FINAL

GROUNDWATER PUMPING TESTS FOR WELLS CS-MW16-LGR AND CS-MW16-CC

Prepared for:

CAMP STANLEY STORAGE ACTIVITY BOERNE, TEXAS

WERC FA8903-04-D-8674/T006

SEPTEMBER 2007

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EXECUTIVE SUMMARY

Parsons conducted two middle Trinity aquifer pumping tests at Camp Stanley Storage Activity (CSSA) in December 2005 at monitoring wells CS-MW16-CC and CS-MW16-LGR. The middle Trinity aquifer is comprised of the Lower Glen Rose (LGR) Limestone, Bexar Shale (BS), and the Cow Creek (CC) Limestone members of the Trinity Group. The overlying LGR and deeper CC water bearing formations are separated by the 60-foot thick BS, which acts as a mostly impermeable barrier (an aquitard) against vertical groundwater movement.

The pumping tests were designed mainly to assess basic aquifer properties and hydraulic flow characteristics in the vicinity of the SWMU B-3 contaminant plume, and to determine to what degree, if any, subsurface geologic features (such as fractures) in the BS permit hydraulic communication between the LGR and CC.

The two test wells are clustered 30 feet apart and located approximately 400 feet northwest of former landfill Solid Waste Management Unit (SWMU) B-3. The pumping wells are completed to different depths in the middle Trinity aquifer. Well CS-MW16-LGR is 310 feet deep and produces groundwater from the LGR. CS-MW16-CC is 431 feet deep and derives its groundwater from the CC. The aquifer is transected by faulting and jointing in the general test area. An existing network of 20 monitoring wells within a radius of 3/4 mile served as observation wells for the tests. While each MW16 well was tested, the adjacent MW16 cluster well served in turn as an observation well. Pumping for each test continued for about 72 hours.

Well CS-MW16-CC was pumped at an average 21.44 gallons per minute (gpm) from December 7 to 10, 2005. Response to pumping was identified within multiple wells up to 3,770 feet from the pumping well. Drawdown occurred in CS-WB05 multi-port intervals CC01 and CC02, and in wells CS-MW1-CC, CS-MW2-CC, and CS-MW12-CC. During three days of continuous pumping a significant vertical hydraulic gradient of more than 130 feet was established in the pumping well. The shallower LGR wells did not respond to the gradient induced in the underlying CC, including adjacent well CS-MW16-LGR. This result would suggest that the BS is functioning as an effective aquitard between the water-bearing strata of the middle Trinity aquifer at this locality. Test data indicate overall low transmissivity and storativity within the CC Limestone, as exemplified by the extensive radius of influence (greater than 3,500 feet) that was developed in less than 72 hours. Groundwater in the CC exhibited confined characteristics and is under artesian pressure (greater than that of gravity [atmospheric]) in the SWMU B-3 test area. Despite local geologic fracturing, the CC behaved as a formation hydraulically separated from the overlying unconfined water table portion of the aquifer in the vicinity of the test site.

The pumping test for CS-MW16-LGR occurred between December 13 and 16, 2005. Drought conditions necessitated a moderately low pumping rate of 10 gpm. Significant response to pumping was limited to the LGR zones in nearby multiport well CS-WB05, and to observation wells CS-D and B3-MW01. Very minimal drawdown was recorded at CS-MW1-LGR, CS-MW2-LGR, and CS-MW5-LGR. No BS or CC wells responded to the CS-MW16-LGR pumping. There was a lack of measurable response in the more

distant observation wells. The saturated zone of the LGR exhibited confining properties at SWMU B-3 under the hydrologic conditions existing at the time of the test.

The confining properties displayed by the tested water-bearing units and the lack of hydraulic communication between them suggest contamination from SWMU B-3 likely migrated into the CC via the former Well-16 open borehole, which would have acted as a conduit from the LGR through the BS aquitard and into the CC. Groundwater flow would also have been facilitated by natural and past pumping gradients. In 2003 this potential contaminant pathway was closed when former water supply Well-16 was backplugged and converted into an LGR monitoring well.

Deep faults and joints that may transect the BS beneath SMWU B-3 are apparently sufficiently plugged or tightly closed, and any fault displacement is small enough that the vertical passage of groundwater through otherwise impermeable layers is prevented, therefore maintaining the integrity of the BS as an effective aquitard in the area of the test.

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ACRONYMS AND ABBREVIATIONS

µg/L	Microgram per liter
BFZ	Balcones fault zone
bgs	below ground surface
BS	Bexar Shale
CC	Cow Creek Limestone
cm/sec	centimeters per second
CSM	Conceptual site model
CSSA	Camp Stanley Storage Activity
CWL	Corrected water level
DCE	Dichloroethene
GAC	Granular activated carbon
gpd/ft	gallon per day per foot
gpm	gallon per minute
HCSM	Hydrological conceptual site model
K	Hydraulic Conductivity
LGR	Lower Glen Rose Limestone
MCL	Maximum contaminant level
MSL	Mean sea level
MWL	Measured water level
PCE	Tetrachloroethene
PVC	Polyvinyl chloride
Q	Average well discharge rate
S	Storativity
S'	Ratio of storativity during pumping to the storativity during recovery
SC	Specific capacity
SDWA	Safe Drinking Water Act
SWMU	Solid waste management unit
T	Transmissivity
TCE	Trichloroethene
TD	Total depth
TOC	Top of casing
TPDES	Texas Pollutant Discharge Elimination System
VOC	Volatile organic compound
Δh	Change in water level

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SECTION 1
INTRODUCTION

The middle Trinity aquifer is comprised of the Lower Glen Rose (LGR) Limestone, Bexar Shale (BS), and the Cow Creek (CC) Limestone members of the Trinity Group. At Camp Stanley Storage Activity (CSSA) and throughout the surrounding area, the middle Trinity aquifer is used as a principal source of potable water. With respect to both time and cost restraints, an aquifer test was conducted utilizing portions of the existing CSSA groundwater monitoring well network. With the exception of multi-port well CS-WB05, no additional wells or piezometers were installed as pumping or observation points for the tests. Figure 1 presents the location map for the pumping and observation wells used during the aquifer testing.

The pumping tests were conducted at the CS-MW16 well cluster located in the central portion of CSSA. Groundwater at the CS-MW16 cluster is impacted by halogenated hydrocarbons. Analytical testing results from groundwater samples collected from wells in the area identified the presence of volatile organic compound (VOC) constituents at concentrations exceeding Federal Safe Drinking Water Act (SDWA) maximum contaminant levels (MCL). The CS-MW16-CC and CS-MW16-LGR pumping tests were designed to provide aquifer characteristics within the area of a groundwater plume, and to assess hydraulic flow characteristics of the CC formation in the vicinity of Solid Waste Management Unit (SWMU) B-3, and how these characteristics affect the VOC contaminant plume. SWMU B-3 is the main suspected source area for the contaminated groundwater.

The principal aquifer characteristics of interest for the project included an analysis to evaluate aquifer specific capacity (SC), hydraulic conductivity (K), transmissivity (T), and storativity (S). Specific capacity is defined as the well yield per unit of drawdown and is typically expressed in terms of gallons per minute per foot (gpm/ft) of drawdown. Specific capacity is a value used to estimate well characteristics such as maximum yield and overall performance. SC usually changes over time as a well is pumping and drawdown is occurring. The higher a value for specific capacity, the better the well's productivity is considered at that point in its operation. This occurs when more water can be pumped out with minimal lowering of the water level in the well. SC can also be used for calculating aquifer characteristics like transmissivity. The main purpose of these pumping tests is to evaluate the local aquifer, not well performance alone; therefore SC values in this instance are applied toward aquifer analysis. No conclusions are based solely on the SC value.

Hydraulic conductivity is the fundamental measurement of the capacity of an aquifer to transmit water, and is defined as the quantity of water that will flow through a unit cross-sectional area of a porous medium per unit time under a hydraulic gradient of one (1). Hydraulic conductivity is useful in calculating the velocity of flow (distance per unit time) within a porous media.

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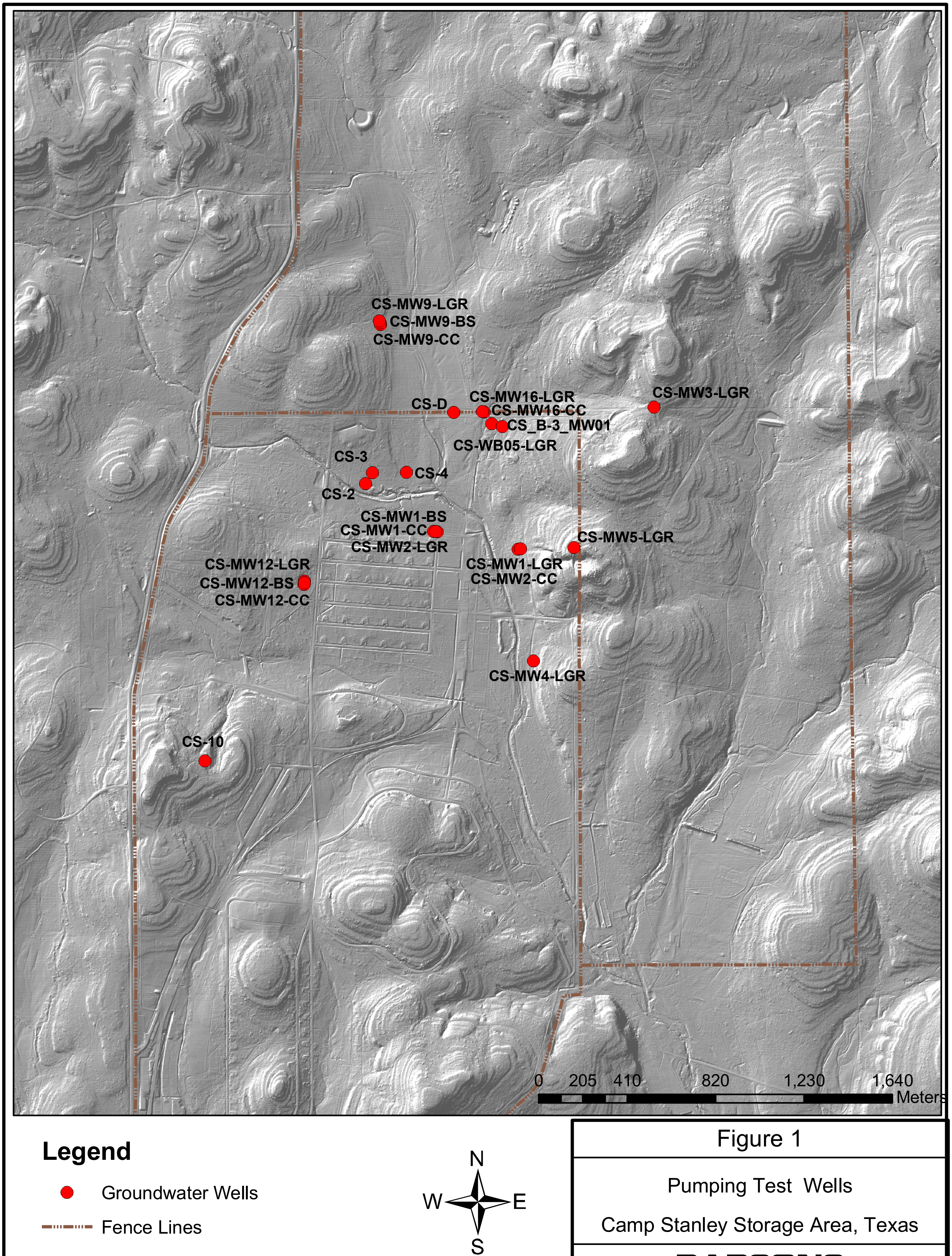

Note: CS-16LGR & CS-MW 16-CC are the pumping wells

Figure 1

Pumping Test Wells

Camp Stanley Storage Area, Texas

PARSONS

J:\744\744223 B3 & AOC65\07000-B3 Monitoring Network\Figure 1\Figure1_Pumping Test WellsUpdate.mxd

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Transmissivity is an aquifer property that allows engineers and hydrogeologists a mechanism for calculating the amount of water an aquifer system is capable of transmitting across the entire thickness of the aquifer. Transmissivity is defined as the flow rate achievable through a 1-foot section of the aquifer system extending the full thickness of the aquifer under a hydraulic gradient equal to 1. Transmissivity can be calculated by multiplying the hydraulic conductivity by the thickness of the aquifer.

Storativity is a measure of the amount of water released from an aquifer per unit area, per unit change in head. In other words, storativity is an indication of the amount of water that can be removed from an aquifer by pumping or draining. Storativity values are indicators of whether an aquifer is functioning under a confining pressure (confined condition) or water table (unconfined condition). Storativity values commonly associated with unconfined aquifer systems generally range from 0.01 to 0.3. Storativity values for confined aquifers generally range between 0.001 and 0.00001. Storativity values between 0.001 and 0.01 typically represent semi-confined aquifer systems.

CSSA has established a groundwater compliance monitoring system to evaluate the extent of groundwater impact from past waste disposal activities. Information gathered from this system is used to update and support the CSSA hydrological conceptual site model (HCSM), and as a predictive tool for remedial activities. The parameters identified through the performance of groundwater pumping tests, when combined within a hydrogeologic model, are used to:

- Predict amount of drawdown associated with the aquifer at various distances away from the pumping well;
- predict amount of drawdown associated with a well at any time following the initiation of pumping;
- predict lateral extent of the radius of influence associated with pumping wells under varying pumping rate scenarios;
- predict amount of drawdown associated with a well at any time using any pumping rate;
- determine relationships between multiple pumping wells and aquifer response within localized areas;
- determine well efficiency;
- develop optimum well designs;
- determine appropriate well pump size and capacity; and
- determine aquifer characteristics in the vicinity of the contaminant plumes for remediation system capacity requirements.

The following sections detail the activities and results of this preliminary evaluation of the aquifer parameters. Section 2 provides an overview of selected published information and references with bearing on this project. The remainder of the document details the activities associated with the field investigation program, and presents an evaluation of the collected data together with an analysis of the project results and conclusions.

SECTION 2
LITERATURE REVIEW

The purpose for conducting the literature review was to identify published aquifer testing results applicable to the middle Trinity aquifer as a comparison to results of the pumping tests conducted for this project and to summarize and document broader knowledge of aquifer parameters than identified in this limited study. Information obtained during the literature review also aided in designing the parameters composing the aquifer analysis. The published literature sources included in the review included:

- Ashworth, John B., 1983. *Ground-Water Availability of the Lower Cretaceous Formations in the Hill Country of South-Central Texas*, Texas Department of Water Resources (TDWR), Report 273.
- Arnow, Ted, 1959. Texas Board of Water Engineers Bulletin 5911, *Ground-Water Geology of Bexar County, Texas*, October 1959.
- Hammond, Weldon, W., Jr., 1984. *Hydrogeology of the Lower Glen Rose Aquifer, South-Central Texas*, Ph.D. dissertation, The University of Texas at Austin, 43p.
- Mace, Robert E., Ph.D., Ali H. Chowdhury, Roberto Anaya, Shao-Chih (Ted) Way, September 2000, *Groundwater Availability of the Trinity Aquifer, Hill Country Area, Texas*: Numerical Simulations Through 2050, Texas Water Development Board – Report No. 353.
- Parsons ES, 1996. *Groundwater Investigation and Associated Source Characterization, Camp Stanley Storage Activity, Texas*, June 1996.
- Parsons, 1993. *Hydrogeologic Report for Evaluation of Groundwater Contamination at Camp Stanley Storage Activity, Texas*, March 1993.
- Parsons, 2002. *Groundwater Pumping Tests for CS-10 and CS-16, Camp Stanley Storage Activity, Texas*, August 2002.
- Parsons, 2006. *Hydrogeologic Conceptual Site Model for Camp Stanley Storage Activity* February 2006.

The following paragraphs discuss the stratigraphy and aquifer properties reported for the middle Trinity aquifer as identified within the published literature.

2.1 Stratigraphy

The middle Trinity aquifer consists of materials representing the LGR Limestone Formation, the Hensell Sand Formation, and the CC Limestone Formation (Mace *et al.*, 2000) further documents that the middle Trinity aquifer is overlain by the Upper Glen Rose Limestone Formation and underlain by the Hammett Shale Formation (HS). At CSSA, the Bexar Shale Formation is a local facies change of the Hensell Sand within the site vicinity. The BS is not considered to be a principal water-bearing unit.

At CSSA, the LGR Limestone is approximately 320 feet thick and consists primarily of massive bedded limestone with a few layers of marl and marly limestone. Regionally, the BS thickness averages from 60 to 150 feet. However, in the CSSA vicinity the BS is typically 60 feet thick. Parsons (1993) documents that the BS has been identified to function as an aquitard between the LGR and the CC Limestone. It is composed of silty dolomite, marl, calcareous shale, and shaley limestone, and thins by interfingering into the Glen Rose Formation. The CC Limestone is a massive fossiliferous, white to gray, shaley to dolomitic limestone that attains a maximum thickness of 90 feet in the CSSA area, but is generally on the order of 75 feet thick. However, because so many water production wells in northwest Bexar and Kendall Counties are open borehole completions, the LGR and the CC Limestones are often considered hydraulically connected.

The Mean Sea Level (MSL) elevations of these formations for the well test network are summarized in Table 1. The CSSA Environmental Encyclopedia (Volume 1-1) documents in more detail the elevations of the various geologic formations comprising the middle Trinity aquifer. The formations generally dip gently to the southeast.

In 1996, CSSA initiated source characterization at SWMU B-3 and Oxidation Pond 1 (O-1) in preparation for source removal. The **Groundwater Investigation and Associated Source Characterization Report** (Parsons ES, 1996) includes source characterizations of SWMU B-3 and O-1. A chronology of work conducted in association with the groundwater investigation is provided in **Volume 1-1** of the **CSSA Environmental Encyclopedia.**

2.2 Middle Trinity Aquifer Characteristics

In his dissertation, Hammond (1984) described regionalized and localized aquifer parameters that can be encountered in the LGR aquifer. According to Hammond, both regional and local groundwater systems occur within the LGR portion of the middle Trinity aquifer. The regional system is dominated by syndepositional porosity where groundwater moves within poorly interconnected avenues of low permeability. Localized systems produced by post-depositional solution activity are characterized by megaporic voids, solutional channels, and caves. The regional trend of fractures controls the occurrence of localized systems, orientation of caves, and locations of many of the modern streams.

Hammond (1984) identified the transmissivity of the LGR as typically ranging from 240 gpd/ft to 3,220 gpd/ft for the regional system, and 5,740 to 16,110 gpd/ft for higher porosity, localized systems. Furthermore, Hammond (1984) identified the typical range in hydraulic conductivity for the LGR regional system as varying from 0.73 gpd/ft^2 to 22 gpd/ft^2 (3.4 x 10^{-5} centimeters per second [cm/sec] to 1.0 x 10^{-3} cm/sec). Hydraulic conductivity values ranging from 29 gpd/ft^2 to 74 gpd/ft^2 (1.4 x 10^{-3} cm/sec to 3.5 x 10^{-3} cm/sec) were reported for localized permeable systems. A pumping test conducted at Camp Bullis, adjacent and east of CSSA, in association with the Hammond (1984)

Table 1 Upper and Lower Formational Contact Elevations of the middle Trinity aquifer (feet above MSL)

Well ID	Surface Elevation *(ft msl)*	Total Completed Depth (screen bottom or open hole TD, ft msl)	Geologic Contacts Depths** *(ft msl)*		
			LGR/BS	BS/CC	CC/HS
CS-2	1234.4	884.4	-	-	-
CS-3	1236.87	908.97	-	-	-
CS-4	1225.66	974.16	-	-	-
CS-D	1233.31	970.31	-	-	-
MW1-LGR	1219.47	905.97	900.47	-	-
MW1-BS	1218.46	852.46	899.46	838.46	-
MW1-CC	1218.82	798.82	899.82	839.32	764.82
MW2-LGR	1236.03	892.03	889.03	-	-
MW2-CC	1237.73	786.73	890.73	831.73	759.73
MW3-LGR	1331.3	904.3	903.3	-	-
MW4-LGR	1207.23	883.23	882.23	-	-
MW5-LGR	1337.36	892.36	889.36	-	-
MW9-LGR	1254.35	933.35	928.35	-	-
MW9-BS	1253.95	876.95	927.95	867.95	-
MW9-CC	1253.24	803.24	927.24	867.24	788.24
CS-MW12-LGR	1256.4	897.9	898.4	-	-
CS-MW12-BS	1255.44	847.74	897.44	842.44	-
CS-MW12-CC	1254.73	789.23	896.73	841.73	761.73
CS-MW16-LGR	1241.59	931.59	913.59	-	-
CS-MW16-CC	1241.97	810.97	913.97	857.97	782.97
CS_B-3_MW01	1239.94	952.94	-	-	-
CS-WB05	1240.19	760.19	904.19	846.19	765.19

** Groundwater Elevation measured at the start of each respective pumping test.*
*** Based geophysical well logs.*
"-" Borehole not advanced deep enough to encounter formation contact.

study, identified the transmissivity and hydraulic conductivity of the LGR as 3,220 gpd/ft and 15 gpd/ft^2 (7.1 x 10^{-4} cm/sec), respectively. The high transmissivity and hydraulic conductivity values identified for local areas are due to discriminating (*i.e.*, heterogeneous) secondary porosity induced by dissolution of limestone.

The findings of Hammond (1984) are corroborated by Ashworth (1983), who reported an average transmissivity value of 1,700 gpd/ft for the middle Trinity aquifer. Hammond (1984) cited that pumping tests conducted for the middle Trinity aquifer in Kerr and Kendall Counties identified a storativity value of 0.00003.

