     0.125      0.3411
      3     2.618           2942            450  VV     0.090      0.1778
      4     3.031           8273            489  PV     0.211      0.5000
      5     3.171           1021            165  VB     0.103      0.0617
      6     3.415            556             66  BB     0.109      0.0336
      7     4.328           8413            189  BV     0.606      0.5085
      8     4.758           2049            225  VB     0.131      0.1238
```

9	7.384	483015	56413	BV	0.132	29.1943
10	11.175	1365	169	BV	0.105	0.0825
11	12.555	109947	16242	BV	0.105	6.6454
12	13.089	17306	1181	VV	0.214	1.0460
13	13.512	10348	734	VV	0.205	0.6254
14	14.173	13835	930	VV	0.204	0.8362
15	14.730	187369	12644	VV	0.214	11.3250
16	15.157	37464	2568	VV	0.201	2.2644
17	15.484	6619	653	VV	0.145	0.4001
18	16.171	39982	3096	PV	0.185	2.4166
19	16.726	116857	9884	VV	0.174	7.0631
20	17.179	8170	981	VV	0.126	0.4938
21	17.622	205732	20776	PV	0.152	12.4348
22	17.837	32638	6110	VV	0.077	1.9727
23	17.984	119526	9623	VV	0.175	7.2244
24	18.518	11692	1612	VV	0.108	0.7067
25	18.758	18200	1468	VV	0.180	1.1000
26	19.075	9367	1205	VV	0.118	0.5662
27	19.353	7492	1359	PV	0.085	0.4528
28	19.568	1690	188	VV	0.129	0.1022
29	19.740	3231	641	VV	0.083	0.1953
30	19.911	4619	774	PBA	0.104	0.2792

Total area = 1654481

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\015R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 09:33 PM Vial Number :
Sample Name : PW5B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\015R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.035	369880	131978	BB	0.044	100.0000

Total area = 369880

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\016F0101.D

```
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  10:02 PM          Vial Number     :
Sample Name      : PW6B                         Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\016F0101.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.061	182467	41851	BV	0.065	5.6892
2	2.385	5026	630	VV	0.106	0.1567
3	2.617	3082	505	VV	0.085	0.0961
4	3.042	13136	815	PV	0.195	0.4096
5	3.412	15016	728	VV	0.249	0.4682
6	4.578	37094	362	VV	1.204	1.1566
7	4.761	9845	1340	VB	0.105	0.3070
8	5.648	1046	140	BB	0.107	0.0326
9	7.386	413849	48625	BB	0.131	12.9036
10	11.172	1814	150	BB	0.173	0.0566
11	12.557	1595633	219093	BV	0.114	49.7509
12	13.086	23410	1471	VV	0.229	0.7299
13	13.513	12790	862	VV	0.209	0.3988
14	14.177	15861	1052	VV	0.204	0.4945
15	14.732	198208	13323	VV	0.214	6.1800
16	15.163	39840	2762	VV	0.206	1.2422
17	15.444	9163	882	VV	0.155	0.2857
18	16.173	42853	3309	PV	0.186	1.3361
19	16.728	128874	10690	VV	0.176	4.0182
20	17.180	8873	1059	VV	0.127	0.2767
21	17.623	217096	21934	PV	0.152	6.7689
22	17.838	35238	6529	VV	0.078	1.0987
23	17.985	133027	10302	VV	0.181	4.1477
24	18.519	12572	1732	VV	0.107	0.3920
25	18.762	21642	1591	VV	0.194	0.6748
26	19.074	10721	1363	VV	0.118	0.3343
27	19.354	7791	1459	PV	0.083	0.2429
28	19.593	2041	246	VV	0.138	0.0636
29	19.739	3921	701	VV	0.091	0.1222
30	19.910	5318	876	PBA	0.101	0.1658

```
Total area = 3207248

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==============================================================================
                              Area Percent Report
==============================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\016R0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  10:02 PM          Vial Number     :
```

```
Sample Name      : PW6B                          Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\016R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.036          16246           5823  BV     0.044    100.0000

Total area = 16246

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================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\017F0101.D
Operator         : Jackson/Nichols               Instrument      : DATA3
Acquired on      : 27 May 96  10:30 PM           Vial Number     :
Sample Name      : PW7B                          Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\017F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.061         173981          40168  BV     0.064      5.8364
      2     2.390           6038            750  VV     0.118      0.2026
      3     2.617           2753            493  VV     0.079      0.0924
      4     2.894           5266            634  PV     0.142      0.1766
      5     3.036           4364            418  VB     0.143      0.1464
      6     3.413           1319            144  BV     0.118      0.0443
      7     4.368          14685            269  VV     0.712      0.4926
      8     4.761           8005           1121  VB     0.106      0.2685
      9     7.387         359802          42440  BB     0.131     12.0699
     10    11.169           1778            155  BB     0.188      0.0596
     11    12.558        1365639         189016  BV     0.114     45.8118
     12    13.089          23299           1521  VV     0.224      0.7816
     13    13.516          14130            969  VV     0.213      0.4740
     14    14.175          16018           1045  VV     0.209      0.5374
     15    14.732         223898          15196  VV     0.214      7.5109
     16    15.165          45036           3128  VV     0.207      1.5108
     17    15.451          12383           1142  VV     0.159      0.4154
     18    15.963           1484            209  PV     0.119      0.0498
     19    16.173          45682           3683  VV     0.178      1.5325
     20    16.728         143984          12158  VV     0.174      4.8301
     21    17.181          10502           1302  VV     0.124      0.3523
     22    17.622         248811          25046  PV     0.152      8.3466
     23    17.840          44706           7869  VV     0.082      1.4997
```