As reported in the Texas Board of Water Engineers Bulletin 5911 (Arnow, 1959), an analysis of wells in the CSSA and Camp Bullis vicinity shows that well yields decrease from east to west. It is possible this condition is a function of distance from the Edwards Limestone Formation outcrop. The Edwards Limestone outcrop denotes the location of the Balcones Fault Zone (BFZ). Well yields at Camp Bullis located south and east of

CSSA were reported to be about four times greater than at CSSA (Arnow, 1959). Because groundwater exits the Glen Rose into the BFZ of the Edwards Limestone, the groundwater flow velocity increases toward Camp Bullis. Proportionally, this causes more dissolution of the Glen Rose Limestone along joints, bedding planes, and faults, resulting in higher well yields at Camp Bullis as compared to CSSA.

In the CSSA HCSM, Parsons (2006) characterized the aquifer based upon the individual properties of the water-bearing strata. In general, the LGR portion of the aquifer tends to behave as a water table (unconfined) aquifer with a generally low capacity for storage whereas the CC portion of the aquifer can be termed as a confined aquifer that is hydraulically separated from other portions of the aquifer by the overlying BS. However, the hydraulic separation between the LGR and CC portions of the aquifer likely does not exist in areas of significant structural impact (fracturing or faults) or in the vicinity of open borehole wells that are fully penetrating throughout the entire thickness of the aquifer. Past studies (Parsons, 2006) have shown that under normal conditions, there is a natural hydraulic tendency for downward movement between the LGR and CC formations. Where the BS has been compromised by structural phenomena or penetrated by wells, downward migration of groundwater and contaminants is greatly enhanced.

SECTION 3
PUMPING TEST METHODOLOGY AND ANALYSIS

This section describes various components and results of the pumping test analysis program implemented for the project. The field investigation program was initiated on December 5, 2005 and completed on December 16, 2005. Several wells included in the analysis received various upgrades to facilitate performing the pumping test program. Upgrades were implemented for wells CS-MW16-LGR and CS-MW16-CC. This included the installation of a new 5 horsepower Grundfos submersible pump in CS-MW16-CC. Also installed at CS-MW16-CC were a different pump controller, a 1 ¼-inch threaded and coupled galvanized column pipe, and two new 1-inch diameter PVC drop pipes for manual water level probes and transducers. Both CS-MW16-CC and CS-MW16-LGR had flow meters installed at their wellheads.

Barometric pressure fluctuations were monitored throughout the pumping test program to determine if atmospheric pressure had any impact on groundwater levels. The barometric sensing transducer was utilized at the nearby multi-port well CS-WB05. Barometric pressure readings were taken at the ground surface. See Figure 1 for the location of CS-WB05. Figure 2 presents a graph illustrating barometric pressure changes with respect to time that occurred over the course of the investigation as measured by the CS-WB05 datalogger that was located 230 feet southwest of the CS-MW16 well cluster. Figure 2 also illustrates precipitation measured at CSSA Weather Station South, located approximately 2.2 miles south-southeast of the CS-MW16 cluster. During the testing period, the weather was cold, with light freezing rain on the first day of the CS-MW16-CC pumping test, while the remainder of the testing period had milder temperatures with no precipitation. Diurnal effects related to the daily heating and cooling of the atmosphere are evident as a recurring cycle during the recording period. Absolute barometric pressure readings ranged from 28.5 inches-of mercury (Hg) to 29.2 inches-Hg over the course of the project. Therefore, barometric pressure was not interpreted as an influential factor during the pumping test.

The following sections detail the investigation programs and results for the CS-MW16-CC and CS-MW16-LGR analysis on an individual basis.

3.1 CS-MW16-CC

Investigation activities associated with the CS-MW16-CC analysis included a program designed to identify the regional groundwater system water level trend, a step-drawdown test, and conducting the pumping/recovery test and analysis. The purpose of the test was to determine how far away hydraulic drawdown could be observed from the pumping well, and if measurable vertical leakage could be detected from wells completed in the overlying LGR. With these objectives in mind, the observation wells included for the CS-MW16-CC pumping test included the following:

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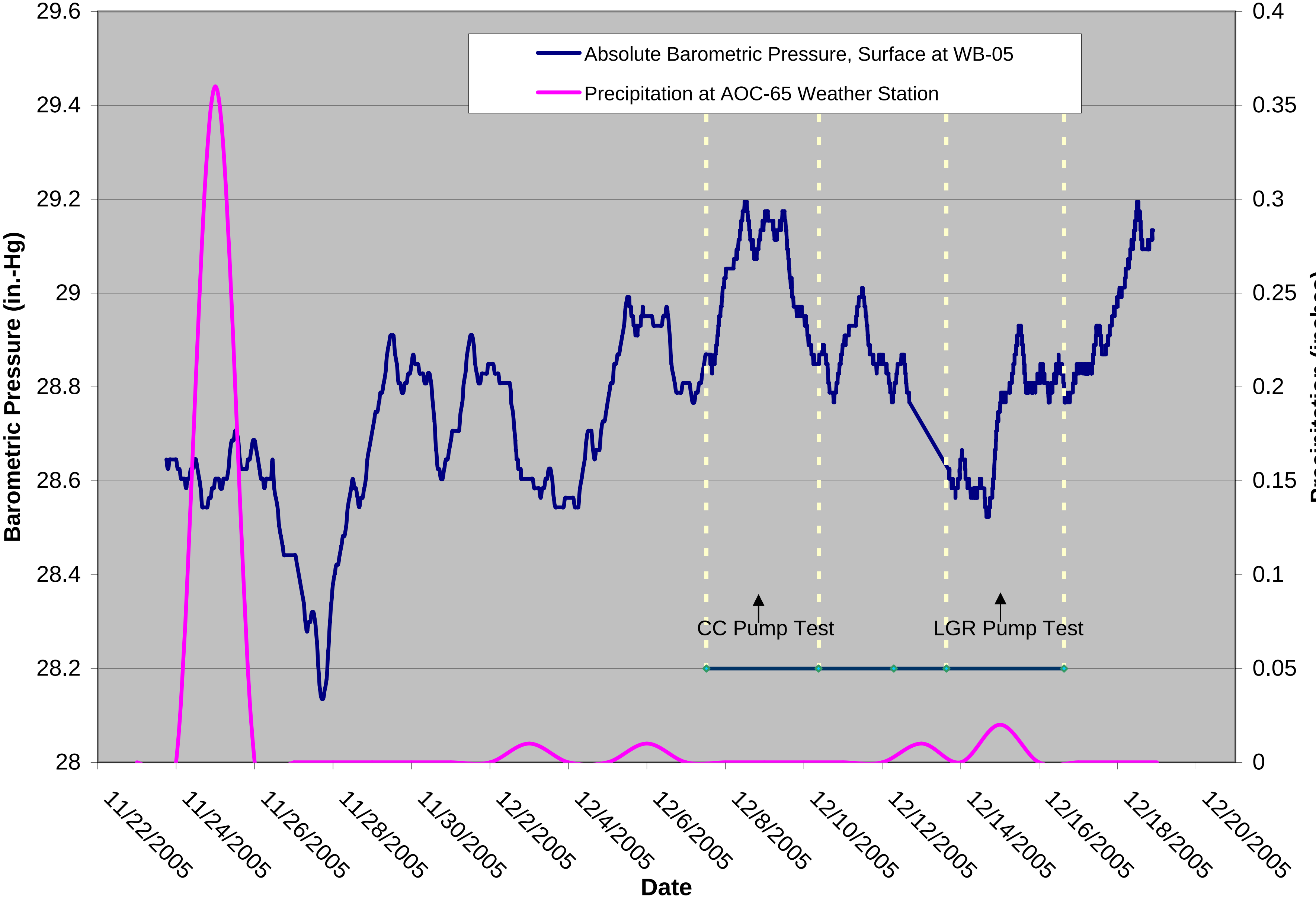
Figure 2
Absolute Barometric Pressure and Precipitation During Pump Tests



J:\744\744223 B3 & AOC65\12000-Pumping Tests\Data from FTP\WB05 16wells P-test data\WB05 MOSDAX pumpingtests.xls

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Lower Glen Rose Wells:	CS-2, CS-3, CS-4, CS-D, CS-MW1-LGR, CS-MW2-LGR, CS-MW3-LGR, CS-MW4-LGR, CS-MW5-LGR, CS-MW9-LGR, CS-MW12-LGR, CS-MW16-LGR, CS-B3-MW01;
Bexar Shale Wells:	CS-MW1-BS, CS-MW9-BS, CS-MW12-BS;
Cow Creek Wells:	CS-MW1-CC, CS-MW2-CC, CS-MW9-CC, CS-MW12-CC;
Multi-port Well:	CS-WB05, with six discrete intervals (LGR03B, LGR04A, LGR04B, BS01, CC01, and CC02) all ported at various depths.

Most wells were equipped with a pressure transducer for automatic and continuous collection of water level data, and a manual water level measuring device (e-line) to calibrate and confirm the readings of the pressure transducers.

Wells CS-3, CS-4, and CS-MW4-LGR were not equipped with transducers; therefore, water levels in these wells were taken manually. Manual readings were taken periodically at all wells to ensure accurate transducer measurements and readings, and to serve as backup in case of transducer malfunction. The locations of these wells are included on Figure 1. Table 2 provides a summary of construction specifications for each well.

CS-MW16-CC is a 431-foot deep well that is completed with a screen from 406 to 431 feet bgs, and was used as the primary pumping well for this investigation. The CC formation contributes water to the CS-MW16-CC well. Other observation wells screened within the CC formation include CS-MW1-CC, CS-MW2-CC, CS-MW9-CC, CS-MW12-CC, and ports CC01 and CC02 of CS-WB05.

Well CS-WB05 is a multi-port well on the north edge of SWMU B-3 drilled to help evaluate the performance and effectiveness of treatability test methods to be later employed for enhanced biological degradation of chlorinated contaminants associated with SWMU B-3. The multi-port well allowed for monitoring of specific hydrogeologic zones within the aquifer. The primary purpose of interval-specific monitoring is to generate data for accurate and detailed characterization of the vertical distribution of target parameters in various hydrogeologic strata. This in turn provides information that allows remediation efforts to be concentrated in appropriate areas and depths, and thus reduces the potential to waste resources through a blanket coverage approach. A string of specialized Modular Subsurface Data Acquisition System (MOSDAX) probes was used for monitoring CS-WB05. The electronic MOSDAX data was converted to potential head (water levels) by translation of hydraulic head pressures. Potential head varies over time as the hydraulic pressure of each zone changes in response to fluctuating hydrologic conditions such as pumping from a nearby well. For the duration of the pumping tests the MOSDAX string collected continuous pressure data from six CS-WB05 observation zones. The data was stored in a data logger at the surface and downloaded at the end of the testing period.

The MOSDAX data contributed to a better understanding of the hydraulic characteristics of the local subsurface geology. Monitoring of the individual zones helped to reveal the hydrologic relationships between the various geologic strata and features, and how such relationships might influence groundwater occurrence and movement between the CC and LGR. This information will also assist in optimizing nearby SWMU B-3 remediation efforts and plume management.

The multi-port well can be equipped to obtain constant fluid pressures using downhole pressure probes specific to each port. Data from the probes are relayed in digital format to a surface device. This provides unique data collection capabilities for use in pump tests, in that many hydrogeologic zones for one specific well can be monitored simultaneously. For the purposes of the CS-MW16 cluster pumping tests, multi-port well CS-WB05 was used to monitor water pressures in six specific hydrogeologic zones. CS-WB05 was specifically located directly between the planned pumping activities and SWMU B-3 to serve as a dual-purpose well: to provide hydrologic data associated with these pumping tests, and afterwards, to support monitoring the effects of SWMU B-3 interim remedial activities.

Groundwater from CS-MW16-CC is contaminated with PCE, TCE. Due to this fact, extracted groundwater required treatment prior to discharge. Groundwater from the test well was conveyed via PVC piping directly to the adjacent existing granular activated carbon unit (GAC) for immediate treatment, before being discharged to TPDES Outfall 002. The discharge was sampled twice weekly and analyzed for PCE and TCE in compliance with the CSSA TPDES permit. DHL Analytical, Inc, Round Rock, Texas conducted the analyses. No detections of the analytes were reported in the outfall releases during the pumping test treatment periods.

The findings and results of the various activities conducted in association with the investigation are presented at the conclusion of each respective sub-section below, and overall program conclusions are summarized in Section 4.0.

3.1.1 CS-MW16-CC Step-Drawdown Test

Parsons conducted a step-drawdown test for CS-MW16-CC on December 5, 2005. The purpose of this preliminary test was to determine the optimum pumping rate to be employed for the 72-hour pumping test. The optimum rate should induce sufficient drawdown to adequately stress the aquifer while remaining sustainable for the duration of the test. Water level drawdown versus elapsed-time measurements were obtained using a pressure transducer installed within CS-MW16-CC. Discharge rate and total flow measurements were monitored via an in-line flow meter. Step-drawdown testing does not require data from observations wells. No observation wells were monitored during the course of the step-drawdown tests.

Table 2 Well Construction Summaries

Well ID	Total Completed Depth (screen bottom or open hole)	Geologic Contacts Depths *(feet bgs)*			Casing Depths (all wells have 4" PVC riser from TOC to screen)			Screen
					12" Steel	8" Steel	6" (steel/PVC) or other	
	(feet bgs)	LGR/BS	BS/CC	CC/HS	(feet bgs)	(feet bgs)	(feet bgs)	(diameter & feet bgs)
CS-2	350.0	-	-	-	-	-	~205	none
CS-3	327.9	-	-	-	-	-	~205	none
CS-4	251.5	-	-	-	-	-	~200	none
CS-D	263	-	-	-	-	-	~205	none
CS-MW1-LGR	313.5	319	-	-	-	-	140' steel	3" @ 288 - 313
CS-MW1-BS	366	319	380	-	-	328	-	4" @ 340.5 - 365.5
CS-MW1-CC	420	319	379.5	454	328.4	380	-	4" @ 394.7 - 419.7
CS-MW2-LGR	344	347	-	-	-	-	140' sch-40 PVC	3" @ 318 - 343
CS-MW2-CC	451	347	406	478	356.5	-	-	4" @ 425.7 - 450.7
CS-MW3-LGR	427	428	-	-	-	-	-	4" @ 402 - 427
CS-MW4-LGR	324	325	-	-	-	-	-	4" @ 299 - 324
CS-MW5-LGR	445	448	-	-	-	-	-	4" @ 420 - 445
CS-MW9-LGR	321	326	-	-	-	-	-	4" @ 296 - 321
CS-MW9-BS	377	326	386	-	-	-	-	4" @ 352 - 377
CS-MW9-CC	450	326	386	465	-	-	-	4" @ 425 - 450
CS-MW12-LGR	358.5	358	-	-	-	-	-	4" @ 333 - 358
CS-MW12-BS	407.7	358	413	-	-	-	-	4" @ 382 - 407
CS-MW12-CC	465.5	358	413	493	-	-	-	4" @ 440 - 465
CS-MW16-LGR	310	328	-	-	-	-	199' - steel	Open Hole 199 - 310
CS-MW16-CC	431	328	384	459	335.5	393	-	4" @ 406 - 431
CS-B3-MW01	287	-	-	-	-	-	-	4" @ 277 - 287
CS-WB05	480	336	394	475	-	-	30' - PVC	Pumping test sample ports: LGR03B @ 262 LGR04A @ 277 LGR04B @ 329 BS01 @ 362 CC01 @ 432 CC02 @ 460

bgs = below ground surface.

Four pumping steps, each lasting approximately 1 hour followed by a 45 to 60 minute recovery period, were completed during the approximate 7-hour long testing period. The pumping rates associated with the various steps were:

- Step 1 - 15 gpm;
- Step 2 - 20 gpm;
- Step 3 - 25 gpm; and,
- Step 4 – 30 gpm.

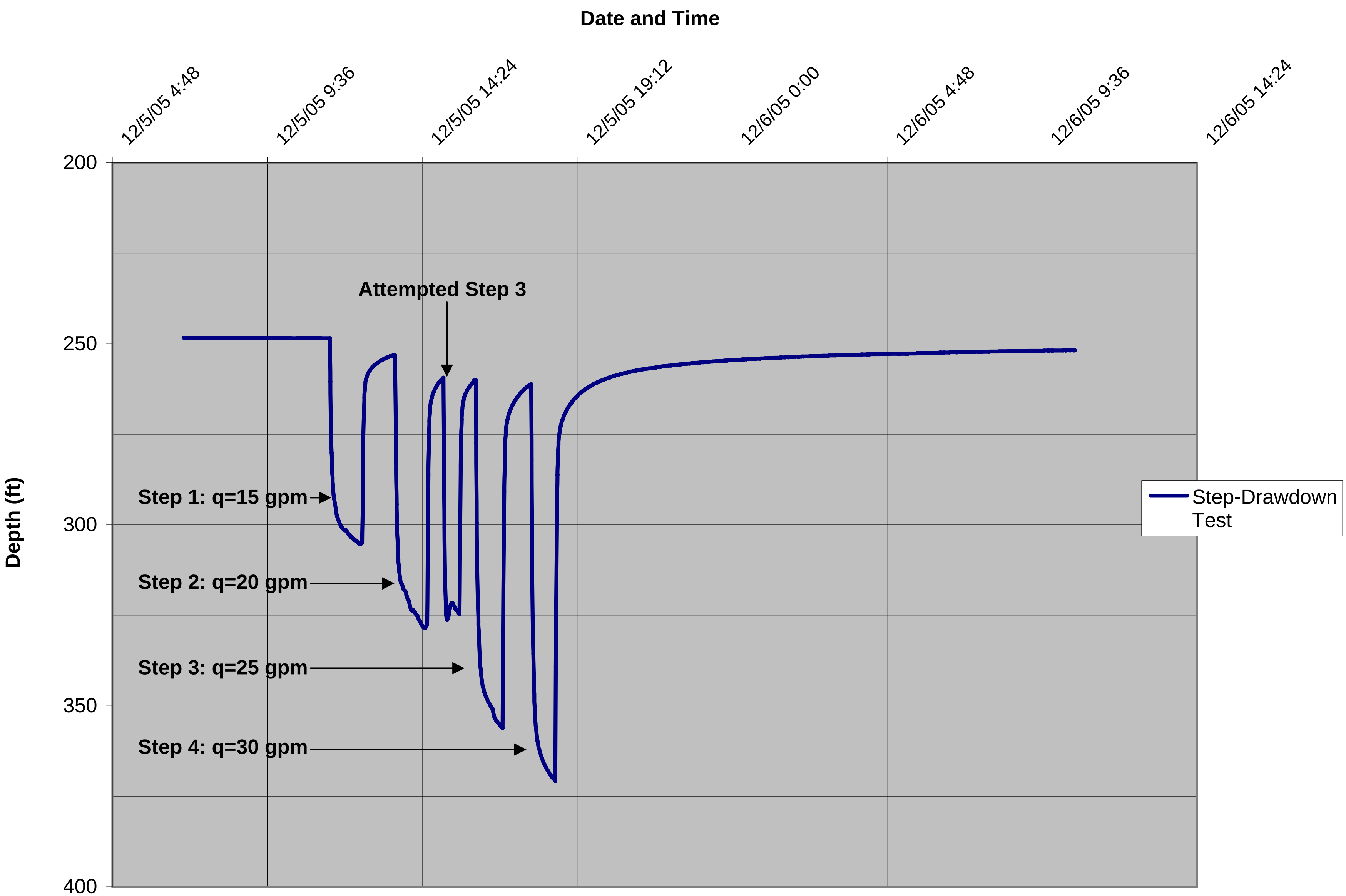
CS-MW16-CC experienced 56.50 feet of drawdown during Step 1, 80.03 feet of drawdown during Step 2, 107.69 feet of drawdown during Step 3, and 122.31 feet of drawdown during Step 4. Figure 3 is a graphic representation of water depth versus elapsed time during the step-drawdown tests. Following Step 2, in an attempt to pump at 25 gpm, it was discovered that the paper filter cartridges used to screen the pumped groundwater before entering the GAC canisters were clogged. This did not allow the pump to produce at a rate greater than 18 gpm. Following this discovery, the filter cartridges were changed and the test continued. This action during Step 3 is clearly seen on Figure 3.

The slope of the drawdown associated with each of the steps conducted for the analysis (Figure 3) is fairly consistent, and relatively steep, throughout each test. Methods described in *Groundwater and Wells* (Driscoll, 1986) were employed to resolve the step-drawdown data to calculate the optimum 72-hour pumping rate. The method involves graphically determining several hydraulic variables based upon the specific capacity determined for each pumping test. Based upon this analysis, the pumping rate employed for the 72-hour test was chosen as 22 gpm. This rate was selected to increase the potential for reaching drawdown equilibrium within the 72-hour pumping period, while at the same time effectively stressing the aquifer system to yield a maximum radius of influence for the aquifer analysis. The optimum rate should induce sufficient drawdown to adequately stress the aquifer and be sustainable for the duration of the test. After evaluating the performance of the well for each step, an optimum rate of 22 gpm was selected for the 72-hour test.

3.1.2 Regional Groundwater System Trend Identification

Parsons conducted an analysis to identify the regional middle Trinity aquifer groundwater level fluctuation trend prior to the 72-hour pumping test. This was conducted in preparation for adjusting water level measurements obtained during the pumping test to account for regional changes in water level that occurred during the test. In the absence of recent recharge due to precipitation events, the general trend of the aquifer is a steady decline in groundwater level as water discharges downgradient to wells or springs. This daily regional decline of the aquifer level has been measured as much as 1.5 feet per day within CSSA wells. Because this regional decline would accumulate over the course of a 72-hour pumping test, it would give the appearance of

Figure 3
CS-MW16-CC Step-Drawdown Test



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additional response (drawdown) to the pumping well and affect the analysis and derivation of hydrogeologic parameters. This trend analysis is performed so that regional trends of groundwater fluctuation are not misinterpreted as drawdown or influence due to the tested pumping well.

Pressure transducers were installed in most observation wells to record changes of water level over time for a period beginning two weeks to two months before the 72-hour pumping test. Data preceding pumping as far as two months showed intermittent fluctuations in water levels in most wells, which could potentially skew any eventual adjustment in the test data. Therefore, the trend immediately preceding the pumping events was identified for all wells and was traced backwards to its general starting point. Based on analysis of these data, it was determined that the time period between November 28 and December 2, 2005 provided the most consistent downward trend for most wells immediately preceding the pumping events. During this time period, the notable exceptions were wells CS-MW9-CC and CS-MW12-CC, which showed a slightly upward trend near the end of this same time period. The average groundwater decline for this time period was -0.76 feet per day (ft/day) for the LGR, -0.68 ft/day for the BS, and -0.26 ft/day for the CC portions of the aquifer.

Figure 4 illustrates a water level versus time graph developed for each of the wells included within the analysis for the time period of November 28 to December 2, 2005. Step test pumping began on December 3. Only those wells that showed a slight change during the actual pumping test of CS-MW16-CC are shown in Figure 4. These include wells CS-MW1-CC, CS-MW2-CC, CS-MW12-CC, and CS-MW16-CC itself. No wells within the LGR or BS portions of the aquifer indicated any response to the pumping of well CS-MW16-CC. The results of the pumping and recovery test are discussed in Section 3.1.3. Figure 5 illustrates a water level versus time trend for the pumping well, CS-MW16-CC, prior to the pumping test, as well as its adjusted trend line. Figure 6 is similar to Figures 4 and 5, but shows the water level trends for the six discrete zones of CS-WB05. Appendix A contains graphs developed for all observation and pumping wells, showing adjusted and unadjusted trend lines for the period of November 28 to December 2, 2005.

As shown in Figures 4, 5, 6, and in Appendix A, most groundwater levels associated with each of the wells included within the regional analysis exhibited a declining trend prior to the pumping test. The trends of observation wells CS-MW9-CC and CS-MW12-CC show a very slight (< 1 foot) rise in water level over the last 3 days of the baseline period, possibly due to minor recharge originating from outside the test area, or from leakage through a geological feature near the observation wells but outside the pumping wells' areas of influence. Overall, the moderate decline in regional water level appears generally consistent from well to well as evidenced by consistent slopes associated with each of the water level versus time trend lines. This observation is consistent with the expected trend as the site area was experiencing drought conditions prior to and during this field investigation program. In Figure 5 and Appendix A, the corrected water level based upon the regional trend analysis is presented to illustrate what effect the correction factor has. The fact that the resultant trend line on the corrected water level is very close to zero indicates that the correction factor is valid.

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Figure 4
Regional Trend of Effected Wells, CS-MW16-CC Pump Test (uncorrected)

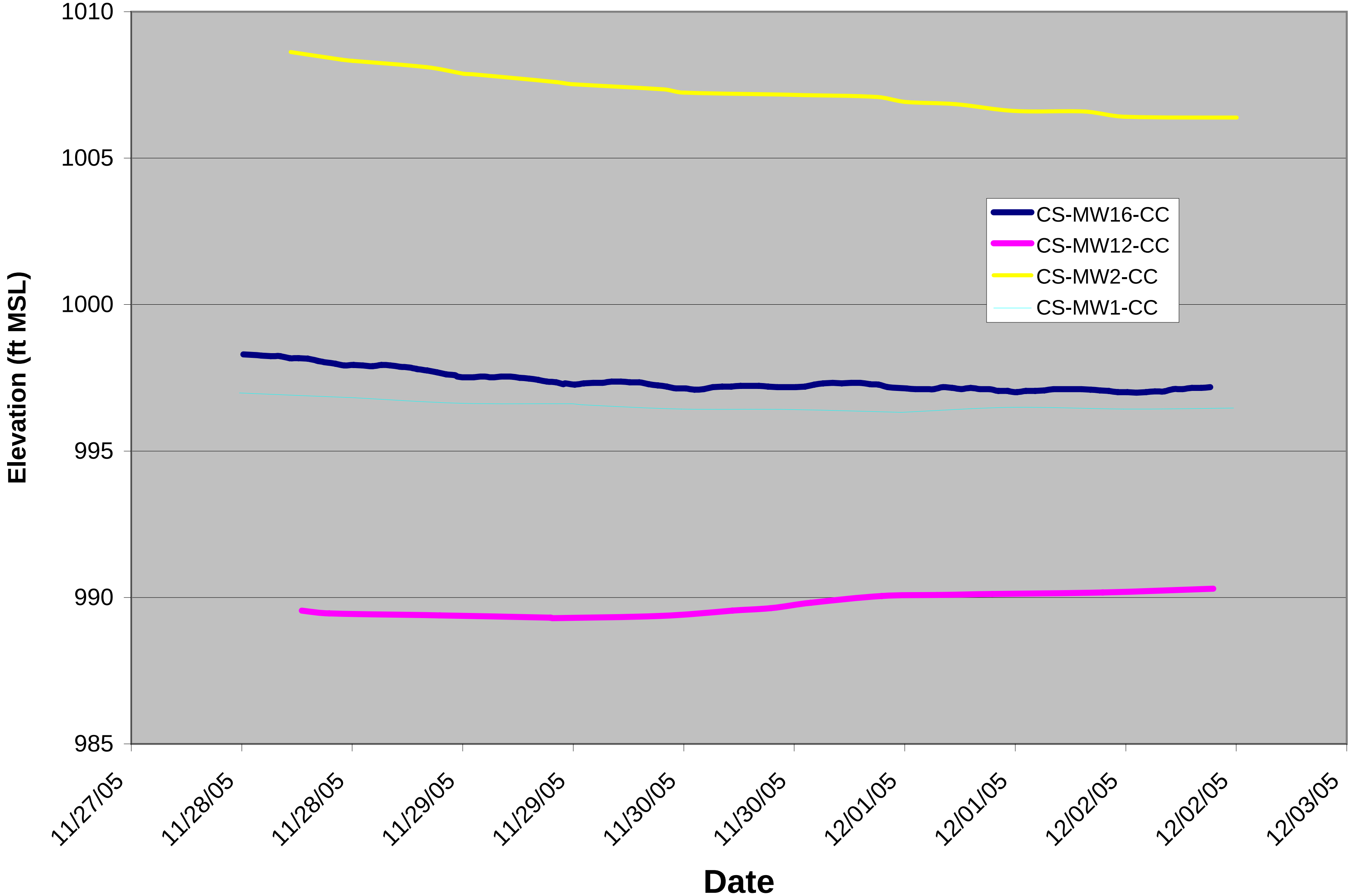

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Figure 5
Regional Trend of CS-MW16-CC

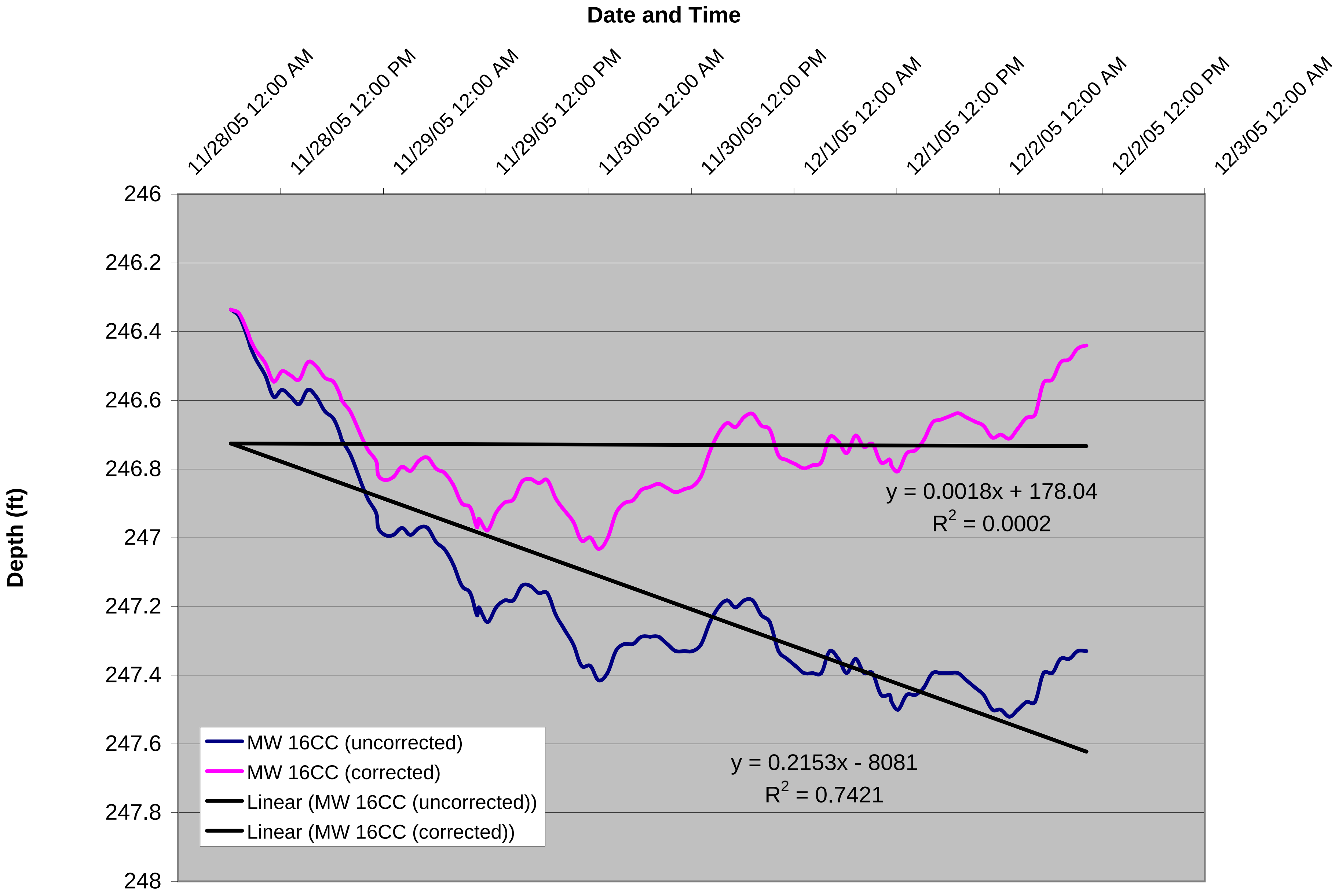

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Figure 6
CS-WB05 Regional Trend (uncorrected)

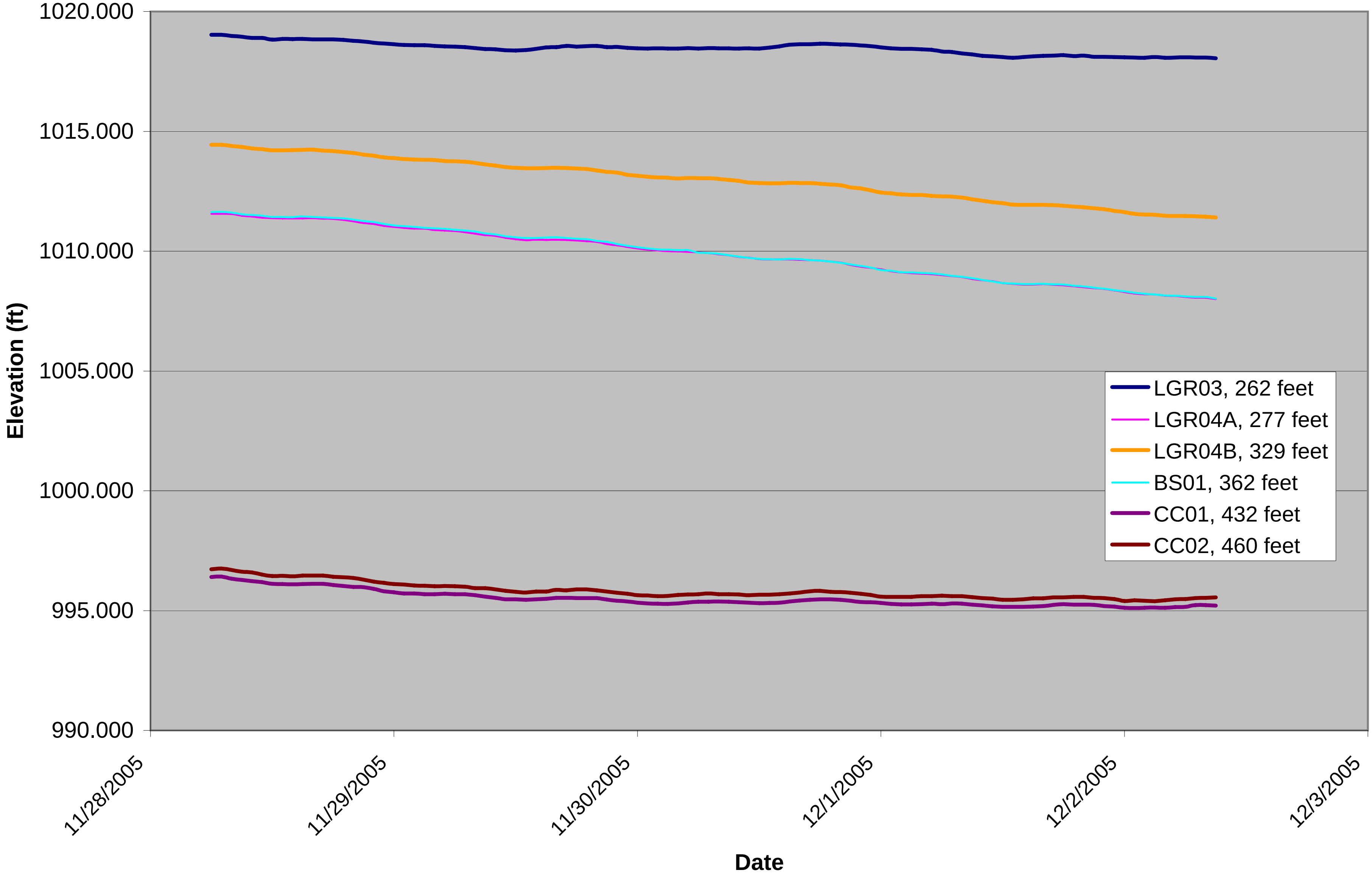

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Figure 5 illustrates the linear equation of the CS-MW16-CC trend line, as calculated by spreadsheet and graphic software, as a regional decline of 0.2153 ft/day. The linear equation defined for the regional water level decline trend is shown below. This equation illustrates the relationship of regional water level decline versus time. This relation was used to adjust the depth to water readings obtained from CS-MW16-CC during the pumping test to account for the regional water level decline that occurred during the test using the following equation. All water level results for all wells in the study were similarly adjusted for a declining trend using their calculated trend line linear equation.

CWL = MWL – Xt

Where:

CWL = corrected water level (feet below top of casing)

MWL = measured water level (feet below top of casing)

X = regional decline (feet per day); specific to each well

t = elapsed time since the start of the test (days)

This action allowed aquifer property computations to proceed as if the regional aquifer was under static conditions throughout the pumping/recovery test performance time period. Table 3 shows the pre-pumping trend for all pumping and observation wells.

Table 3 Pre-Pumping Groundwater Trends for All Wells

Observation or Pumping Well	Regional Trend Between 11/28/05 and 12/2/05 (ft/day)	Gain or Loss
CS-MW16-CC	-0.2153	Loss
CS-16-LGR	-0.9553	Loss
CS-D	-1.0348	Loss
CS-2	-1.2417	Loss
CS-MW1-LGR	-0.8132	Loss
CS-MW1-BS	-0.6758	Loss
CS-MW1-CC	-0.0981	Loss
CS-MW2-LGR	-0.6899	Loss
CS-MW2-CC	-0.5094	Loss
CS-MW4-LGR	-0.1437	Loss
CS-MW5-LGR	-0.6781	Loss
CS-MW9-LGR	-1.0705	Loss

Observation or Pumping Well	Regional Trend Between 11/28/05 and 12/2/05 (ft/day)	Gain or Loss
CS-MW9-BS	-0.5906	Loss
CS-MW9-CC	+0.8242	Gain
CS-MW12-LGR	-0.9085	Loss
CS-MW12-BS	-0.5576	Loss
CS-MW12-CC	+0.2516	Gain
CS-B3-MW01	-0.1923	Loss
CS-WB05, LGR03B	-0.1898	Loss
CS-WB05, LGR04A	-0.8973	Loss
CS-WB05, LGR04B	-0.744	Loss
CS-WB05, BS01	-0.9152	Loss
CS-WB05, CC01	-0.2422	Loss
CS-WB05, CC02	-0.2598	Loss

3.1.3 CS-MW16-CC Pumping/Recovery Test

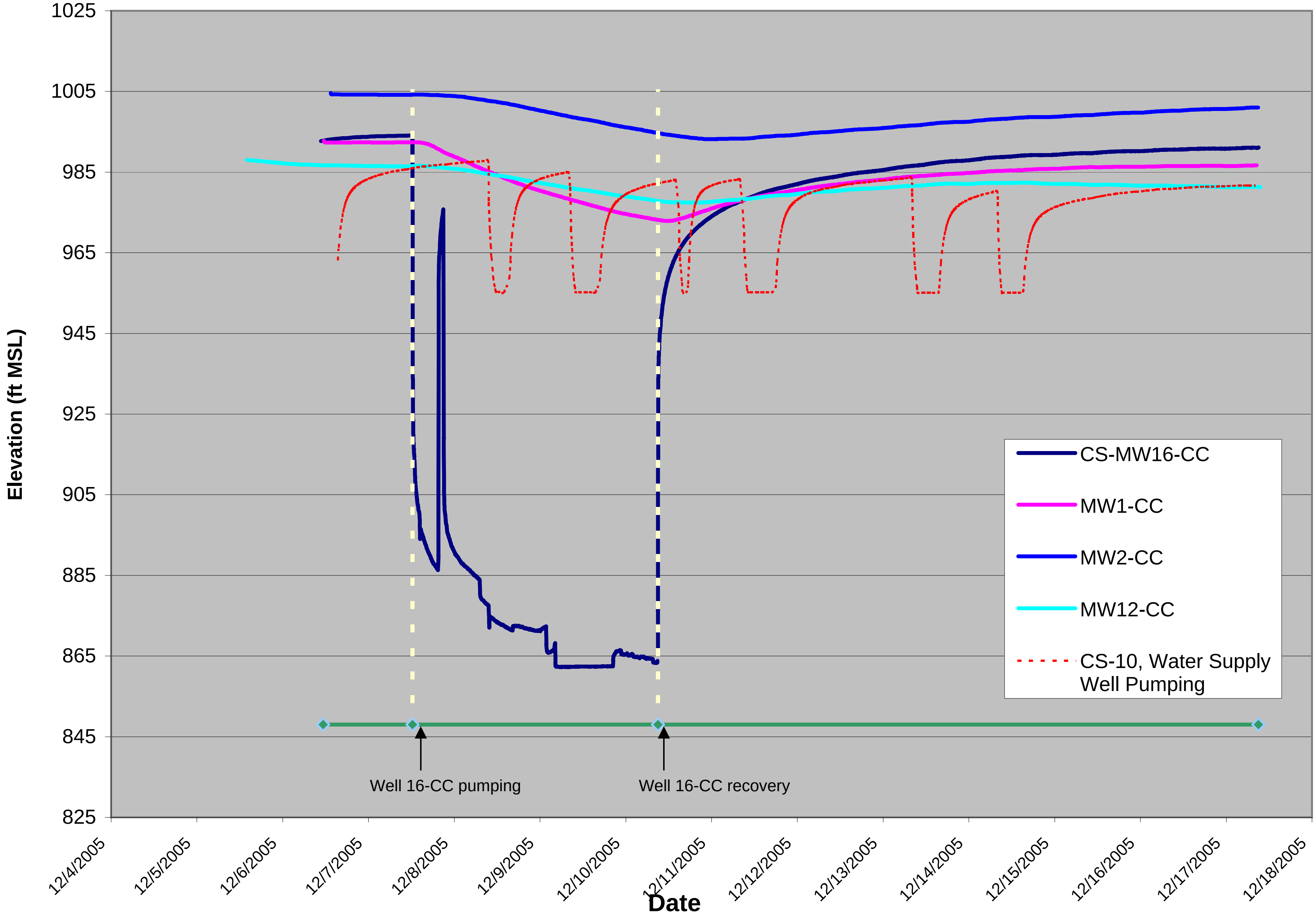
Parsons personnel executed the pumping/recovery test for CS-MW16-CC between December 7 and December 10, 2005. The pumping test consisted of an analysis of aquifer water level drawdown with respect to elapsed time associated with removing groundwater from CS-MW16-CC. Groundwater recovery was monitored for a period of 24 hours upon completion of the 72-hour pumping test.

Groundwater pumping rates and discharge totals were monitored via a flow meter/totalizer installed along the CS-MW16-CC discharge piping. Discharge rate was monitored throughout the pumping test and was adjusted as needed to maintain a discharge as close as possible to the prescribed 22 gpm flowrate. According to the wellhead flowmeter, a total of 88,341 gallons of groundwater were pumped over the duration of the test (4,120 minutes), with an average pumping rate of 21.44 gpm.