24	17.984	139440	11734	VV	0.169	4.6777
25	18.521	15047	2159	VV	0.105	0.5048
26	18.757	20860	1873	VV	0.166	0.6998
27	19.078	10156	1432	VV	0.109	0.3407
28	19.354	9601	1746	PV	0.085	0.3221
29	19.742	6824	1026	VV	0.104	0.2289
30	19.917	5488	892	PBA	0.102	0.1841

Total area = 2980979

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\017R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 10:30 PM Vial Number :
Sample Name : PW7B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\017R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.036	20818	7566	BV	0.043	100.0000

Total area = 20818

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\018F0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 10:58 PM Vial Number :
Sample Name : PW8B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\018F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.061	185544	42737	BV	0.065	5.5899
2	2.387	5894	792	VV	0.109	0.1776
3	2.615	2977	486	VV	0.086	0.0897
4	3.043	11156	748	PV	0.190	0.3361
5	3.416	11177	541	VV	0.250	0.3367

6	4.342	13980	25	VV	6.445	0.4212
7	4.762	6924	1203	PB	0.089	0.2086
8	5.655	1495	193	BB	0.115	0.0451
9	7.388	404198	47433	BB	0.131	12.1772
10	11.176	2238	185	BB	0.167	0.0674
11	12.559	1531264	210381	BV	0.114	46.1322
12	13.090	26139	1685	VV	0.225	0.7875
13	13.516	14749	991	VV	0.213	0.4443
14	14.179	17747	1255	VV	0.191	0.5347
15	14.731	242271	15999	VV	0.219	7.2989
16	15.165	48172	3335	VV	0.201	1.4513
17	15.449	12339	1151	VV	0.153	0.3717
18	15.962	1373	201	PV	0.105	0.0414
19	16.171	55474	4487	VV	0.179	1.6713
20	16.728	157643	13165	VV	0.176	4.7493
21	17.182	11073	1367	VV	0.124	0.3336
22	17.621	277846	27897	PV	0.152	8.3706
23	17.839	47039	8517	VV	0.080	1.4171
24	17.985	156194	12852	VV	0.172	4.7056
25	18.521	16744	2254	VV	0.110	0.5045
26	18.759	23077	2009	VV	0.170	0.6952
27	19.079	11795	1620	VV	0.112	0.3554
28	19.354	9682	1818	PV	0.083	0.2917
29	19.743	6782	1008	VV	0.105	0.2043
30	19.916	6309	1121	PBA	0.094	0.1901

Total area = 3319294

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Area Percent Report
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Data File Name : C:\HPCHEM\3\DATA\053096J\018R0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 10:58 PM Vial Number :
Sample Name : PW8B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\018R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.035	5952	2112	BV	0.044	100.0000

Total area = 5952

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Area Percent Report

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Data File Name : C:\HPCHEM\3\DATA\053096J\019F0101.D
Operator : Jackson/Nichols Instrument : DATA3
Acquired on : 27 May 96 11:26 PM Vial Number :
Sample Name : PW9B Injection Number: 1
Run Time Bar Code: Sequence Line : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\019F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.061	177136	41261	BV	0.064	11.5272
2	2.409	8202	1016	VV	0.113	0.5338
3	2.617	3045	542	VV	0.079	0.1982
4	2.873	5434	940	PV	0.080	0.3537
5	2.951	9473	1162	VV	0.109	0.6164
6	3.425	18797	890	VV	0.266	1.2232
7	3.552	5781	772	VV	0.101	0.3762
8	3.770	9521	750	VV	0.161	0.6196
9	4.018	11601	778	VV	0.192	0.7549
10	4.316	10822	744	VV	0.203	0.7043
11	4.761	9833	748	VB	0.175	0.6399
12	5.274	2927	361	BV	0.123	0.1905
13	5.653	2664	182	VB	0.199	0.1734
14	7.389	7630	941	BV	0.125	0.4965
15	11.173	4369	283	BV	0.193	0.2843
16	11.710	4452	137	VV	0.484	0.2897
17	12.557	32367	4255	PV	0.115	2.1063
18	13.094	28318	1805	VV	0.233	1.8428
19	13.518	18369	1220	VV	0.218	1.1953
20	14.177	22759	1469	VV	0.211	1.4810
21	14.731	265844	17489	VV	0.219	17.3000
22	15.166	56354	3822	VV	0.208	3.6672
23	15.450	16182	1428	VV	0.164	1.0530
24	15.963	2973	345	PV	0.144	0.1935
25	16.171	52442	4524	VV	0.170	3.4127
26	16.729	171820	14179	VV	0.178	11.1813
27	17.183	12472	1509	VV	0.126	0.8116
28	17.621	282393	28410	PV	0.152	18.3769
29	17.839	49105	8822	VV	0.093	3.1956
30	17.985	161924	13301	VV	0.172	10.5373
31	18.521	18025	2480	VV	0.108	1.1730
32	18.757	23615	2061	VV	0.170	1.5368
33	19.078	11106	1634	VV	0.106	0.7227
34	19.351	11665	1876	PV	0.092	0.7591
35	19.739	7252	1043	PV	0.106	0.4720