Groundwater discharge was routed to the CSSA GAC system. The pumped groundwater was treated by granular activated carbon to remove VOC contaminants prior to being discharged the TPDES-permitted Outfall 002. The flow totalizer within the GAC system indicated a total of 87,675 gallons of water was discharged to the outfall during the course of the pumping test. The flow meters were in agreement by less than 1 percent (666 gallons). Conceivably, the discrepancy between water volume pumped from CS-MW16-CC and water discharged from the GAC system can be accounted for as held in storage within the GAC filtration system. The system had drained prior to pumping.

Figure 7 is a graph depicting corrected water level versus elapsed time for the affected CC monitoring wells, including CS-MW16-CC during the pumping/recovery test period. The graph clearly shows the loss of power experienced at the pumping well on the evening of 7 December 2005. As soon as the loss of power was recognized, the pumping well was immediately re-started. Camp Stanley Security estimates the power supply went down in that section of CSSA at 1930 hours. Transducer water level data indicate the pump was idle for 89 minutes. Pumping was restarted at 2059 hours. It was decided to continue with the current pumping test due to the very tight schedule, and since CSSA is often susceptible to power surges, and because the freezing, icy weather was likely compounding the effect. Fortunately, no other power losses were experienced during the remainder of the test. With the exception of the CC zones in CS-WB05, no notable recharge due to the power loss was measured in the other observation wells. The overall effect of the power loss at CS-MW16-CC to the pumping test was determined to be negligible. The lack of a smooth drawdown line in the pumping well as time progressed was the inability to precisely control the flow of the pump, therefore any adjustments in the pumping rate resulted in a noticeable change in water level in the pumping well.

Figure 7
CS-MW16-CC Pump Test (corrected)



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As shown on Figure 7, responses to pumping were exhibited within CS-MW1-CC, CS-MW2-CC, and CS-MW12-CC. CS-MW9-CC was the only CC well under observation that did not show influence from pumping CS-MW16-CC. Drawdown within water supply well CS-10 during apparent pumping events is also shown on Figure 7. This pumping, combined with operating schedules of off-post private wells, may have influenced nearby wells, mainly CS-MW12-CC. The location of CS-10 is shown on Figure 1. All other observation wells completed in either the LGR or BS showed no response to the pumping test conducted at CS-MW16-CC.

The lack of drawdown in wells completed in strata above the CC Limestone would indicate that the BS functions as a significant confining layer below the LGR Limestone in the vicinity of the northern inner cantonment area. This point is well demonstrated by the lack of any observable drawdown in CS-MW16-LGR as well as the LGR zones of CS-WB05. During nearly three days of continuous pumping, a significant vertical gradient was established by drawing down the CC water level by more than 130 feet. Yet, the co-located CS-MW16-LGR did not respond to the induced gradient, inferring that the BS is functioning as aquitard at this location.

This notion is well supported by the observations recorded at the multi-port well CS-WB05, which is located approximately 300 feet southeast of the CS-MW16-CC pumping well. Figure 8 shows the corrected water levels versus elapsed time for all six zones monitored in CS-WB05 during the CS-MW16-CC pumping test. Immediate and dramatic drawdown responses to pumping in excess of 50 feet were exhibited within zones CC01 and CC02. However, no response was recorded within the BS (BS01), or the LGR Limestone (LGR03B, LGR04A, and LGR04B). These data show conclusive evidence that the vertical connection between the LGR, BS, and CC Limestone is imperceptible within the vertical profile of a single borehole with discrete monitoring zones.

As a caveat, hydraulic connection between strata of the middle Trinity aquifer could exist in areas of faulting or other structural compromise. Significant VOC contamination in excess of 200 µg/L is confirmed to exist within the CC Limestone at the test area. The mere presence of contaminants below the BS would conclude either of the following:

1. Structural compromise (faulting) has occurred at, or very near the plume source area (SWMU B-3) allowing for the downward migration of contaminants, or
2. Cross contamination between the LGR and CC portions of the aquifer has occurred within the open borehole completion of the former water production well CS-16 (now CS-MW16-LGR).

Figure 9 presents the corrected water level drawdown/recovery with respect to elapsed time identified within CS-MW16-CC, during the pumping test program. The first notable feature of the graphic is that the pump lost power during a post-wide power failure 400 minutes into the test. As soon as the power to the well was regained, the pumping test resumed. The inconsistent slope of the drawdown curve was the result of minor adjustments to the flowrate in attempt to maintain the specified 22 gpm test rate.

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Figure 8
CS-WB05 Data During the CS-MW16-CC Pump Test (corrected)

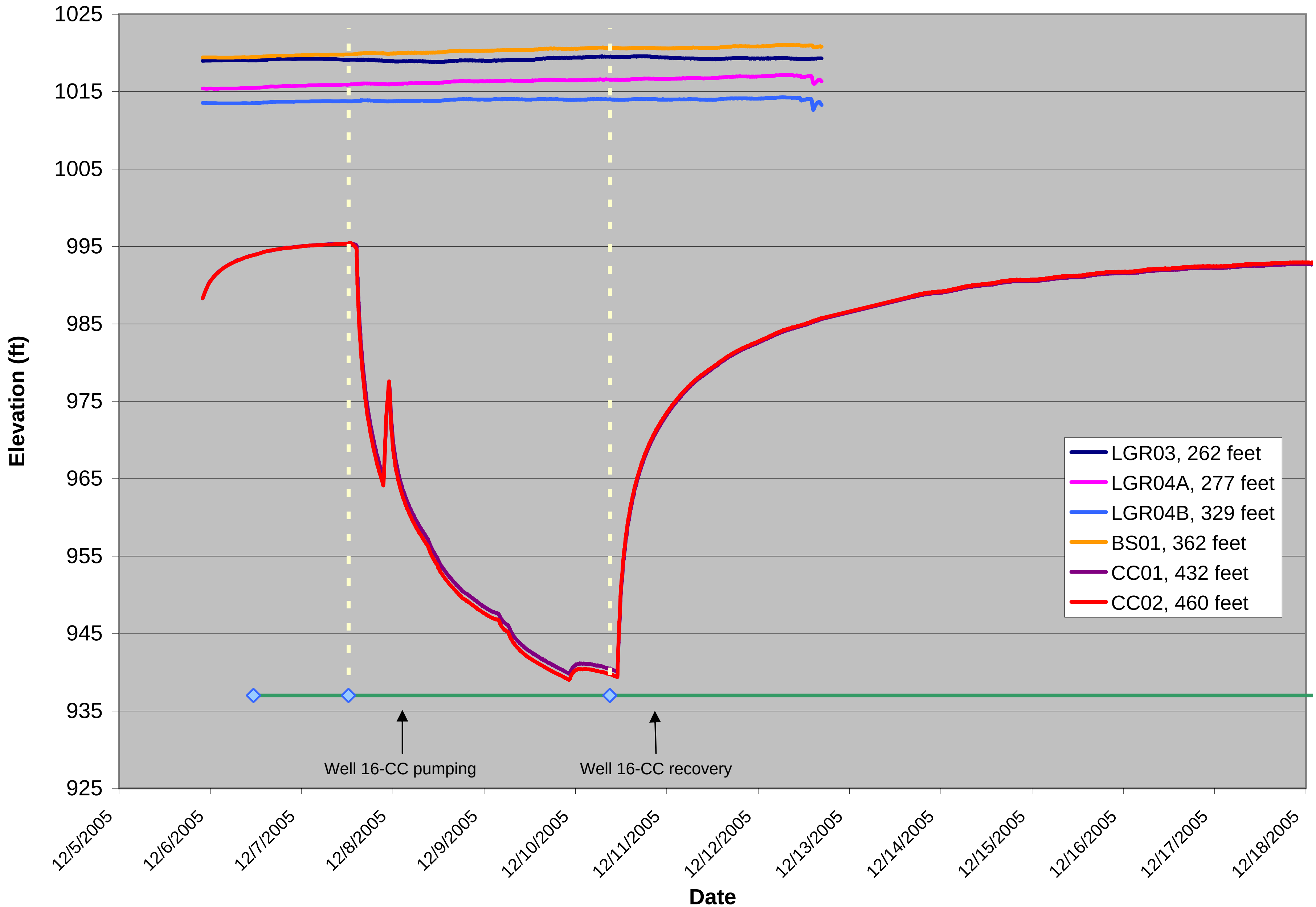

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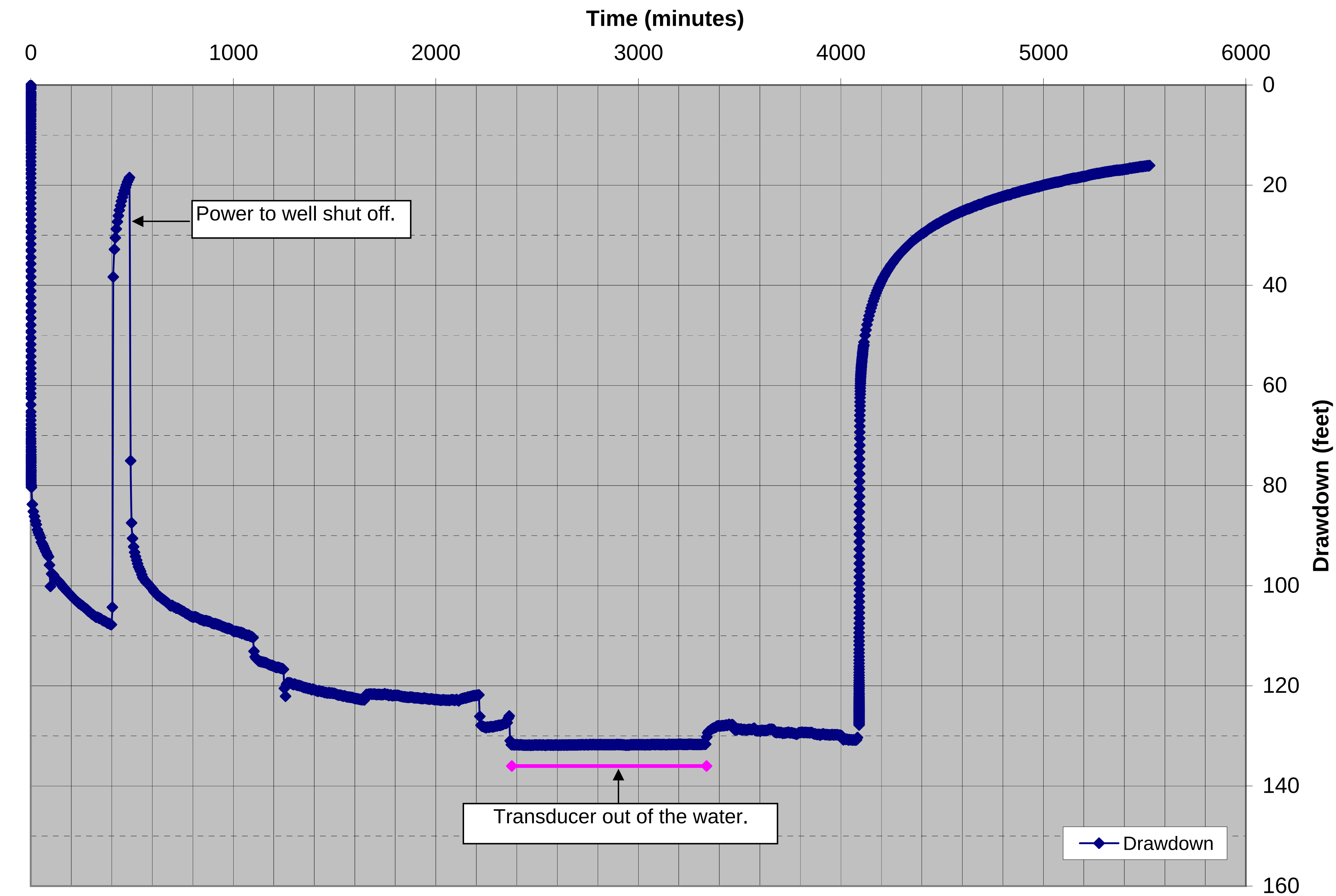
Figure 9
CS-MW16-CC Drawdown/Recovery (corrected)



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As measured by the downhole transducer, a maximum of 131 feet of total groundwater drawdown was measured within CS-MW16-CC in association with the pumping test. However, manual measurements confirmed that the pumping water level had been lowered somewhat below the depth of the transducer by the time 2,200 minutes had elapsed. The flow rate was found to be slightly in excess of the target rate, and was subsequently adjusted. Manual measurements indicated that the pumping level was in danger of being lowered to the pump prior to the conclusion of the 72-hour test. Because pumping water levels down to the pump could potentially damage the motor, the pump test was stopped short after 69 hours to prevent the well pump from cavitating. Ultimately, the 22 gpm test rate determined during the step test proved slightly too high to maintain for an entire 72-hour test.

Using the total drawdown and average discharge rate, specific capacity for CS-MW16-CC is calculated using the following equation:

$SC = Q/\Delta h$

Where:

SC = specific capacity (gpm/ft)

Q = average well discharge rate (gpm)

Δh = total corrected drawdown at end of test (ft)

The specific capacity of CS-MW16-CC was calculated as 0.164 gpm/ft (21.44 gpm/131 ft).

An analysis of transmissivity and storativity was conducted with respect to the pumping wells, utilizing the Theis equation. AQTESOLV for Windows™ version 3.01 was employed for the Theis equation calculations. The Theis equation is based on the following assumptions:

- The aquifer has infinite areal extent;
- the aquifer is homogeneous, isotropic, and of uniform thickness;
- the pumping well is fully or partially penetrating;
- flow to the pumping well is horizontal when the pumping well is fully penetrating;
- flow is unsteady;
- water is released instantaneously from storage with decline of hydraulic head; and
- diameter of the pumping well is very small so that storage in the well can be neglected.

Obviously, the Theis equation is based on conditions principally achievable in a laboratory setting because true aquifer systems will seldom meet all the criteria formulating the basis of the Theis solution. Nevertheless, the Theis equation is considered valid for most pumping test analyses as the margin of error associated with not meeting the above criteria in a natural setting is usually considered negligible without a significant impact on the results. Parsons identified the Theis solution to be valid for this study.

Various well construction details required as input parameters into AQTESOLV were obtained from the existing CSSA database and summarized within **Volume 5-2, Groundwater, Water Well Survey**. One input parameter required by AQTESOLV was unknown at the time of the analysis and was therefore assumed. The assumed parameter included the:

- Ratio of vertical versus horizontal hydraulic conductivity (K_z/K_r).

The ratio K_z/K_r was assumed as unity for the analysis. A sensitivity analysis was conducted to identify the impact to T and S results while substituting the smallest value for K_z/K_r available (0.001) for inclusion within AQTESOLV. The results identified T and S values to be within 20 percent of the T and S values obtained using the assumed unity value for K_z/K_r. The sensitivity analysis identified a direct relationship between K_z/K_r value and T/S values. Reducing the K_z/K_r value (*i.e.* representing an increased K horizontal vs. K vertical) yields lower T and S values. Based on stated intended use of the preliminary T and S data generated by this investigation, Parsons is of the opinion that using $K_z/K_r = 1$ yields the most usable results.

Because of the design of the pumping test well (CS-MW16-CC), the saturated thickness of the aquifer was assumed to be the water-bearing portions of the CC Limestone, which is confined by the BS above and the Hammett Shale below. Based upon the lithologic contacts presented in Table 2, the aquifer thickness of the CC at pumping well CS-MW16-CC is approximately 75 feet. However, the preponderance of the groundwater occurs within the first 50 feet of the unit. As such, CS-MW16-LGR was constructed as a partially penetrating well based upon contaminant investigation requirements.

Appendix B presents the aquifer analysis curve and associated report generated by AQTESOLV in association with the CS-MW16-CC pumping test analysis program. Depth to water observations obtained during the conductance of the pumping/recovery test are included in the report generated by AQTESOLV. Visual curve matching was conducted to increase the accuracy of T and S values generated from the pumping test data. The observation wells that had an obvious response to pumping (CS-WB05, CS-MW1-CC, CS-MW2-CC, and CS-MW12-CC) were included in the analysis.

Table 4 is a summary of the aquifer parameters generated by AQTESOLV for the CS-MW16-CC pumping test.

Table 4 AQTESOLV Results for Transmissivity and Storativity for the CS-MW16-CC Pumping Test

	Theis Confined Solution		Theis Recovery Solution	
Observation Well Name	**Transmissivity (gpd/ft)**	**Storativity**	**Transmissivity (gpd/ft)**	**S'**
CS-WB05-CC01	210.2	3.22E-05	182.5	1.11
CS-MW1-CC	197.1	1.02E-05	267.5	0.75
CS-MW2-CC	210	1.94E-05	157.5	1.15
CS-MW12-CC	272.1	8.69E-06	394.4	0.89
CS-MW16-CC	446.7	N/A	213.2	N/A
Average[1]	267.22	1.76E-05	243.02	0.97
Combined[2]	255.9	9.17E-06	248.4	0.91

[1] Average - Does not include "Combined" results.
[2] Combined -Represents the "combined" solution when all observation wells are graphed and resolved simultaneously.

The results produced by AQTESOLV software were generated utilizing two different analytical methods. The first columns represent data generated using the Theis solution for a confined aquifer. Using this method, AQTESOLV can produce data for the transmissivity and the storativity coefficient of the aquifer. The Theis recovery method of aquifer evaluation was also performed utilizing the same data set. This method analyzes only those data recorded after the pumping stopped. Transmissivity values are calculated as they are for the regular Theis solution, however, instead of computing a storage coefficient, the Theis recovery method calculates an S' (prime) which is defined as the ratio of storativity during pumping to the storativity during recovery. A value of S' greater than 1.0 indicates the influence of a recharge boundary while a value of S' less than 1.0 suggests the presence of a barrier of no-flow boundary. Overall, the aquifer parameters generated by the two evaluation methods are in agreement.

As presented within Table 4, transmissivity and storativity values identified for the middle Trinity aquifer based on the CS-MW16-CC combined analysis are 255.9 gpd/ft and 0.00000917, respectively. The value of storativity determined from the CS-MW16-CC pumping test indicates that water-producing intervals are under confining conditions.

Using transmissivity (255.9 gpd/ft) and saturated thickness (75 ft), hydraulic conductivity may be calculated using the following equation:

K=T/b

Where:

K = hydraulic conductivity (gpd/ft^2)

T = transmissivity (gpd/ft)

b = saturated thickness (ft) and,

1 gpd/ft^2 = 0.0000472 centimeters per second (cm/sec)

As presented, the hydraulic conductivity of the CC portion of the middle Trinity aquifer at CS-MW16-CC was calculated as 3.41 gpd/ft^2, or 1.61×10^{-4} cm/sec.

3.2 CS-MW16-LGR

The methodology of the CS-MW16-LGR pumping test was the same methodology employed for the CS-MW16-CC pumping test. This involved determination of a regional pre-test groundwater level trend, step tests used to determine an ideal pumping rate for the test, a 72-hour pumping test, and recordation of the aquifer recovery after the pumping stops. Because the tests were conducted sequentially, with the CS-MW16-CC test occurring first, the same observation wells were used during both tests listed in Section 3.1. This allowed data to be collected for both aquifers while each one was pumped separately.

Well CS-MW16-LGR is a former base supply well that was originally drilled through the entire thickness of the middle Trinity aquifer to the bottom of the CC, but was decommissioned in 1991 upon discovery of the VOC contamination. It was originally constructed as an open borehole completion with 21 feet surface casing. In 1996, the well was upgraded with 6-inch PVC surface casing to a depth of 195 feet. In July 2002, the BS and CC portions of the well were plugged to eliminate the possibility of any further downward migration of contaminants to lower strata through the open borehole.