Total area = 1536673

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\019R0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  11:26 PM            Vial Number     :
Sample Name      : PW9B                           Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\019R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.038           349            136  BB     0.043     10.5954
      2     2.239           446            170  BB     0.042     13.5414
      3     2.915           617            183  BV     0.052     18.7519
      4     3.002          1265            274  VB     0.068     38.4463
      5     3.458           614            143  BB     0.065     18.6649

Total area = 3290

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\020F0101.D
Operator         : Jackson/Nichols                Instrument      : DATA3
Acquired on      : 27 May 96  11:54 PM            Vial Number     :
Sample Name      : PW10B                          Injection Number: 1
Run Time Bar Code:                                Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 1 in C:\HPCHEM\3\DATA\053096J\020F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.059         182715          42016  BV     0.064      6.6286
      2     2.387           5033            626  VV     0.113      0.1826
      3     2.617           2466            472  VV     0.076      0.0895
      4     3.034           4922            316  PB     0.195      0.1785
      5     3.414           1113            128  BV     0.108      0.0404
      6     4.351          13066            270  VV     0.605      0.4740
      7     4.560           1753            233  VV     0.106      0.0636
      8     4.761           8209           1154  VB     0.105      0.2978
      9     7.389         333350          39141  BV     0.131     12.0933
     10    11.172           2216            161  BV     0.187      0.0804
     11    11.757            537             25  VB     0.265      0.0195
```

12	12.560	1253967	173682	BV	0.113	45.4917
13	13.091	21550	1375	VV	0.227	0.7818
14	13.518	12454	838	VV	0.216	0.4518
15	14.179	15516	998	VV	0.212	0.5629
16	14.734	198594	13421	VV	0.214	7.2046
17	15.167	39172	2734	VV	0.203	1.4211
18	15.454	10503	976	VV	0.158	0.3810
19	16.176	44049	3360	PV	0.187	1.5980
20	16.730	129973	10808	VV	0.176	4.7152
21	17.184	9666	1165	VV	0.126	0.3507
22	17.625	222323	22423	PV	0.152	8.0655
23	17.843	39671	7104	VV	0.081	1.4392
24	17.987	136306	10803	VV	0.177	4.9449
25	18.522	13337	1847	VV	0.107	0.4838
26	18.764	23252	1814	VV	0.185	0.8436
27	19.077	10959	1410	VV	0.117	0.3976
28	19.356	8590	1587	PV	0.084	0.3116
29	19.593	2131	193	VV	0.184	0.0773
30	19.745	4155	794	VV	0.087	0.1508
31	19.915	4927	818	PBA	0.100	0.1787

Total area = 2756476

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================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\020R0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
Acquired on      : 27 May 96  11:54 PM          Vial Number     :
Sample Name      : PW10B                        Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\020R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.034          20690           7290  BV     0.045     98.3026
      2     2.239            357            123  VB     0.045      1.6974

Total area = 21047

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================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\3\DATA\053096J\021F0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
```

```
Acquired on       : 28 May 96  00:22 AM          Vial Number     :
Sample Name       : PW5RB                        Injection Number: 1
Run Time Bar Code:                               Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH
```

Sig. 1 in C:\HPCHEM\3\DATA\053096J\021F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	2.059	187183	42848	BV	0.065	7.9207
2	2.391	6614	870	VV	0.115	0.2799
3	2.616	2275	402	VV	0.080	0.0963
4	3.038	14935	1013	PV	0.196	0.6320
5	3.175	6888	985	VV	0.096	0.2915
6	3.409	14772	1026	VV	0.194	0.6251
7	4.119	69901	1122	VV	0.877	2.9579
8	4.762	25560	1744	VV	0.194	1.0816
9	5.272	15297	756	VV	0.265	0.6473
10	5.655	13970	579	VB	0.312	0.5911
11	7.388	832058	95532	BV	0.134	35.2089
12	8.562	1333	112	VB	0.160	0.0564
13	11.170	2039	190	BV	0.177	0.0863
14	12.559	85796	12643	BV	0.106	3.6305
15	13.094	21556	1520	VV	0.213	0.9121
16	13.519	12750	988	VV	0.193	0.5395
17	14.177	15734	1129	VV	0.195	0.6658
18	14.733	241564	16406	VV	0.214	10.2219
19	15.167	49195	3432	VV	0.204	2.0817
20	15.453	12811	1187	VV	0.157	0.5421
21	16.174	50403	3963	PV	0.183	2.1328
22	16.730	153267	12946	VV	0.174	6.4856
23	17.184	10892	1353	VV	0.123	0.4609
24	17.623	258001	25981	PV	0.152	10.9174
25	17.841	44772	8004	VV	0.081	1.8946
26	17.986	146392	12098	VV	0.172	6.1946
27	18.521	15535	2214	VV	0.105	0.6574
28	18.759	20761	1833	VV	0.168	0.8785
29	19.079	10228	1449	VV	0.109	0.4328
30	19.354	8908	1686	PV	0.082	0.3769
31	19.741	5692	910	PV	0.099	0.2409
32	19.913	6123	1024	PBA	0.100	0.2591

Total area = 2363203

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\3\DATA\053096J\021R0101.D
Operator         : Jackson/Nichols              Instrument      : DATA3
```

```
Acquired on      : 28 May 96  00:22 AM          Vial Number     :
Sample Name      : PW5RB                        Injection Number: 1
Run Time Bar Code:                              Sequence Line   : 1
Instrument Method: SPLTCLMD.MTH
Analysis Method  : SPLTCLMD.MTH

Sig. 2 in C:\HPCHEM\3\DATA\053096J\021R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     2.034           7653           2791  BV     0.043    100.0000

Total area = 7653

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\2\DATA\101496r\001F0101.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 1
Sample Name      : H20                          Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 1
Acquired on      : 14 Oct 96  02:34 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  02:59 PM          Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\001F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|

Total area = 0

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\2\DATA\101496r\001R0101.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 1
Sample Name      : H20                          Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 1
Acquired on      : 14 Oct 96  02:34 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  02:59 PM          Analysis Method  : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\001R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|

Total area = 0
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================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\2\DATA\101496r\002F0101.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 2
Sample Name      : 3 PPB                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 1
Acquired on      : 14 Oct 96  03:02 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  03:27 PM          Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\002F0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1    21.258            368             47  BB S   0.108    100.0000

Total area = 368

================================================================================
================================================================================
                              Area Percent Report
================================================================================

Data File Name   : C:\HPCHEM\2\DATA\101496r\002R0101.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 2
Sample Name      : 3 PPB                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 1
Acquired on      : 14 Oct 96  03:02 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  03:27 PM          Analysis Method  : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\002R0101.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|

Total area = 0

================================================================================
================================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\004F0101.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 4
Sample Name      : 10 PPB                       Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 1
Acquired on      : 14 Oct 96  03:44 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  04:09 PM          Analysis Method  : NASAHSE.MTH
```

Sig. 1 in C:\HPCHEM\2\DATA\101496r\004F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.923	44039	8605	BB S	0.078	7.8523
2	5.629	159759	44393	BV	0.058	28.4858
3	5.823	45185	9689	VV	0.073	8.0567
4	5.992	5181	989	VB	0.080	0.9238
5	7.443	123	29	BV	0.064	0.0219
6	7.604	20221	3728	VB	0.084	3.6055
7	8.062	59688	10837	BV	0.086	10.6426
8	8.403	128732	27687	VV	0.073	22.9535
9	8.663	519	72	VB	0.109	0.0926
10	9.516	29452	5434	BB	0.084	5.2515
11	13.106	67938	14386	BB	0.073	12.1137

Total area = 560838

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\004R0101.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 4
Sample Name : 10 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 1
Acquired on : 14 Oct 96 03:44 PM Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96 04:09 PM Analysis Method : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\004R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.872	507	144	BB S	0.058	0.6982
2	5.214	0	5439	Fsho	0.000	0.0000
3	5.232	65391	10361	BV	0.085	90.0826
4	5.932	1093	186	VB	0.085	1.5058
5	6.408	1178	213	BB	0.087	1.6232
6	8.606	4421	755	BB	0.089	6.0902

Total area = 72590

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\005F0101.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 5