3.2.1 CS-MW16-LGR Step-Drawdown Test

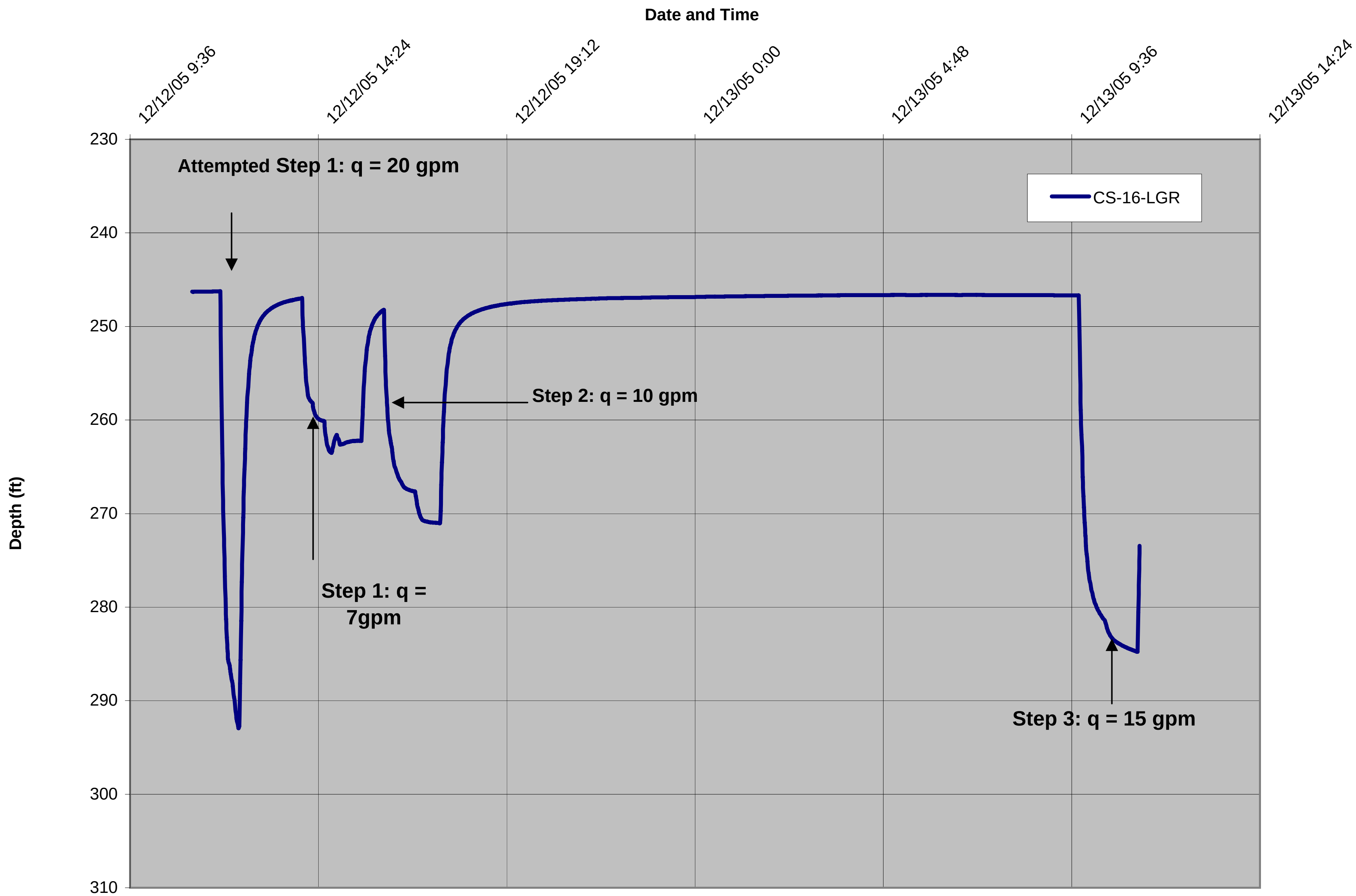
The step-drawdown test for CS-MW16-LGR was conducted on December 12 and 13, 2005. The purpose of the test was to determine the optimum pumping rate to be employed for the 72-hour pumping test. Water level drawdown versus elapsed time measurements were obtained using a pressure transducer installed in CS-MW16-LGR. Discharge rate and total flow measurements were monitored via an in-line turbine meter. A gate valve was installed to allow adjustment of the discharge rate.

Three full pumping steps, each lasting approximately 90 minutes, were completed during the test. The step-drawdown test was initiated on December 12, 2005, but wasn’t completed until December 13, 2005. The pumping rates associated with the various steps were:

- Step 1 - 7 gpm;
- Step 2 - 10 gpm; and
- Step 3 - 15 gpm.

A partial step was attempted before the full Step 1, at 20 gpm. At this rate, the well water level decreased at a much greater rate than was expected, and the pump was shut down after only 28 minutes of pumping. This initial step of the analysis provided data that were unusable in the evaluation. Figure 10 is a graphic representation of the depth to water versus elapsed time during the step-drawdown test.

Figure 10
CS-16-LGR Step-Drawdown Test



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Well CS-MW16-LGR experienced 24.47 feet of drawdown during Step 1, 37.42 feet of drawdown during Step 2, and 49.7 feet of drawdown during Step 3. As shown on Figure 10, the slope of the trend lines associated with each of the steps conducted for the analysis are fairly consistent, and relatively steep, throughout each step. This was interpreted upon completion of the step test, as evidence suggesting that the amount of time required for the well drawdown to reach equilibrium using discharge rates near full well capacity could extend greater than the planned 72-hour pumping period.

The pumping rate employed for the 72-hour test 10 gpm. This rate was selected to increase the potential for reaching drawdown equilibrium within the 72-hour pumping period while at the same time effectively stressing the aquifer system to yield a maximum radius of influence for the aquifer analysis.

3.2.2 Regional Groundwater System Trend Analysis

A discussion of this analysis is presented in Paragraph 3.1.2 which relates to the CS-MW16-CC pump test but is relevant to the CS-MW16-LGR test as well.

Figure 11 presents a graph illustrating the regional trend for several wells included within the CS-MW16-LGR analysis, during the time-period prior to initiating the CS-MW16-LGR pumping test. Only those wells that showed a slight change during the pumping test, due potentially to the pumping of CS-MW16-LGR, are shown in Figure 11. As shown on Figure 11, a consistent trend of regional water level decline was experienced within each of the wells as exhibited by consistent water level versus time graph slope.

Figure 12 illustrates the linear equation of the CS-MW16-LGR trend line as calculated using spreadsheet and graphing software. From this, a correction factor was used to adjust the depth to water readings obtained from CS-MW16-LGR during the pumping test to correct for regional water level decline that occurred during the test. Water level correction was conducted using a decline of 0.9553 feet per day as the water level versus time ratio within the equation presented in Section 3.1.2. The same process was repeated for all other observation wells. Table 3 summarizes the pre-pumping groundwater trends. This action allowed aquifer property computations to proceed as if the regional aquifer was under static conditions throughout the pumping/recovery test analysis.

3.2.3 CS-MW16-LGR Pumping/Recovery Test

Parsons personnel executed the pumping/recovery test for CS-MW16-LGR between December 13, 2005 and December 16, 2005. The initial 72 hours of the test consisted of an analysis of aquifer water level drawdown with respect to time associated with removing groundwater from CS-MW16-LGR at a constant rate of 10 gpm. The groundwater recovery rate was monitored for approximately 24 hours within CS-MW16-LGR and observation wells, following the 72-hour pumping test. Groundwater levels with respect to time were also monitored within all observation wells throughout the CS-MW16-LGR test. Depth-to-water measurements were obtained within the various observation wells using pressure transducers.

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Figure 11
Regional Trend of Effected Wells, CS-16-LGR Pump Test (uncorrected)

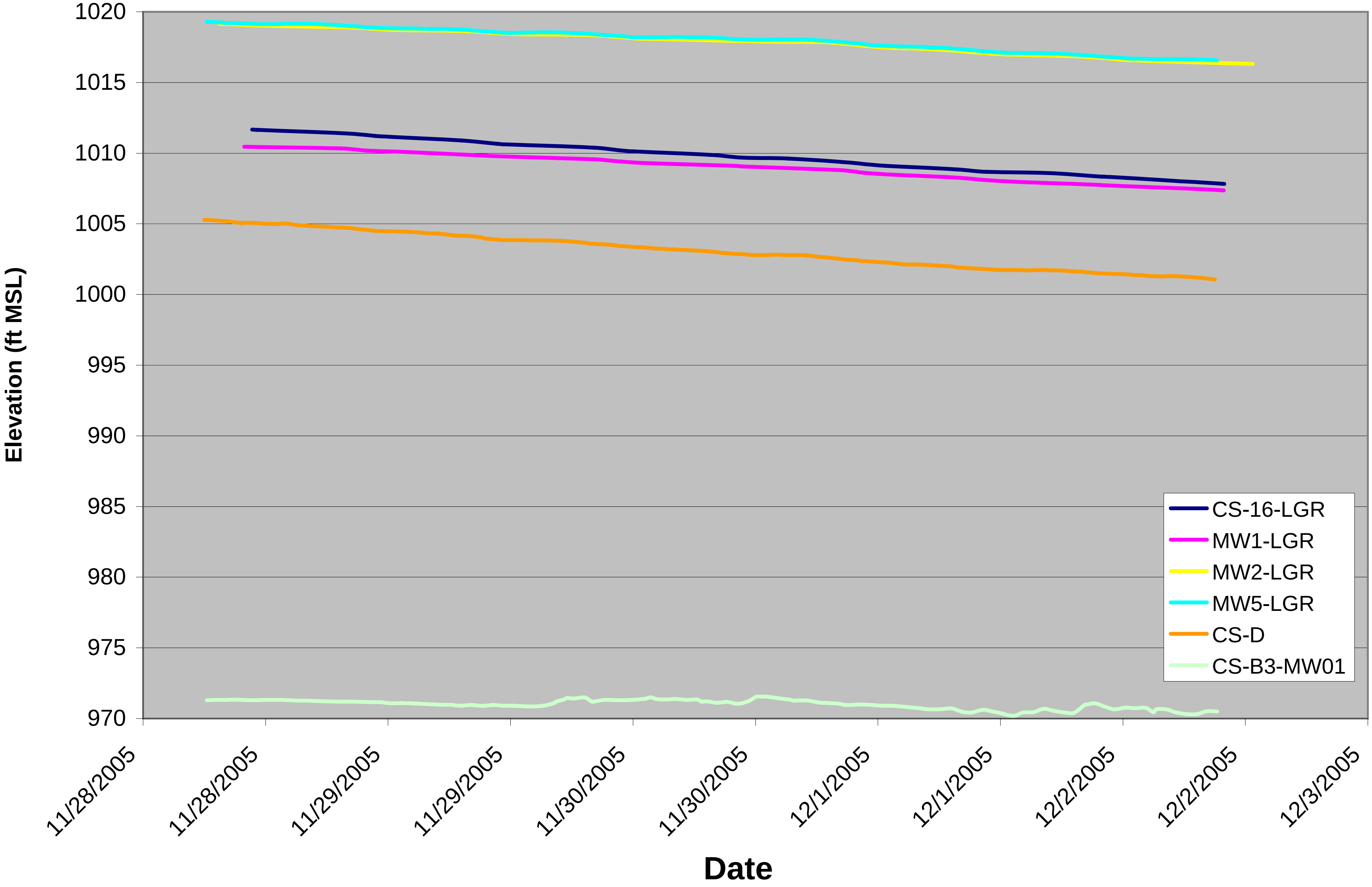

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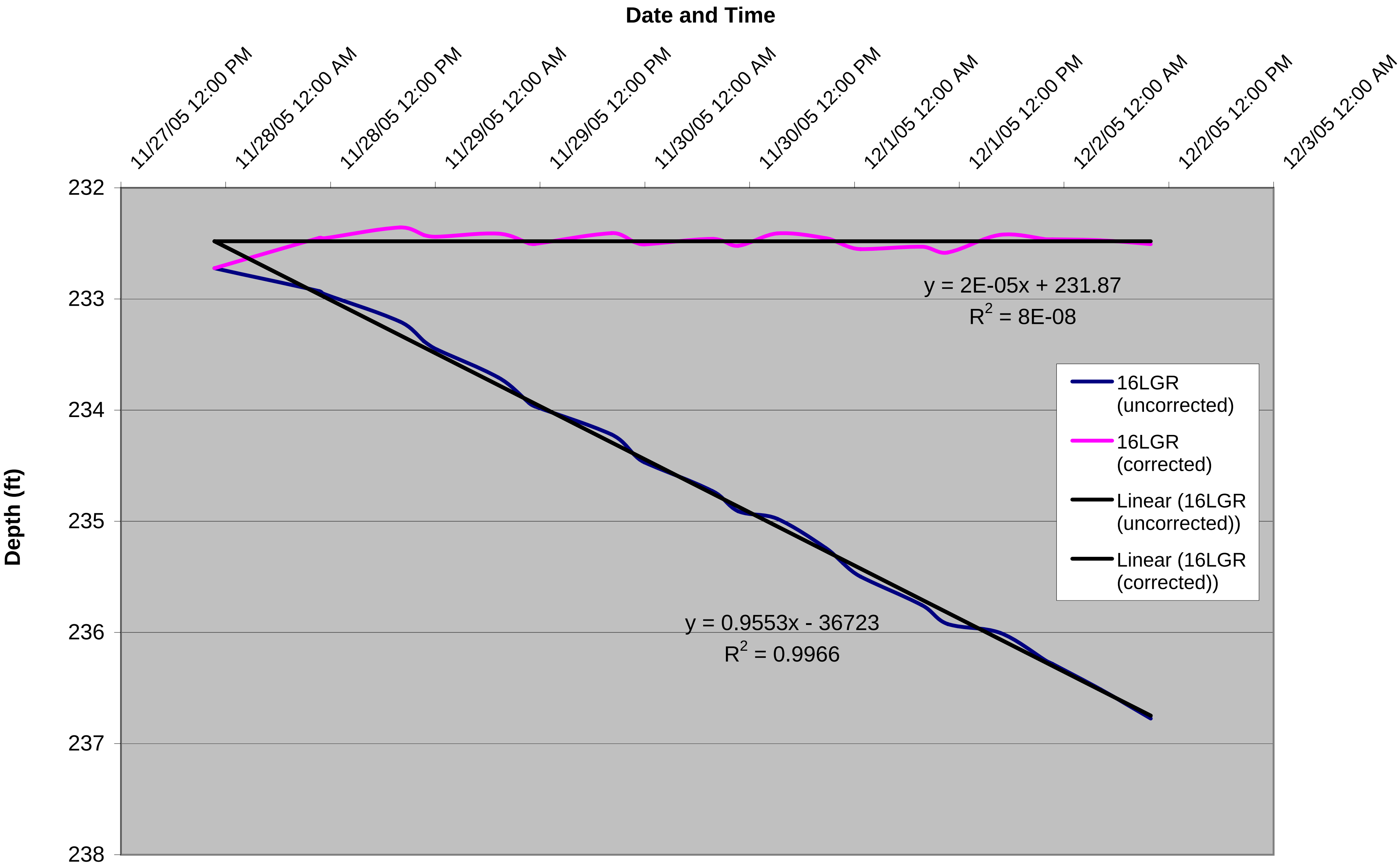
Figure 12
Regional Trend of CS-16-LGR



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Manual e-line measurements were also collected periodically from the pumping and observation wells to verify accuracy of the pressure transducer readings. E-line measurements were consistent with transducer readings thus validating the pressure transducer readings.

Groundwater pumping rates and discharge totals were monitored via a flow meter/totalizer installed along the CS-MW16-LGR discharge piping. Discharge rate was monitored throughout the pumping test and was adjusted as needed.

As with the CS-MW16-CC pumping test, the pumped groundwater from CS-MW16-LGR was routed to the CSSA GAC system for treatment. Discharge quantities were monitored at two locations during the pumping analysis. The total amount of water discharged from the pumping well was recorded as 43,193 gallons. The average pumping rate, based on volume pumped by the wellhead flowmeter, was 9.99 gpm. The total amount of water discharged from the GAC system was measured as 41,688 (9.65 gpm). The reasons for the 3 percent discrepancy between these two totalizer measurements are not known, but could have been due to system storage as previously. However, the measured flow rate from the wellhead totalizer was used for the purposes of this report.

Figure 13 presents a graph depicting corrected water level versus elapsed time for the pumping and observation wells included in the CS-MW16-LGR pumping/recovery analysis. As shown on Figure 13, responses to pumping were exhibited within CS-MW1-LGR, CS-MW2-LGR, CS-MW5-LGR, CS-D, and B3-MW1-LGR. The remainder of the conventional observation wells did not respond to the LGR pumping. Figure 14 shows the corrected water levels versus time for all six zones monitored in CS-WB05 during the CS-MW16-LGR pumping test. Responses were dramatic in LGR04A, LGR04B, and BS01. But, LGR03 only showed a slight and delayed response to pumping. CC01 and CC02 showed no response to the CS-MW16-LGR pumping, and in fact, were still recovering from the previous CS-MW16-CC pumping test.

Figure 15 presents a plot of corrected water level drawdown and recovery with respect to elapsed time as recorded in CS-MW16-LGR. The slight (less than 1 foot) but sudden drops in water level seen during the test coincided with pumping rate adjustment. As the pumping water level declines, the associated head loss causes a small but steady reduction of the discharge rate. To compensate and maintain a constant discharge rate the valve controlling flow must periodically be opened by small increments to allow more water to flow out and return the discharge to its prescribed rate. Each adjustment of the valve to a slightly more open position is reflected as a small, very brief and temporary drop in water level.

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Figure 13
CS-16-LGR Pump Test (corrected)

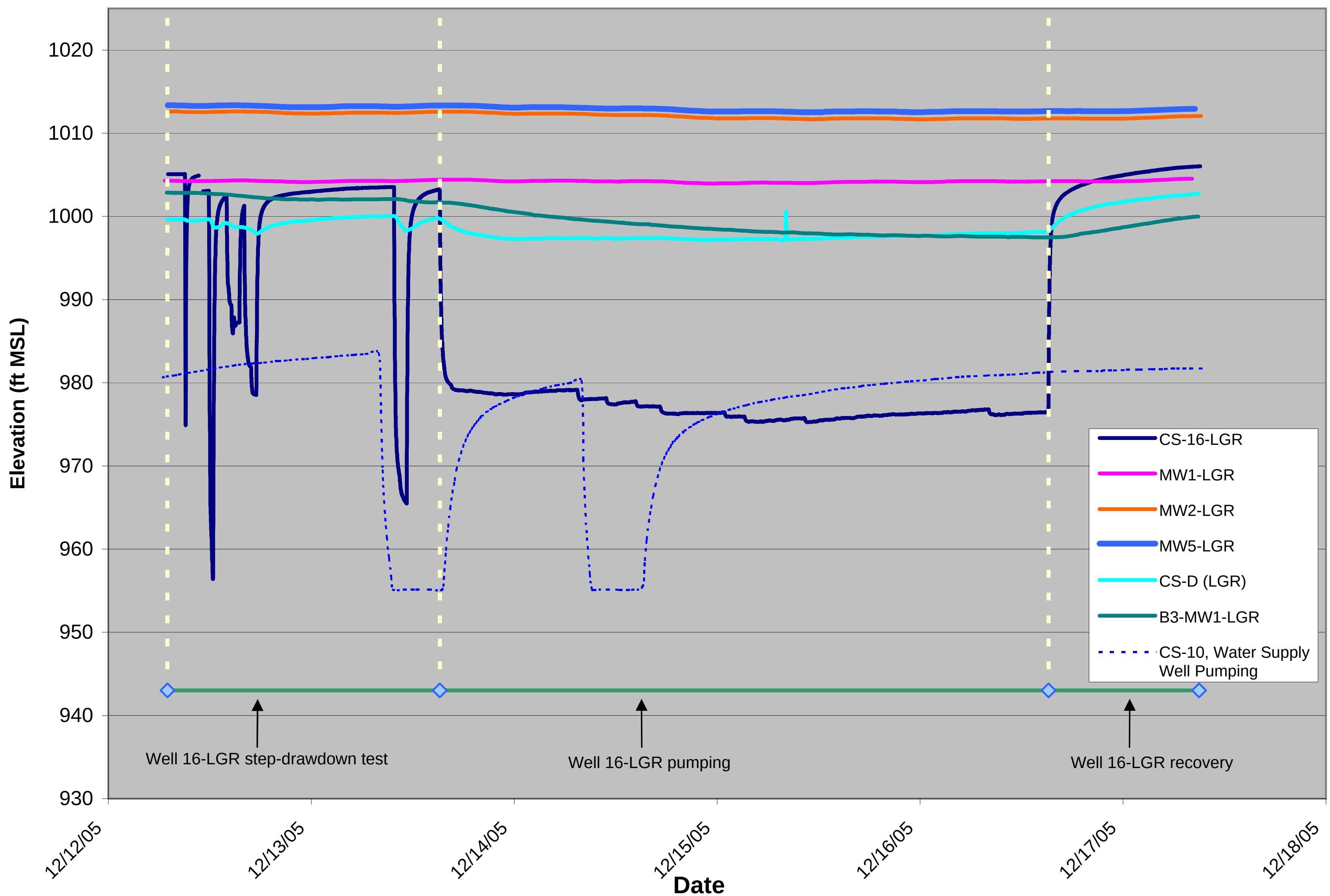

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Figure 14
CS-WB05 Data During the CS-16-LGR Pump Test (corrected)