```
Sample Name      : 50 PPB                        Injection Number : 1
Run Time Bar Code:                               Sequence Line    : 1
Acquired on      : 14 Oct 96  04:12 PM           Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  04:37 PM           Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\005F0101.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.921	43136	8287	BB S	0.079	1.1047
2	5.245	653	140	BB T	0.074	0.0167
3	5.626	1145393	269309	BV	0.068	29.3345
4	5.821	237498	49603	VV	0.075	6.0825
5	5.989	23453	4442	VB	0.080	0.6007
6	6.501	2334	437	BB	0.083	0.0598
7	7.444	728	163	BV	0.070	0.0186
8	7.603	94883	17397	VV	0.085	2.4300
9	8.063	346390	60512	VV	0.090	8.8713
10	8.404	1200982	220079	VB	0.087	30.7582
11	8.645	0	173	Rsho	0.000	0.0000
12	9.518	167974	30221	BB	0.086	4.3020
13	13.109	641167	121852	BB	0.083	16.4208

```
Total area = 3904591

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\005R0101.D
Operator         : rdr                           Page Number      : 1
Instrument       : ECD_FID                       Vial Number      : 5
Sample Name      : 50 PPB                        Injection Number : 1
Run Time Bar Code:                               Sequence Line    : 1
Acquired on      : 14 Oct 96  04:12 PM           Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  04:37 PM           Analysis Method  : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\005R0101.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.870	544	147	BB S	0.059	0.1205
2	5.198	415578	96806	BV	0.063	92.1146
3	5.762	6801	959	VV	0.100	1.5075
4	5.933	9968	1018	VV	0.132	2.2094
5	6.408	7846	1313	VB	0.091	1.7392
6	7.389	1445	334	BV	0.070	0.3203
7	8.012	1800	348	BB	0.081	0.3990
8	8.351	613	124	BB	0.077	0.1358
9	8.613	3550	604	BB	0.088	0.7869
10	9.464	1568	333	BB	0.075	0.3475
11	13.055	1440	308	BB	0.072	0.3191

Total area = 451154

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\006F0101.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 6
Sample Name : 100 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 1
Acquired on : 14 Oct 96 04:40 PM Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96 05:05 PM Analysis Method : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\006F0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.922	42413	8189	BB S	0.078	0.5681
2	5.237	1033	185	BB T	0.086	0.0138
3	5.627	2208675	502501	BV	0.070	29.5861
4	5.822	439016	90467	VV	0.076	5.8808
5	5.990	41543	7908	VB	0.079	0.5565
6	6.503	4432	830	BB	0.083	0.0594
7	7.447	1542	339	BV	0.071	0.0207
8	7.604	177841	32512	VV	0.085	2.3823
9	8.064	652345	111801	VV	0.092	8.7384
10	8.405	2340167	412511	VB	0.090	31.3475
11	9.518	318512	56557	BB	0.088	4.2666
12	13.110	1237718	228053	BB	0.085	16.5798

Total area = 7465238

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\006R0101.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 6
Sample Name : 100 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 1
Acquired on : 14 Oct 96 04:40 PM Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96 05:06 PM Analysis Method : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\006R0101.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.871	545	149	BB S	0.061	0.0595

2	5.191	854296	214117	BV	0.060	93.2729
3	5.604	0	1734	Rsho	0.000	0.0000
4	5.764	11088	1542	VV	0.102	1.2106
5	5.934	16556	1802	VV	0.125	1.8076
6	6.409	15135	2459	VB	0.093	1.6524
7	7.389	3027	685	BV	0.070	0.3305
8	7.550	1078	236	VB	0.072	0.1177
9	8.011	3553	684	BB	0.082	0.3879
10	8.353	1198	237	BB	0.080	0.1308
11	8.613	3562	582	BB	0.092	0.3889
12	9.464	3083	656	BB	0.074	0.3366
13	13.054	2790	596	BB	0.073	0.3046

Total area = 915910

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\007F0201.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 7
Sample Name : 250 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 2
Acquired on : 14 Oct 96 05:09 PM Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96 05:34 PM Analysis Method : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\007F0201.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.921	41239	8038	BB S	0.078	0.2441
2	5.231	1445	223	BB T	0.099	0.0086
3	5.625	5048682	1141786	BV	0.069	29.8779
4	5.820	954328	193866	VV	0.077	5.6477
5	5.987	88105	16808	VB	0.079	0.5214
6	6.502	9745	1823	BB	0.083	0.0577
7	7.446	3688	808	BV	0.071	0.0218
8	7.602	376713	68622	VV	0.086	2.2294
9	8.062	1425100	240551	VV	0.093	8.4337
10	8.403	5490670	952010	VV	0.090	32.4936
11	9.516	691722	121377	PV	0.088	4.0936
12	10.245	654	102	VB	0.096	0.0039
13	13.108	2765608	500387	BB	0.086	16.3668

Total area = 1.68977E+007

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Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\007R0201.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 7
Sample Name      : 250 PPB                      Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 2
Acquired on      : 14 Oct 96  05:09 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  05:34 PM          Analysis Method  : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\007R0201.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.869	527	146	BB S	0.060	0.0234
2	5.183	2126368	561290	BV	0.059	94.2585
3	5.547	0	3416	Rsho	0.000	0.0000
4	5.764	20087	2908	VV	0.098	0.8904
5	5.932	31898	3847	VV	0.114	1.4140
6	6.407	38709	5959	VB	0.097	1.7159
7	7.387	7064	1592	BV	0.071	0.3131
8	7.549	2515	547	VB	0.072	0.1115
9	8.009	8483	1622	BB	0.082	0.3760
10	8.350	2912	574	BB	0.080	0.1291
11	8.611	3464	561	BB	0.092	0.1536
12	9.462	7234	1554	BB	0.073	0.3207
13	13.053	6630	1428	BB	0.073	0.2939

```
Total area = 2255890

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\008F0301.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 8
Sample Name      : 500 PPB                      Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 3
Acquired on      : 14 Oct 96  05:37 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  06:02 PM          Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\008F0301.D
```

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.921	40828	7985	BB S	0.077	0.1274
2	5.239	1954	296	BB T	0.103	0.0061
3	5.625	1.06067E+007	2541746	BV	0.064	33.1055
4	5.819	1800658	359642	VV	0.078	5.6202
5	5.986	164267	30923	VV	0.079	0.5127
6	6.502	18527	3391	VB	0.084	0.0578
7	7.445	7182	1558	BV	0.072	0.0224

8	7.601	687065	124658	VV	0.086	2.1445
9	8.061	2586093	433499	VV	0.093	8.0717
10	8.402	1.03921E+007	1846940	VV	0.086	32.4354
11	9.516	1198963	209415	PV	0.089	3.7422
12	10.246	1191	187	VB	0.094	0.0037
13	13.108	4533684	823019	BB	0.085	14.1504

Total area = 3.20392E+007

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\008R0301.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 8
Sample Name : 500 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 3
Acquired on : 14 Oct 96 05:37 PM Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96 06:02 PM Analysis Method : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\008R0301.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.869	554	154	BB S	0.058	0.0123
2	5.178	4261933	1143390	BV	0.059	94.8530
3	5.548	0	4909	Rsho	0.000	0.0000
4	5.764	32092	4974	VV	0.093	0.7142
5	5.932	54346	7147	VV	0.106	1.2095
6	6.407	74692	10911	VB	0.102	1.6623
7	7.386	14088	3177	BV	0.070	0.3135
8	7.548	5043	1093	VB	0.073	0.1122
9	8.009	16535	3154	BV	0.082	0.3680
10	8.349	5538	1087	PB	0.080	0.1233
11	8.610	3327	526	BB	0.094	0.0741
12	9.461	13622	2912	BB	0.074	0.3032
13	13.053	11425	2449	BB	0.073	0.2543

Total area = 4493197

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\009F0401.D
Operator : rdr Page Number : 1
Instrument : ECD_FID Vial Number : 9
Sample Name : 1000 PPB Injection Number : 1
Run Time Bar Code: Sequence Line : 4

```
Acquired on      : 14 Oct 96  06:05 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  06:31 PM          Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\009F0401.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.921          39740           7634  BH S   0.078      0.0601
      2     5.244           3308            465  BV T   0.103      0.0050
      3     5.644    2.0529E+007        3676776  HB S   0.086     31.0507
      4     5.818        2618911         593615  BV T   0.070      3.9612
      5     5.985         131200          38143  PB T   0.057      0.1984
      6     6.501          32735           6135  BB T   0.082      0.0495
      7     7.445          13348           2851  BV     0.073      0.0202
      8     7.601        1214951         221942  VV     0.085      1.8376
      9     8.061        4912026         832119  VV     0.091      7.4296
     10     8.421    2.3817E+007        3676976  VV     0.100     36.0240
     11     9.516        2321680         407182  PV     0.088      3.5116
     12    10.246           2307            320  VB     0.105      0.0035
     13    13.109   1.04782E+007        2035193  BB     0.078     15.8486