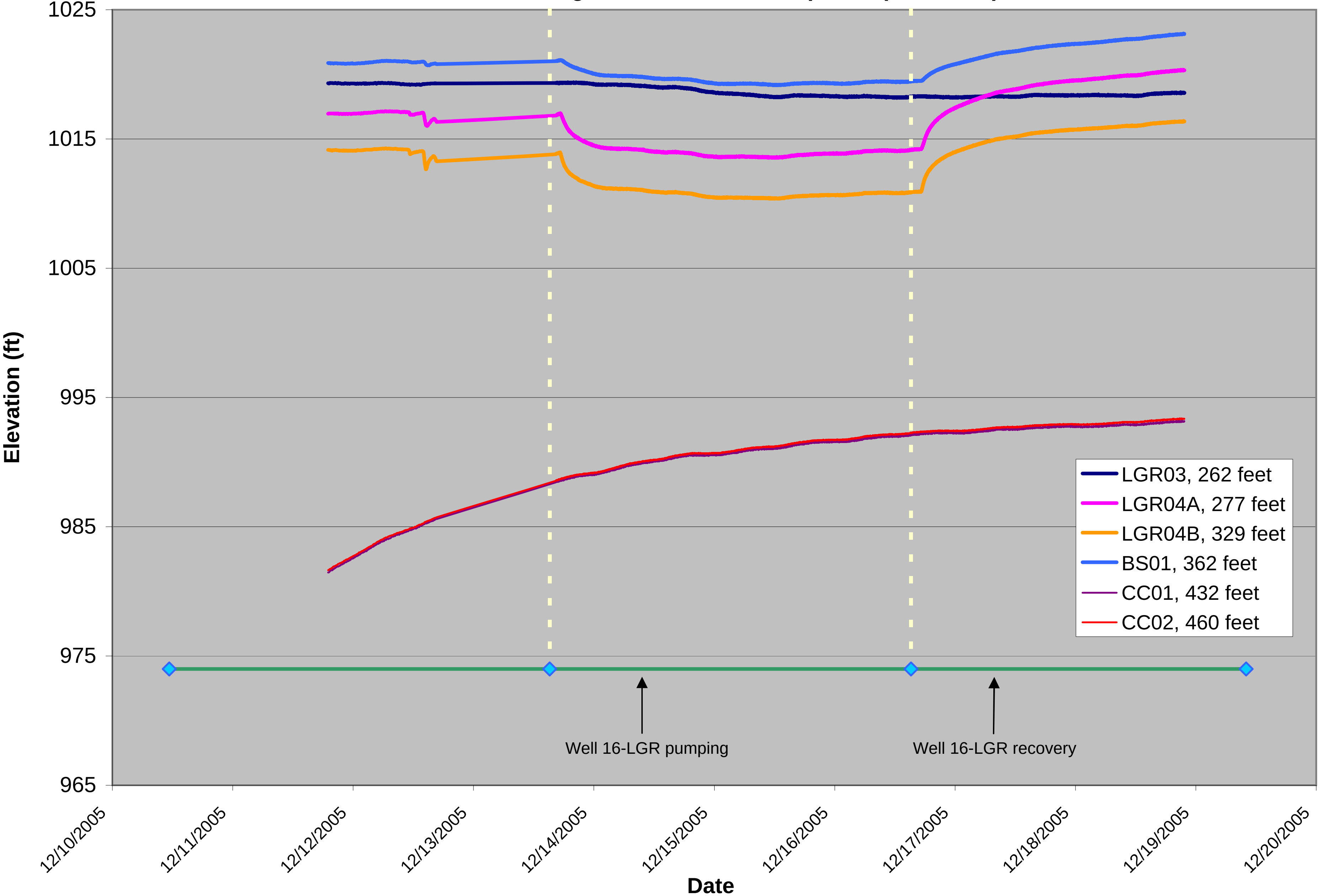

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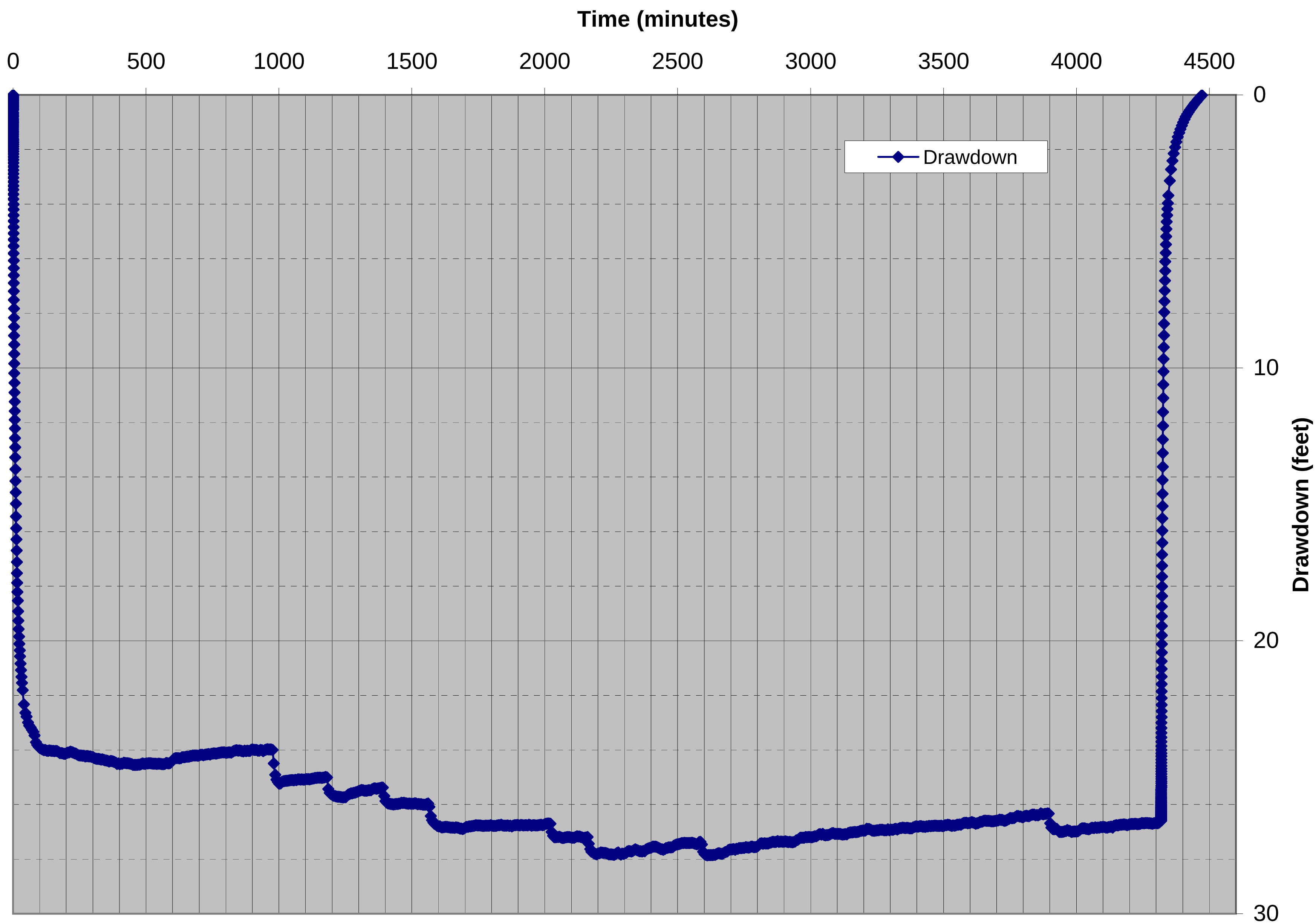
Figure 15
CS-16-LGR Drawdown/Recovery (corrected)



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As shown on Figure 15, approximately 28 feet of drawdown was measured within CS-MW16-LGR in association with the pumping test. Using the total drawdown (28 ft) and discharge rate (9.99 gpm), the specific capacity for CS-MW16-LGR was calculated using the following equation:

$$\mathbf{SC = Q/\Delta h}$$

Where:

SC = specific capacity

Q = CS-Discharge rate

Δh = total drawdown

As presented, the specific capacity of CS-MW16-LGR was calculated as 0.36 gpm/ft (9.99 gpm/28 ft).

Analysis of aquifer T and S was conducted with respect to CS-MW16-LGR utilizing the Theis equation via the aid of AQTESOLV For Windows^{TM} version 3.01. Assumptions associated with the Theis equation were presented in Section 3.1.3 the discussion relating to the CS-MW16-CC pumping/recovery test.

Various well construction details required as inputs into AQTESOLV were obtained from the existing CSSA database and summarized within Table 2. Values of K_z/K_r were assumed as unity for reasons discussed in Section 3.1.3. Values of aquifer saturated thickness were derived by assuming that the depth to water measurement at the start of the pumping test was representative of the static water level coupled with stratigraphic information summarized within the literature review section of this report. The saturated thickness (111.5 feet) was determined as the distance from the static water level to the contact of the LGR formation with the BS.

Using AQTESOLV, the original test runs using an unconfined solution indicated that the storativity values were too low to truly represent a water table condition, therefore the Theis confined solution was applied to the analysis of the CS-MW16-LGR pumping test data.

Appendix C presents the aquifer analysis curve and associated report generated by AQTESOLV in association with the CS-MW16-LGR pumping test analysis program. Depth to water observations obtained during the pumping/recovery test are included in the report generated by AQTESOLV. Visual curve matching was conducted to increase the accuracy of T and S values generated from the pumping test data. The observation wells that had an obvious response to pumping (CS-B3-MW1, CS-D, CS-WB05-4A, and CS-WB05-4B) were included in the analysis. The response of the BS zone (CS-WB05-BS1) is considered to be an artifact of the lower packer placement between the LGR and BS zones, and not truly an indicator of direct hydraulic response under natural conditions during pumping.

Table 5 is a summary of the aquifer parameters generated by AQTESOLV for the CS-MW16-LGR pumping test.

Table 5 AQTESOLV Results for Transmissivity and Storativity for the CS-MW16-LGR Pumping Test

	Theis Confined Solution		Theis Recovery Solution	
Observation Well Name	**Transmissivity (gpd/ft)**	**Storativity**	**Transmissivity (gpd/ft)**	**S'**
B3-MW1	726.8	4.25E-06	558	2.00
CS-D	1,423.4	1.54E-06	1,108.7	0.41
CS-WB5-4A	1,602.9	7.70E-09	519.3	2.35
CS-WB5-4B	1,267.9	1.22E-07	689.1	2.16
CS-16-LGR	1,095	N/A	231.6	N/A
Average[1]	1,223.2	1.48E-06	621.34	1.73
Combined[2]	1,219.5	1.22E-07	621.5	2.11

[1] Average - Does not include "Combined" results.
[2]Combined -Represents the "combined" solution when all observation wells are graphed and resolved simultaneously.

As discussed previously in Section 3.1.3, the results produced by AQTESOLV software were generated utilizing two different analytical methods. The first columns represent data generated using the Theis solution for a confined aquifer. Using this method, AQTESOLV can produce data for the transmissivity and the storativity coefficient of the aquifer. Based on the combined model, the transmissivity and storativity for the LGR at CS-MW16-LGR is 1,219.5 gpd/ft and 0.000000122, respectively. The value of storativity determined from the CS-MW16-LGR pumping test indicates that water-producing intervals are under confining conditions.

The Theis recovery method of aquifer evaluation was also performed utilizing the same data set. This method analyzes only those data recorded after the pumping stopped. Transmissivity values are calculated as they are for the regular Theis solution, however, instead of computing a storage coefficient, the Theis recovery method calculates an S' (prime) which is defined as the ratio of storativity during pumping to the storativity during recovery. The values determined from the Theis recovery method are approximately 50 percent of those determined by the tradition Theis confined solution.

For the recovery solution, the results of S' being greater than 1.0 indicates the influence of a recharge boundary during the test. A recharge boundary could include a structural feature that conveys significantly more groundwater that what is typically present around the well, or could be a hydraulic effect due to a surface water body or active precipitation recharge. While the total precipitation received at the site during the CS-MW16-LGR pumping test was less than 0.05 inches, it could possibly have influenced the test enough such that the results are divergent. Potentially, significantly more rainfall was received elsewhere that could unknowingly skewed the data.

Using transmissivity (1,219.5 gpd/ft) and saturated thickness (111.5 ft), hydraulic conductivity may be calculated using the following equation:

K=T/b

Where:

K = hydraulic conductivity (gpd/ft^2)

T = transmissivity (gpd/ft)

b = saturated thickness (ft) and,

1 gpd/ft^2 = 0.0000472 centimeters per second (cm/sec)

As presented, the hydraulic conductivity of the LGR portion of the middle Trinity aquifer was calculated as 10.937 gpd/ft^2 or 5.16×10^{-4} cm/sec in the CS-MW16-LGR vicinity.

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SECTION 4
DISCUSSIONS AND CONCLUSIONS

4.1 DISCUSSIONS

The performance of these two tests is a departure from the traditional approach of determining hydraulic properties for the middle Trinity aquifer. Typically, the aquifer is tested a single unit within open borehole wells that penetrate both the LGR and CC Limestones. However, this study has been unique in the fact that it allowed separate testing of the LGR and CC aquifer members at the same basic location. In addition, it allowed the retesting of a previously tested well that was once open through the entire thickness of the middle Trinity aquifer, and then had been re-completed in one formation (the LGR).

Table 6 summarizes and compares results of the 2005 individual pumping tests with respect to those values obtained in 2001 when former CS-16 was a fully penetrating open borehole completion. In theory, the summation of results for specific capacity and transmissivity for the individual LGR and CC tests should approximate the results of the 2001 test of the single middle Trinity aquifer well completion (assuming that the contribution from the BS is negligible).

Table 6 Comparison of Aquifer Parameters at the CS-MW16 Well Location (2001 and 2005)

	CSSA (2001)	**CSSA (2005)**	
Aquifer Parameter	**CS-16 (middle Trinity aquifer)**	**CS-MW16-CC *(Cow Creek)***	**CS-16-LGR (Lower Glen Rose)**
Specific Capacity *(gpm/ft)*	0.71	0.16	0.36
Transmissivity *(gpd/ft)*	1,600	255.9	1,219.5
Hydraulic Conductivity *(cm/sec)*	5.7×10^{-4}	1.61×10^{-4}	5.16×10^{-4}
Storativity	0.00008	0.00000917	0.000000122

While the LGR did not yield as high a flow rate as the CC portion of the aquifer, the LGR was found that it transmits groundwater more efficiently with less overall drawdown per unit of yield. This aspect is best demonstrated by the results of specific capacity and transmissivity for each well. The summations of the individual tests are approximately 75 to 90 percent of the values previously determined for specific capacity and transmissivity in the 2001 single-well test.

The individual results for storativity would appear to be erroneously small when compared to the 2001 single-well test and literature values. For the middle Trinity aquifer, storativity values typically range in magnitude on the order of 10^{-4}. However, results from the 2005 pumping tests indicate storativity values between the range of 10^{-6} and 10^{-7} for the CC and LGR, respectively. Intuitively, these values would be expected to greater.

Possible explanations for the lower hydraulic parameter values can be associated with the ongoing current drought that is affecting the central Texas region. Groundwater water levels are severely depressed from their normal levels, and therefore are expected to impact the behavior and yield of a well. It is likely that potential water-bearing zones in upper strata of the LGR were completely dry and therefore non-yielding at the time of the December 2005 testing.

Another potential scenario is that the overall yield of the LGR portion of CS-MW16-LGR has been impacted by the plugging and reconstruction activities of 2002. Well CS-MW16-LGR was anticipated to yield between 25 and 30 gallons per minute for the duration of the December 2005 test. The actual sustainable yield between 10 and 15 gpm was unexpected. It is possible, if not likely, that a major flowpath at the base of the LGR aquifer has been plugged by cement or bentonite during the 2002 reconstruction activities. If a major flowpath has been compromised, the expected result would be an overall decrease in capacity, transmissivity, and storativity. The lesser hydraulic parameters determined in this study may very be the result a major flowpath not being averaged into the analysis if it has been eliminated from the borehole.

These differences may also be explained by the fact that the hydrologic setting deviates from the basic underlying assumptions of the Theis equation. More specifically, the middle Trinity aquifer does not behave as a homogenous and isotropic entity. For example, the Theis curve analysis indicates that the aquifer is behaving under a confined condition given the low values of storativity calculated. However, some literature considers the LGR as a water table aquifer and the CC member as a confined aquifer.

4.2 CONCLUSIONS

Parsons conducted two pumping tests at CSSA wells CS-MW16-CC and CS-MW16-LGR in December 2005. The tests were performed to achieve a more detailed understanding of middle Trinity aquifer characteristics at SWMU B-3, the relationship between the formations comprising the aquifer, and how this relates to the SWMU B-3 groundwater contaminant plume. The two test wells are about 275 feet from the northwest edge of SWMU B-3, are 30 feet apart, and monitor the main water-bearing zones of the LGR and CC formations. The wells are within the SWMU B-3 chlorinated solvent plume. The LGR and underlying CC are separated by the 60-foot thick BS aquitard. The two pumping tests showed that in the test area the effectiveness of the BS as an aquitard is uncompromised by secondary geologic features such as faults, and that the BS maintains hydraulic separation between overlying LGR and underlying CC in the vicinity of the test area.

4.2.1 CS-MW16-CC

The CS-MW16-CC pumping and recovery test was conducted December 7 to 10, 2005. CS-MW16-CC is completed with 25 feet of screen in the main water-bearing zone of the CC and sealed from the overlying BS and LGR. The discharge rate was held at an average 21.44 gpm for 69 hours, pumping a total of 88,341 gallons. A vertical gradient of 131.45 feet was established in the pumping well. Moderate drawdown was observed in other CC wells up to 3,770 feet away. Monitored LGR wells showed no response to the induced CC groundwater gradient, indicating no significant hydraulic interconnection between the CC and LGR within the pumping well's radius of influence. The radius of influence spread laterally but its upward effects stopped at the BS. The BS was an effective hydraulic barrier, blocking the induced gradient from expanding into the LGR. The BS is generally acting as an impermeable barrier to vertical groundwater movement between the LGR and CC. The CC portion of the aquifer is under pressure and exhibits confining properties at SWMU B-3. Groundwater contamination in the CC at SWMU B-3 was likely the result of man-made openings (open wells) through the BS aquitard. Former supply well CSSA Well-16 was such a conduit. The well was backplugged and modified to an LGR monitoring well in 2003 and redesignated CS-MW16-LGR. The borehole is open to the LGR and no longer in contact with the BS and CC.

4.2.2 CS-16-LGR

Parsons performed a pumping and recovery test at CS-MW16-LGR from December 13 to 16, 2005 at a steady rate of 10 gpm for 72 hours. Total discharge was recorded as 43,193 gallons. CS-MW16-LGR is cased from ground surface to 193 feet, and is an open borehole from 193 to 310 feet, to near the base of the LGR. Obvious response to CS-MW16-LGR pumping was limited to only 3 nearby LGR wells. No BS or CC well water levels were influenced by CS-MW16-LGR pumping. Influence from pumping expanded horizontally through the LGR, but the BS blocked any downward effects of groundwater withdraw, leaving the underlying formations unaffected. Very shallow drawdowns between 0.2 and 0.7 feet were observed in more distant LGR wells up to 2,500 feet away. The saturated portion of the LGR exhibited confining properties under the hydrologic conditions existing at the time. This indicates that there are semi-permeable to relatively impermeable geologic layers above the main water-bearing zones of the LGR that hinder quick hydraulic communication with the more shallow subsurface.

The CS-MW16-LGR and CS-MW16-CC pumping test results both show that the BS acts as a confining layer above the CC. In the test area, the BS appears to lack open fractures or other structural features that would allow significant vertical groundwater movement through it, thus maintaining hydraulic separation of the LGR and CC. Groundwater VOC contamination in the CC at SWMU B-3 likely resulted from the open hole construction of former CSSA Well-16, which breached the BS and provided a connection from the LGR to the CC. Former CSSA Well-16 is now an LGR monitoring well closed to the BS and CC.