Total area = 6.61144E+007

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                                Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\009R0401.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 9
Sample Name      : 1000 PPB                     Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 4
Acquired on      : 14 Oct 96  06:05 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  06:31 PM          Analysis Method  : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\009R0401.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.870            525            151  BB S   0.058      0.0060
      2     5.175        8393103        2289538  BV     0.059     95.1906
      3     5.547              0           7000  Rsho   0.000      0.0000
      4     5.765          52323           8480  VV     0.090      0.5934
      5     5.932          87685          13188  VV     0.095      0.9945
      6     6.406         140259          22853  VV     0.093      1.5908
      7     7.386          27139           6184  BV     0.070      0.3078
      8     7.549           9710           2125  VB     0.072      0.1101
      9     8.009          33844           6493  BV     0.081      0.3838
     10     8.350          11995           2359  PV     0.080      0.1360
     11     8.613           3588            512  PB     0.102      0.0407
     12     9.462          28946           6227  BB     0.073      0.3283
     13    13.054          26678           5734  BB     0.073      0.3026
```

14	19.879	800	198	BB	0.063	0.0091
15	22.112	562	138	BB	0.062	0.0064

Total area = 8817157

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\010F0501.D
Operator : rdr
Instrument : ECD_FID
Sample Name : 0 H2O
Run Time Bar Code:
Acquired on : 14 Oct 96 06:34 PM
Report Created on: 14 Oct 96 06:59 PM
Page Number : 1
Vial Number : 10
Injection Number : 1
Sequence Line : 5
Instrument Method: NASAHSE.MTH
Analysis Method : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496r\010F0501.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.923	39490	7873	BB S	0.076	95.0704
2	7.600	155	31	BB	0.073	0.3739
3	8.055	262	48	BB	0.073	0.6313
4	8.392	297	56	BB	0.069	0.7142
5	8.687	220	38	BB	0.079	0.5290
6	9.515	294	56	BB	0.072	0.7081
7	13.101	820	163	BB	0.078	1.9731

Total area = 41537

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Area Percent Report
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Data File Name : C:\HPCHEM\2\DATA\101496r\010R0501.D
Operator : rdr
Instrument : ECD_FID
Sample Name : 0 H2O
Run Time Bar Code:
Acquired on : 14 Oct 96 06:34 PM
Report Created on: 14 Oct 96 06:59 PM
Page Number : 1
Vial Number : 10
Injection Number : 1
Sequence Line : 5
Instrument Method: NASAHSE.MTH
Analysis Method : nasahsf.MTH

Sig. 2 in C:\HPCHEM\2\DATA\101496r\010R0501.D

Pk#	Ret Time	Area	Height	Type	Width	Area %
1	4.870	593	163	BB S	0.059	15.5671
2	8.614	3218	556	BB	0.087	84.4329

Total area = 3811

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\011F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 11
Sample Name      : PW-24                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:02 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  07:27 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Field Blank

Sig. 1 in C:\HPCHEM\2\DATA\101496r\011F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.924          40029           7945  BB S   0.076     88.7157
      2     7.602            128             26  BB     0.068      0.2828
      3     8.687            194             35  BB     0.077      0.4310
      4     9.518            398             74  BB     0.079      0.8831
      5    13.104            757            150  BB     0.079      1.6775
      6    22.550           3614            162  BB     0.294      8.0099

Total area = 45121

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\011R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 11
Sample Name      : PW-24                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:02 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  07:27 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Field Blank

Sig. 2 in C:\HPCHEM\2\DATA\101496r\011R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.872            634            166  BB S   0.060     13.8183
      2     5.155            900            274  BB     0.054     19.6059
      3     8.615           3055            544  BB     0.085     66.5758

Total area = 4589

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\012F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 12
Sample Name      : PW-25                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:31 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  07:56 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 300'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\012F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.917          37018           7561  BB S   0.074     30.1459
      2     7.597            257             52  BB     0.074      0.2093
      3     8.395            104             20  BB     0.079      0.0847
      4     8.688            253             41  BB     0.092      0.2059
      5     9.517          59840          11148  BB     0.083     48.7308
      6    13.109          25325           5232  BB     0.075     20.6233

Total area = 122798

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==============================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\012R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 12
Sample Name      : PW-25                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:31 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  07:56 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 300'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\012R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.871           2174            454  BB S   0.073     30.8963
      2     4.979            365            116  BV T   0.051      5.1819
      3     5.153            454            143  PB T   0.052      6.4529
      4     8.611           3487            605  BB     0.087     49.5469
      5     9.462            557            125  BB     0.072      7.9221

Total area = 7037

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==============================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\013F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 13
Sample Name      : PW-26                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:59 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  08:24 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 370'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\013F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.926          36060           7449  BB S   0.074     22.3566
      2     7.604            340             69  BB     0.073      0.2105
      3     8.402            102             20  BB     0.076      0.0633
      4     8.698            268             45  BB     0.076      0.1661
      5     9.524          80617          15031  BB     0.083     49.9816
      6    13.116          43907           9304  BB     0.073     27.2218

Total area = 161293

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==============================================================================
                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\013R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 13
Sample Name      : PW-26                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  07:59 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  08:24 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 370'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\013R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.880           3085            549  BB S   0.083     36.7158
      2     4.987            371            120  BV T   0.050      4.4210
      3     5.162            463            144  PV T   0.052      5.5156
      4     8.621           3719            636  BB     0.089     44.2665
      5     9.470            763            166  BB     0.072      9.0810

Total area = 8402

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496R\014F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 14
Sample Name      : PW-27                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  08:27 PM          Instrument Method: NASAHSE.MTH
Report Created on: 15 Oct 96  09:54 AM          Analysis Method  : NASAHSE.MTH

Sig. 1 in C:\HPCHEM\2\DATA\101496R\014F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.927          38390           7833  BB S   0.075     22.6579
      2     7.610            327             68  BB     0.074      0.1928
      3     8.405             92             18  BB     0.079      0.0545
      4     8.698            221             39  BB     0.074      0.1302
      5     9.527          83787          15531  BB     0.084     49.4514
      6    13.118          46617           9877  BB     0.073     27.5132

Total area = 169434

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\014R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 14