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APPENDIX A
REGIONAL TRENDS FOR ALL OBSERVATION WELLS

Figure A.1
Regional Trend of CS-WB05-LGR03

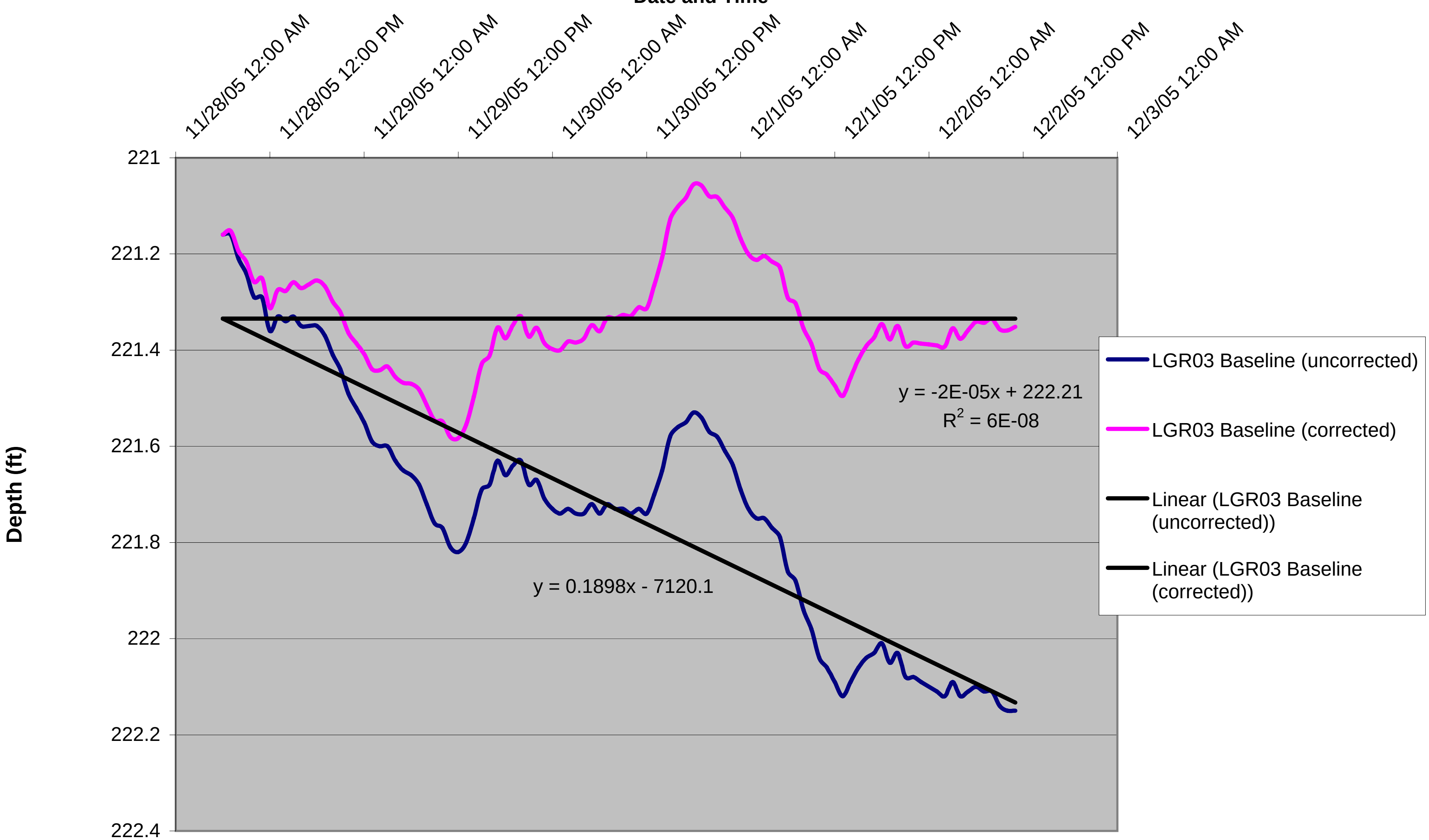

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Figure A.2
Regional Trend of CS-WB05-LGR04A

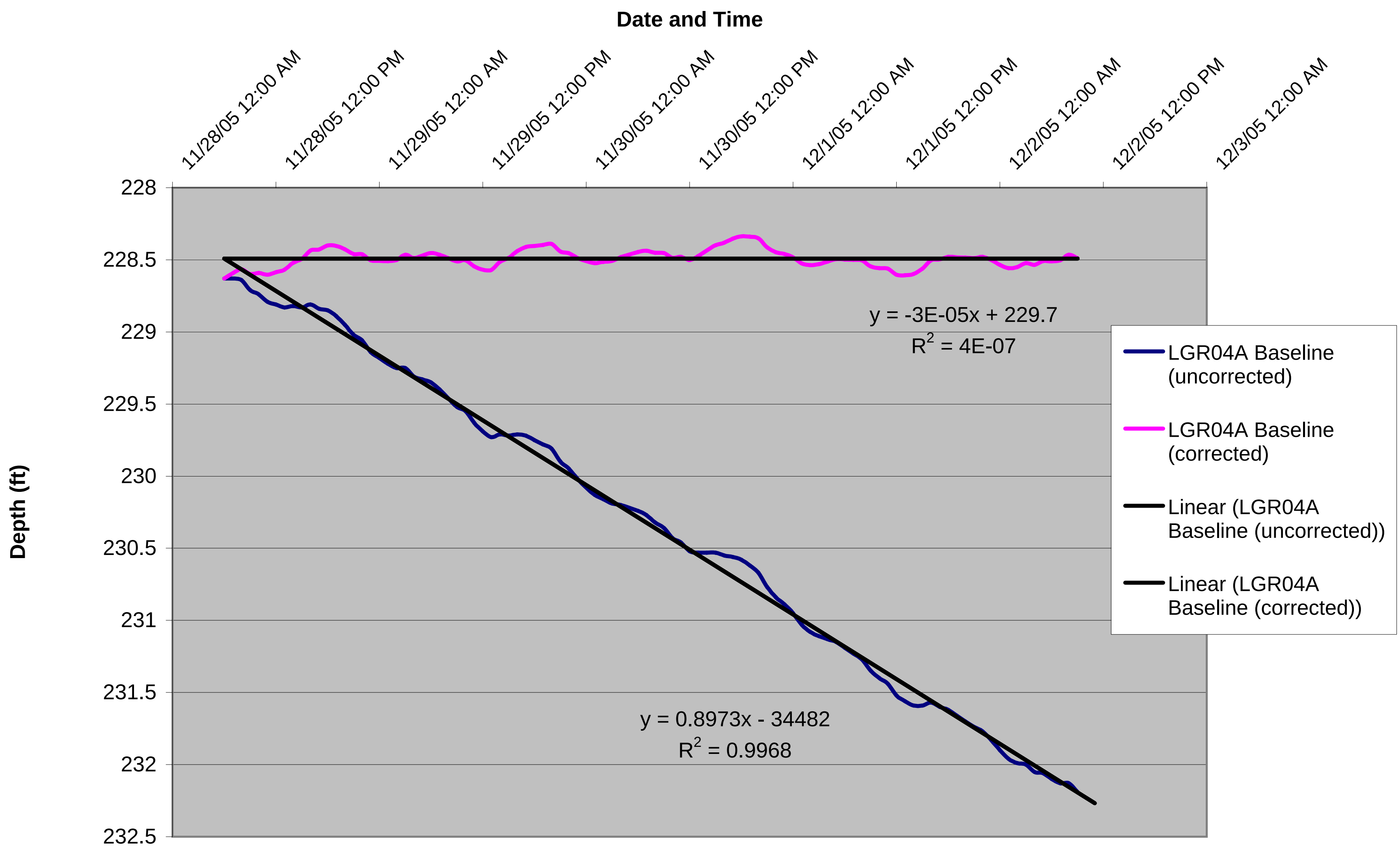

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Figure A.3
Regional Trend of CS-WB05-LGR04B

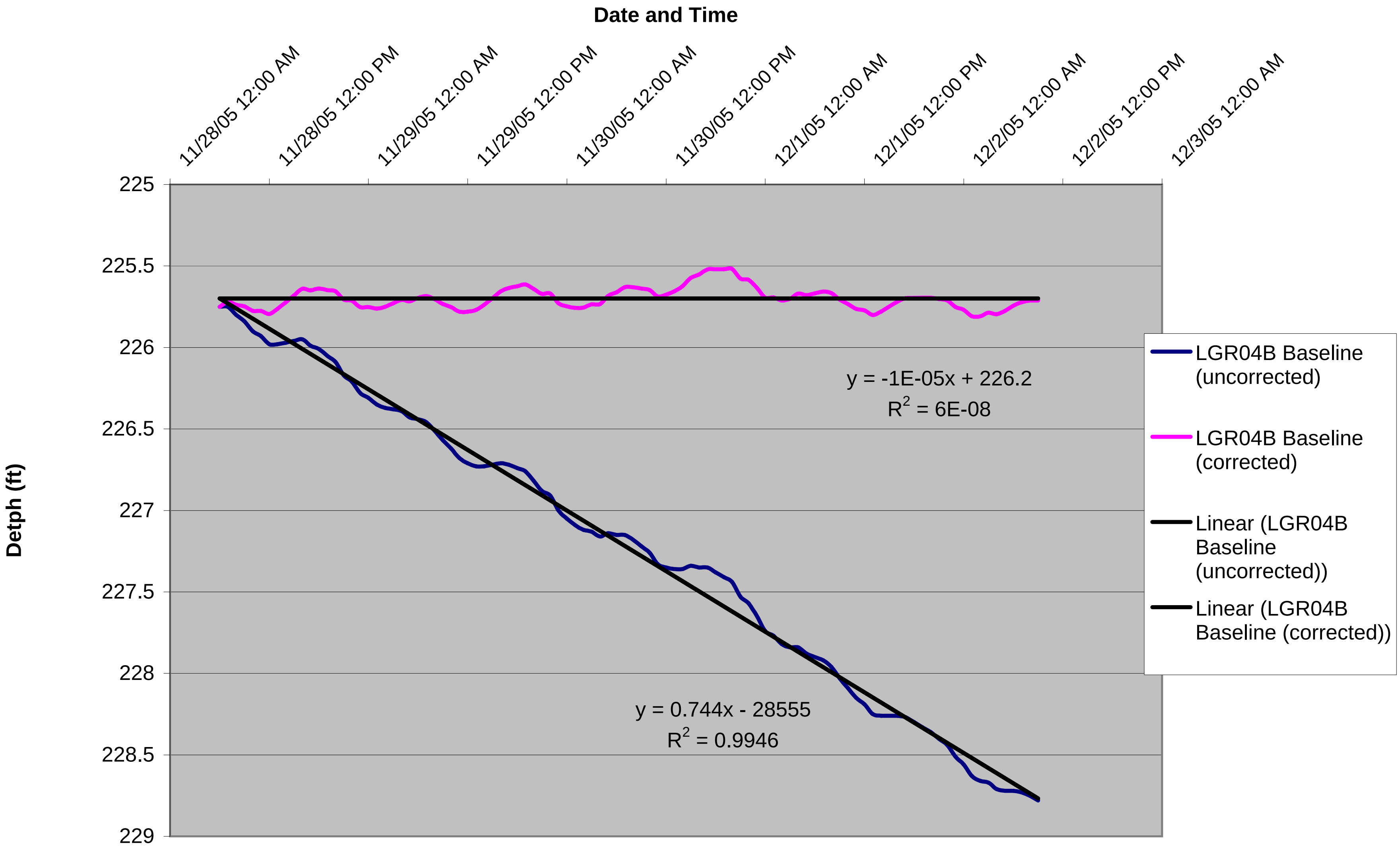

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Figure A.4
Regioanl Trend of CS-WB05-BS01

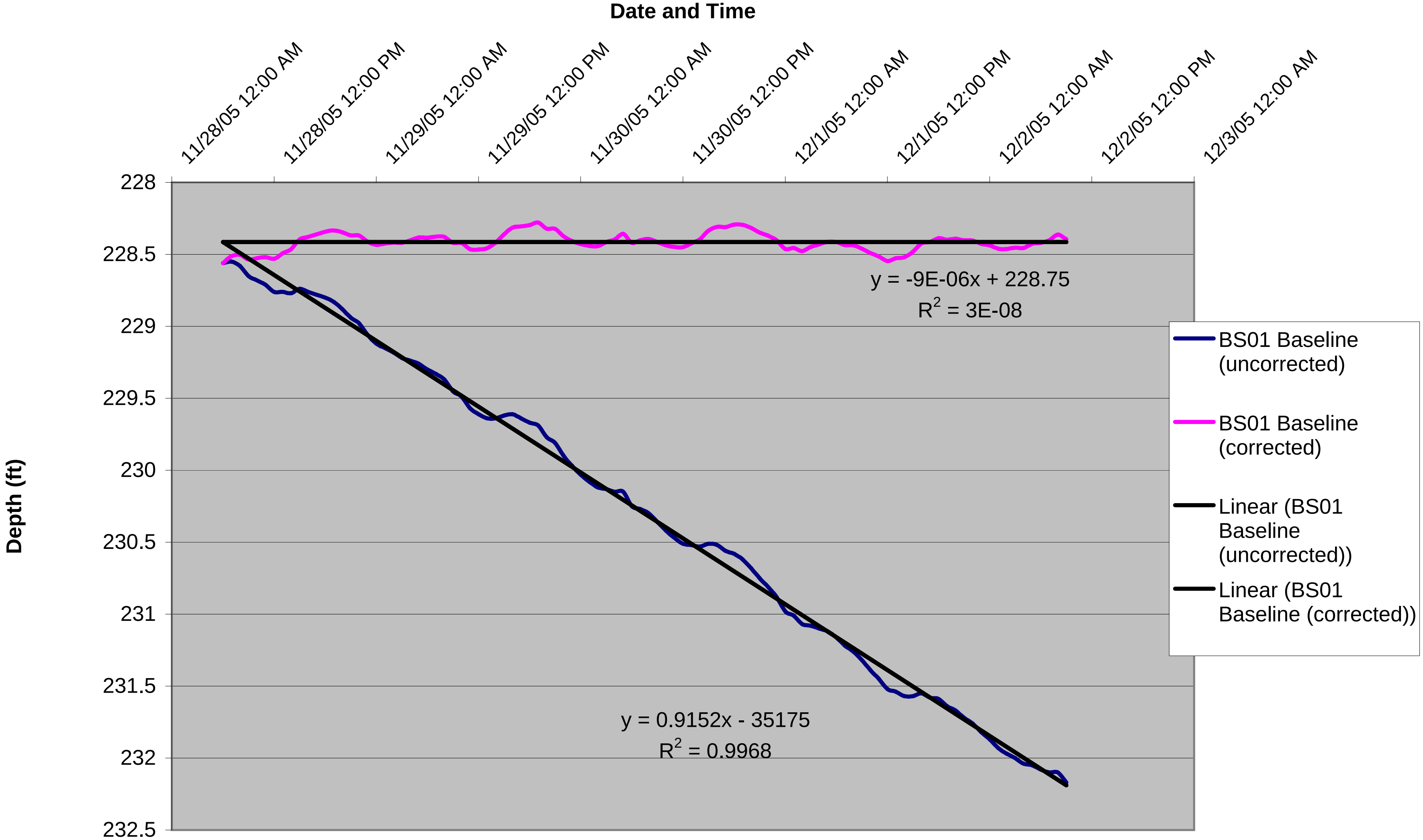

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Figure A.5
Regional Trend of CS-WB05-CC01

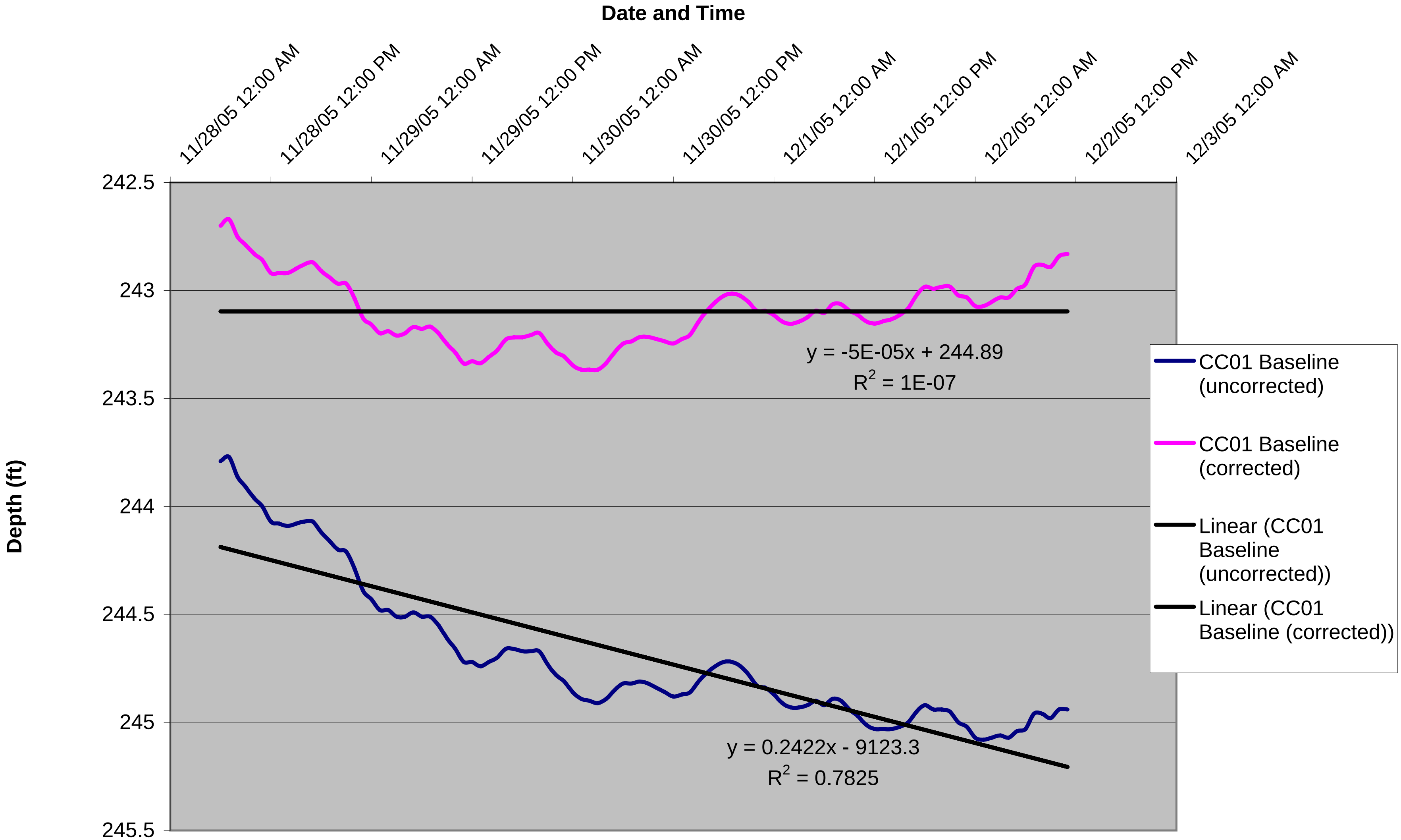

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Figure A.6
Regional Trend of CS-WB05-CC02

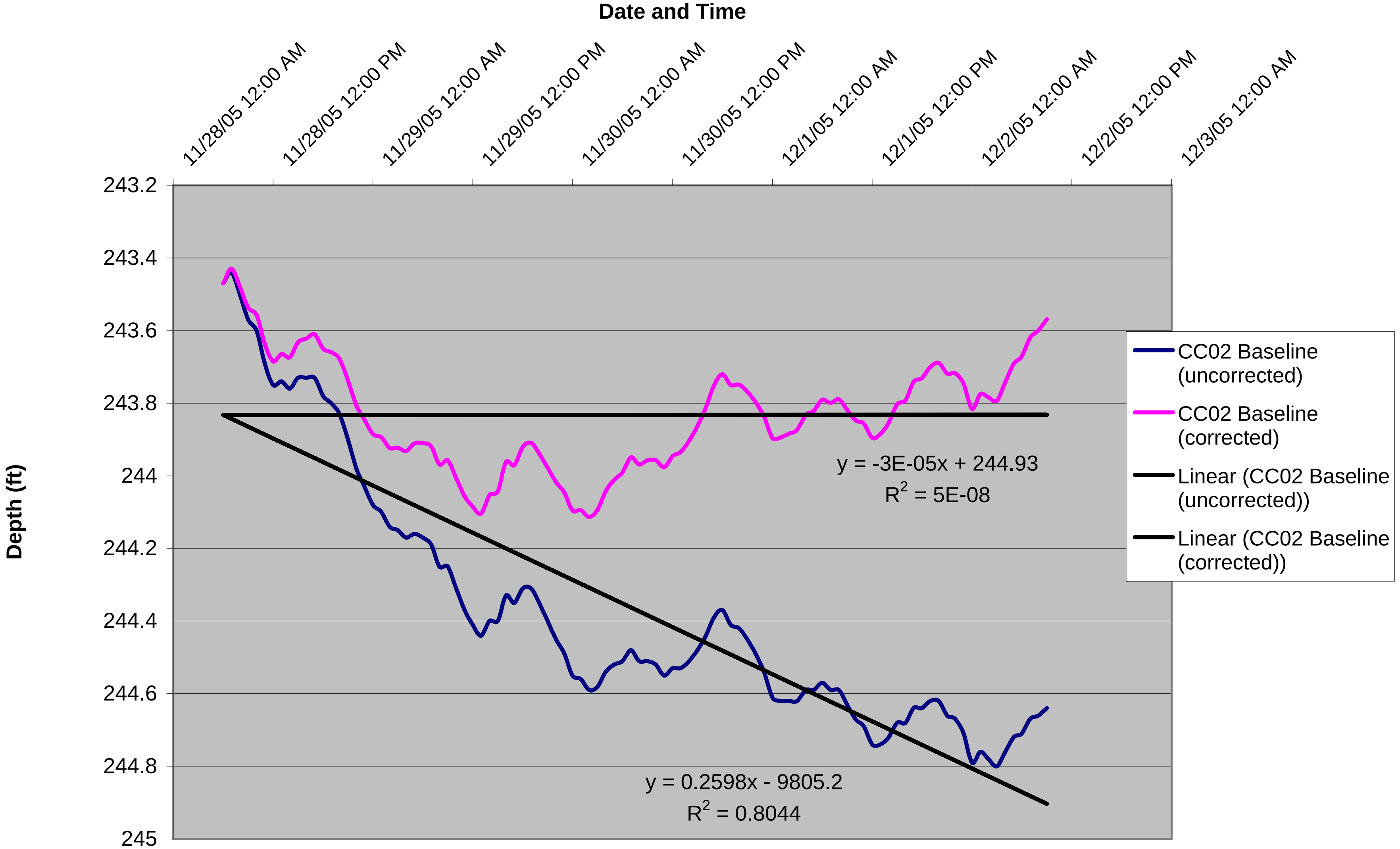

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Figure A.7
Regional Trend of B3-MW01-LGR