Sample Name      : PW-27                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  08:27 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  08:53 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 401'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\014R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.881           3404            576  BB S   0.086     41.5139
      2     4.989            354            116  BV T   0.050      4.3125
      3     5.162            427            145  PV T   0.050      5.2099
      4     8.620           3209            557  BB     0.087     39.1422
      5     9.472            805            172  BB     0.073      9.8215

Total area = 8199

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\015F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 15
Sample Name      : PW-28                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  08:56 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  09:21 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 485'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\015F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.927          38479           7865  BB S   0.074     31.4920
      2     7.608            222             44  BB     0.076      0.1820
      3     8.692            220             39  BB     0.080      0.1804
      4     9.527          58370          10848  BB     0.083     47.7714
      5    13.117          24894           5136  BB     0.075     20.3742

Total area = 122186

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\015R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 15
Sample Name      : PW-28                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  08:56 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  09:21 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 485'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\015R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.881           2907            454  BB S   0.092     43.2925
      2     4.989            318            107  BV T   0.049      4.7364
      3     5.163            349            134  PV T   0.045      5.1901
      4     8.620           3141            555  BB     0.086     46.7810

Total area = 6715

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\016F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 16
Sample Name      : PW-29                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  09:24 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  09:49 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 595'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\016F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.925          38418           7874  BB S   0.074     21.6808
      2     7.608            348             70  BB     0.076      0.1964
      3     8.405             90             17  BB     0.080      0.0511
      4     8.697            222             38  BB     0.076      0.1253
      5     9.526          89242          16543  BB     0.083     50.3633
      6    13.119          48876          10373  BB     0.073     27.5831

Total area = 177196

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                                Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\016R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 16
Sample Name      : PW-29                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  09:24 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  09:49 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 595'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\016R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.880           3347            555  BB S   0.088     41.4973
      2     4.987            352            110  BV T   0.051      4.3626
      3     5.161            444            143  PV T   0.051      5.5091
      4     8.620           3075            545  BB     0.085     38.1268
      5     9.473            847            183  BB     0.072     10.5040

Total area = 8066

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                                Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\017F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 17
Sample Name      : PW-30                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  09:52 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  10:18 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 621'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\017F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.920          38085           7826  BB S   0.074     28.5994
      2     7.605            256             51  BB     0.071      0.1920
      3     8.690            217             38  BB     0.081      0.1632
      4     9.523          65575          12212  BB     0.083     49.2425
      5    13.115          29034           6037  BB     0.074     21.8029

Total area = 133166

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\017R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 17
Sample Name      : PW-30                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  09:52 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  10:18 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 621'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\017R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.874           3309            514  BB S   0.092     41.0754
      2     4.982            412            136  BV T   0.050      5.1100
      3     5.156            517            163  PV T   0.052      6.4184
      4     8.615           3195            559  BB     0.088     39.6622
      5     9.469            623            135  BB     0.072      7.7340

Total area = 8055

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\018F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 18
Sample Name      : PW-31                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  10:21 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  10:46 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : Production Well 20A 660'

Sig. 1 in C:\HPCHEM\2\DATA\101496r\018F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.928          36194           7549  BB S   0.073     18.9190
      2     7.613            378             77  BB     0.073      0.1978
      3     8.402            142             29  BB     0.068      0.0740
      4     8.698            267             46  BB     0.077      0.1394
      5     9.528         100705          18797  BB     0.083     52.6396
      6    13.121          53625          11434  BB     0.072     28.0301

Total area = 191311

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\018R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 18
Sample Name      : PW-31                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  10:21 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  10:46 PM          Analysis Method  : nasahsf.MTH
Sample Info      : Production Well 20A 660'

Sig. 2 in C:\HPCHEM\2\DATA\101496r\018R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.882           3355            540  BB S   0.089     38.1150
      2     4.990            352            115  BV T   0.050      4.0002
      3     5.165            480            149  PV T   0.052      5.4594
      4     8.624           3625            621  BB     0.087     41.1883
      5     9.474            989            211  BB     0.072     11.2370

Total area = 8801

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\019F0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 19
Sample Name      : PW-32                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  10:49 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  11:14 PM          Analysis Method  : NASAHSE.MTH
Sample Info      : field blank

Sig. 1 in C:\HPCHEM\2\DATA\101496r\019F0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.928          39448           8046  BB S   0.075     82.3549
      2     5.628           6588           1659  BV     0.062     13.7545
      3     7.618            106             21  BB     0.069      0.2218
      4     8.698            199             37  BB     0.071      0.4161
      5     9.526            661            128  BB     0.079      1.3807
      6    13.113            897            179  BB     0.077      1.8720

Total area = 47900

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                              Area Percent Report
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Data File Name   : C:\HPCHEM\2\DATA\101496r\019R0501.D
Operator         : rdr                          Page Number      : 1
Instrument       : ECD_FID                      Vial Number      : 19
Sample Name      : PW-32                        Injection Number : 1
Run Time Bar Code:                              Sequence Line    : 5
Acquired on      : 14 Oct 96  10:49 PM          Instrument Method: NASAHSE.MTH
Report Created on: 14 Oct 96  11:14 PM          Analysis Method  : nasahsf.MTH
Sample Info      : field blank

Sig. 2 in C:\HPCHEM\2\DATA\101496r\019R0501.D
    Pk#  Ret Time       Area          Height     Type   Width     Area %
   |---|----------|--------------|--------------|----|---------|----------|
      1     4.877            728            202  BB S   0.059     15.9129
      2     5.161            824            255  BB     0.053     18.0168
      3     8.622           3021            527  BB     0.086     66.0704

Total area = 4573

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