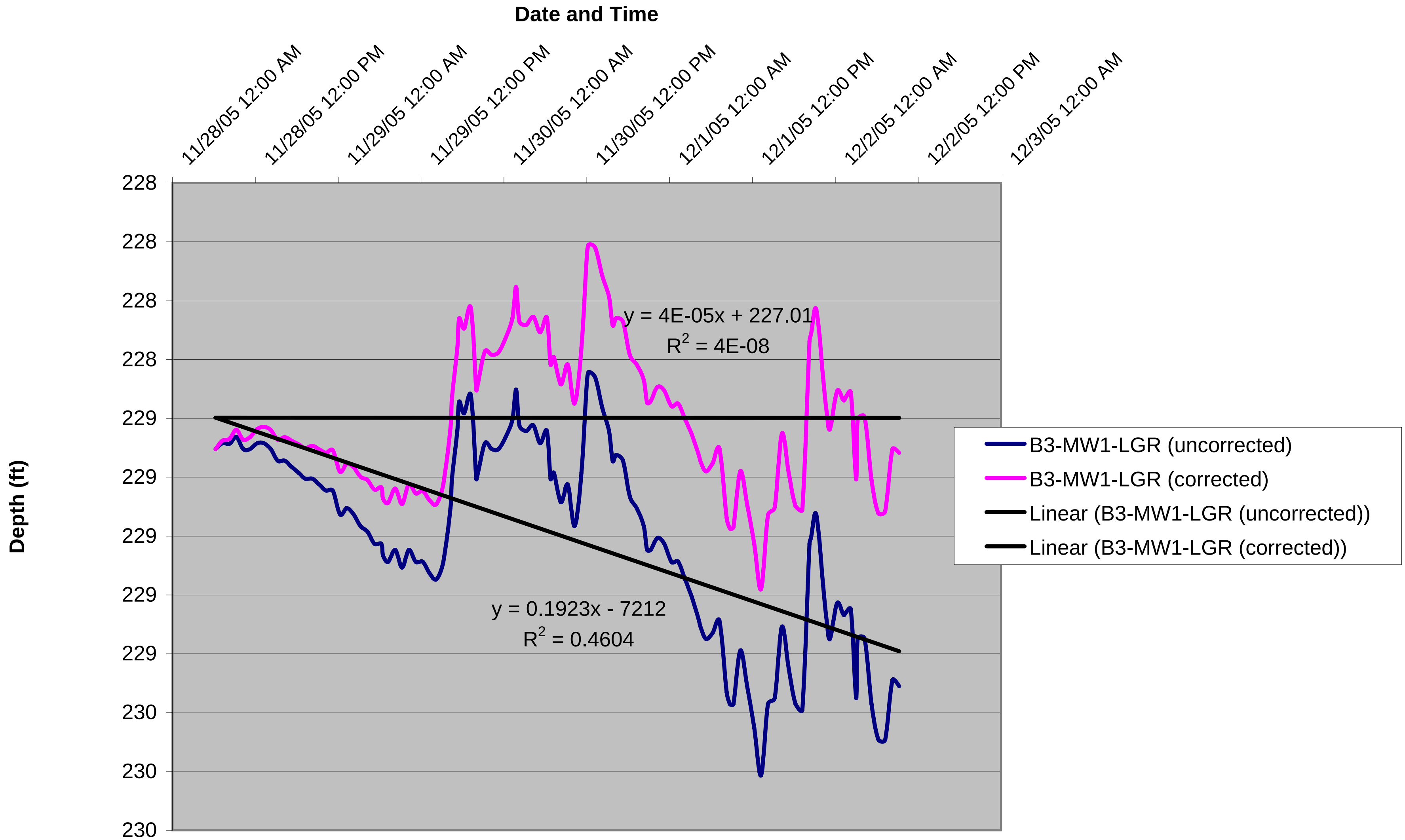

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Figure A.8
Regional Trend of CS-D

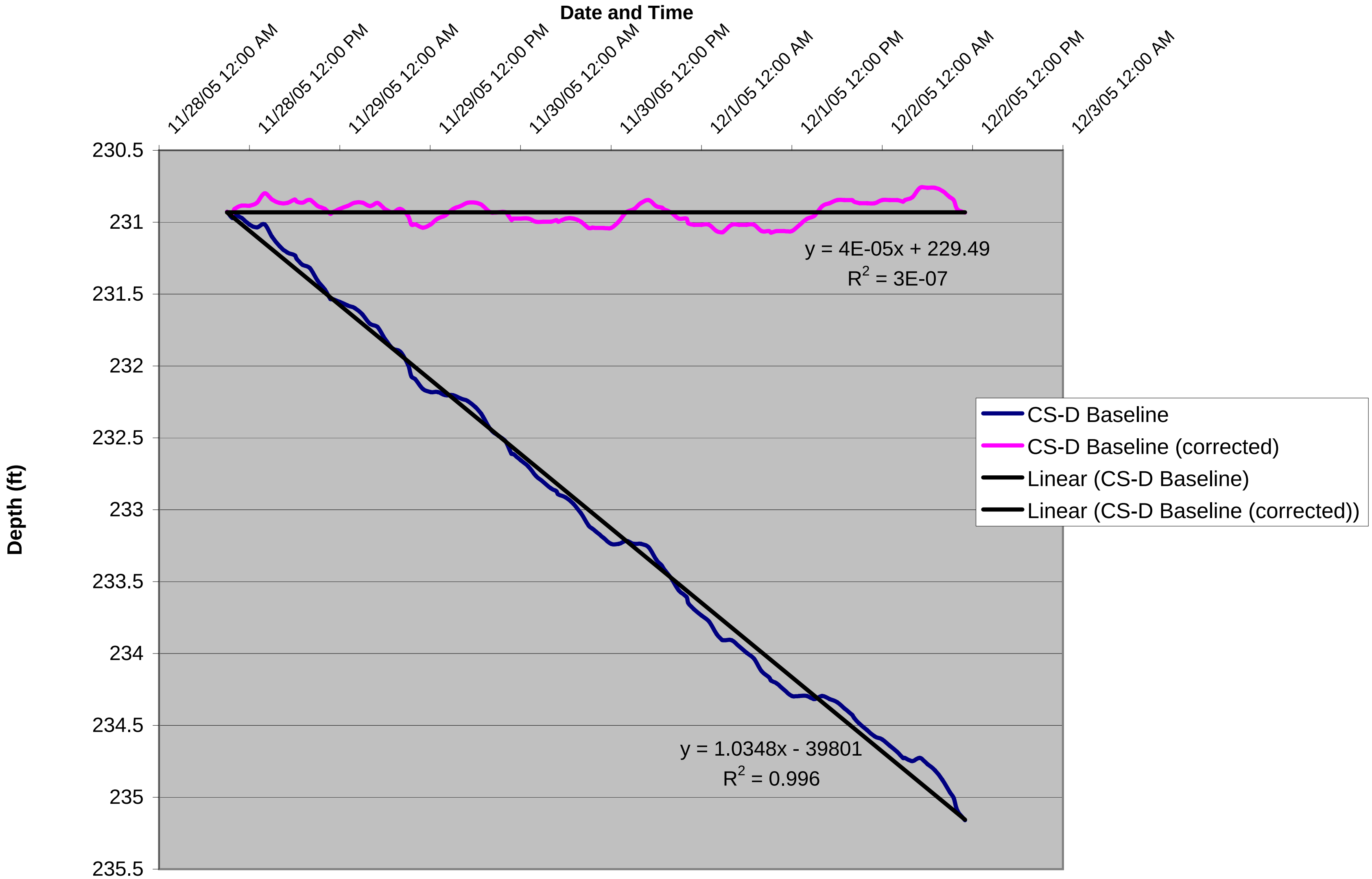

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Figure A.9
Regional Trend of CS-2

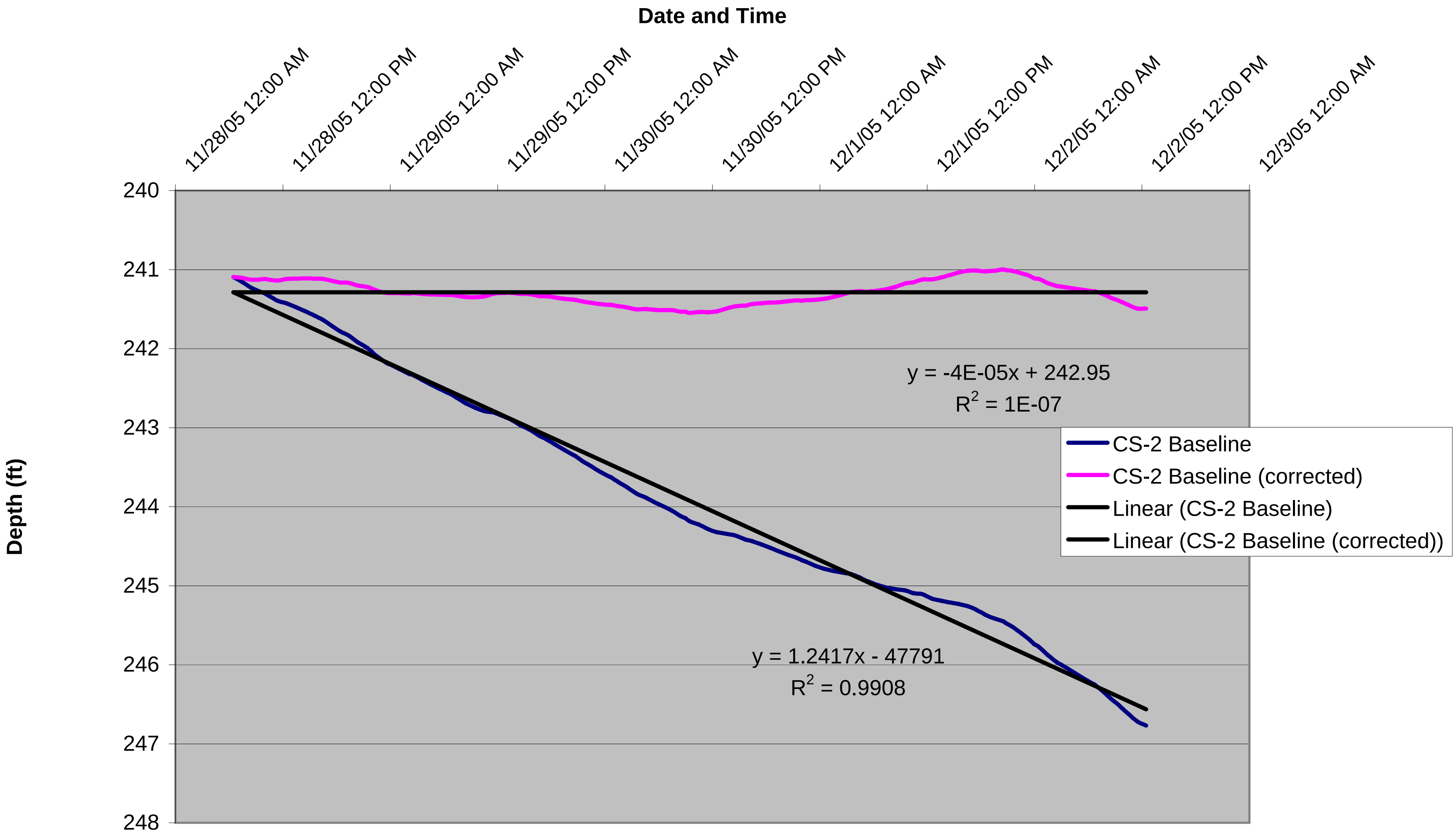

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Figure A.10
Regional Trend of MW1-LGR

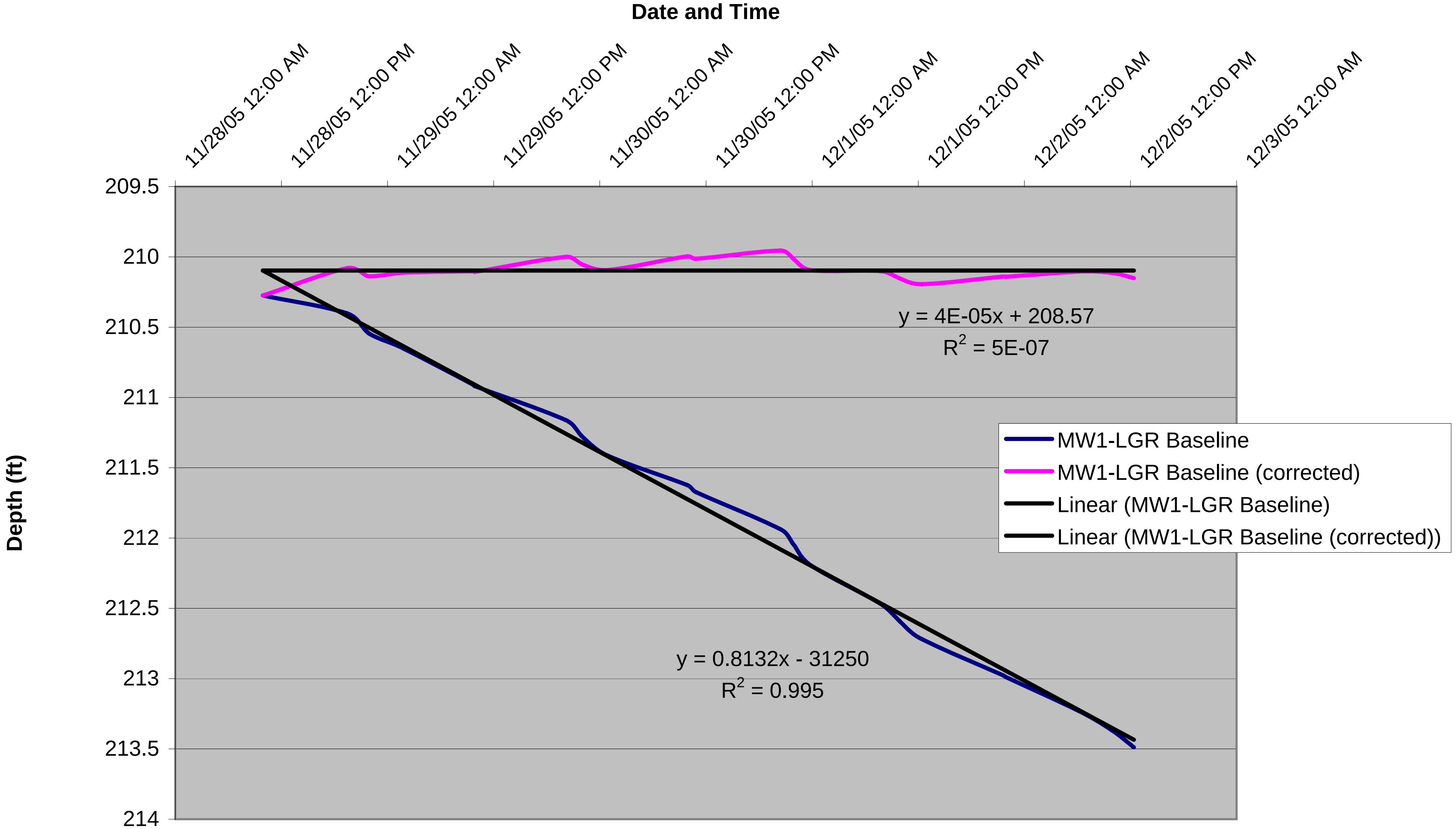

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Figure A.11
Regional Trend of MW1-BS

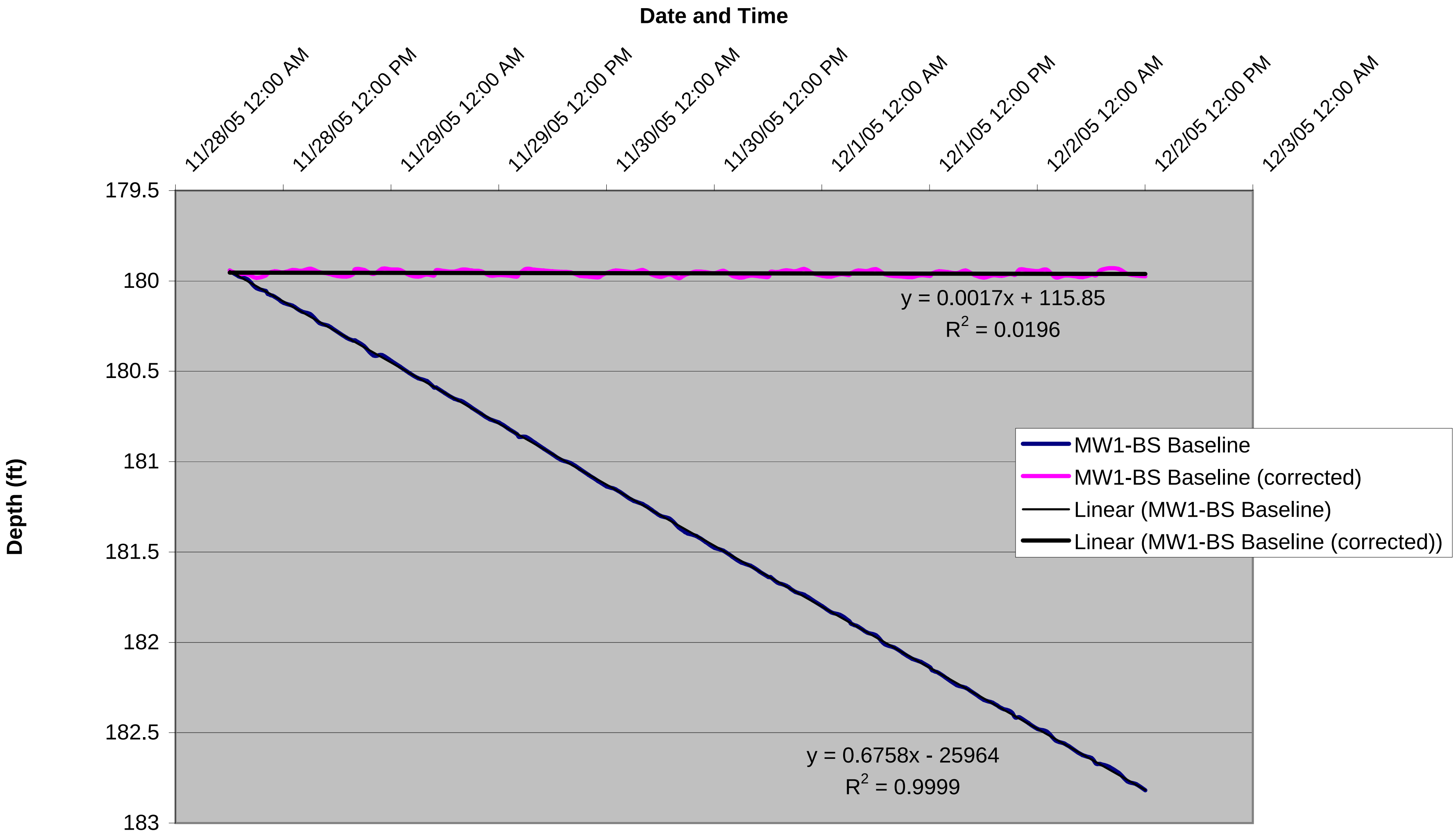

Figure A.12
Regional Trend of MW1-CC

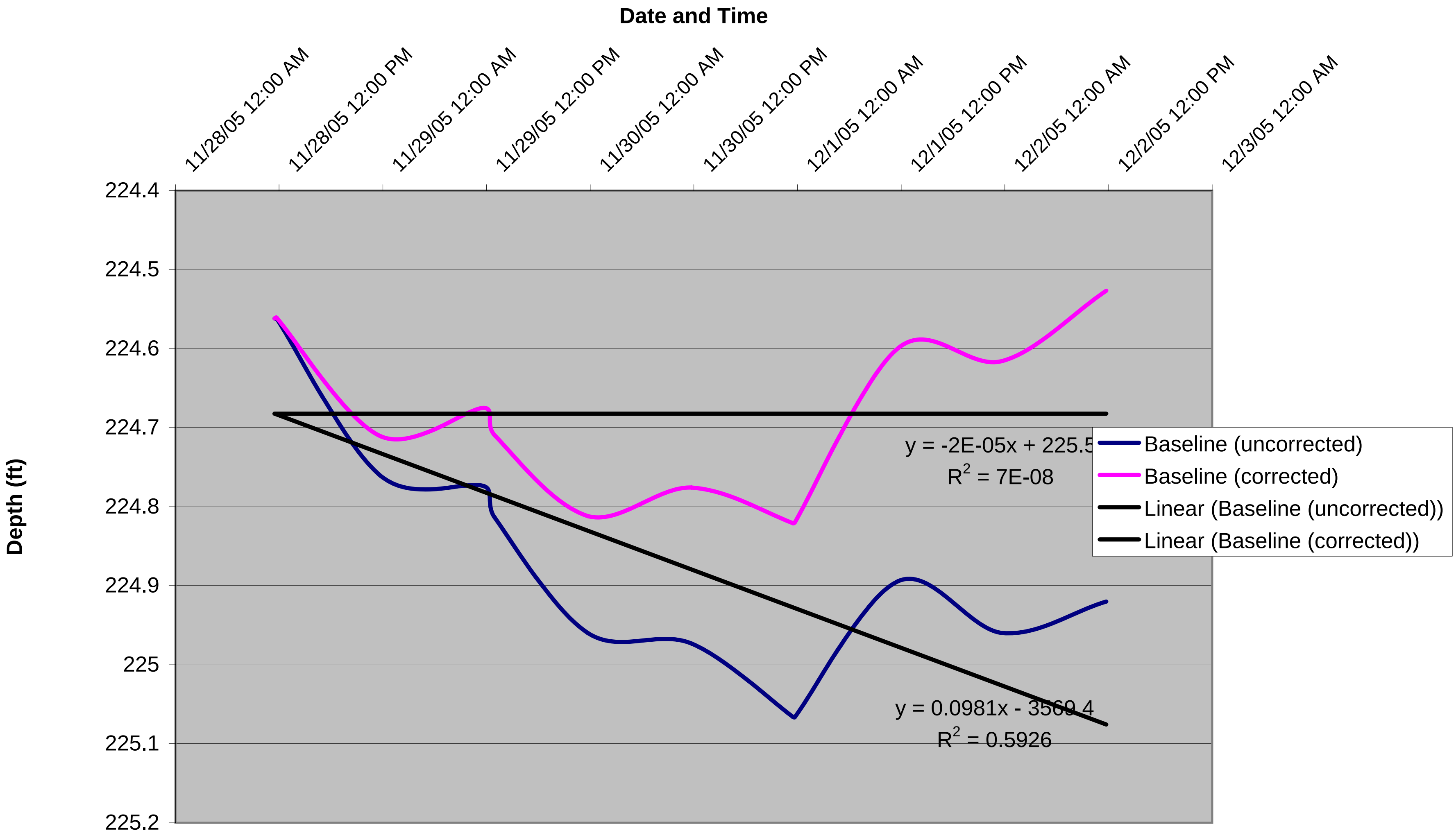

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Figure A.13
Regional Trend of MW2-LGR

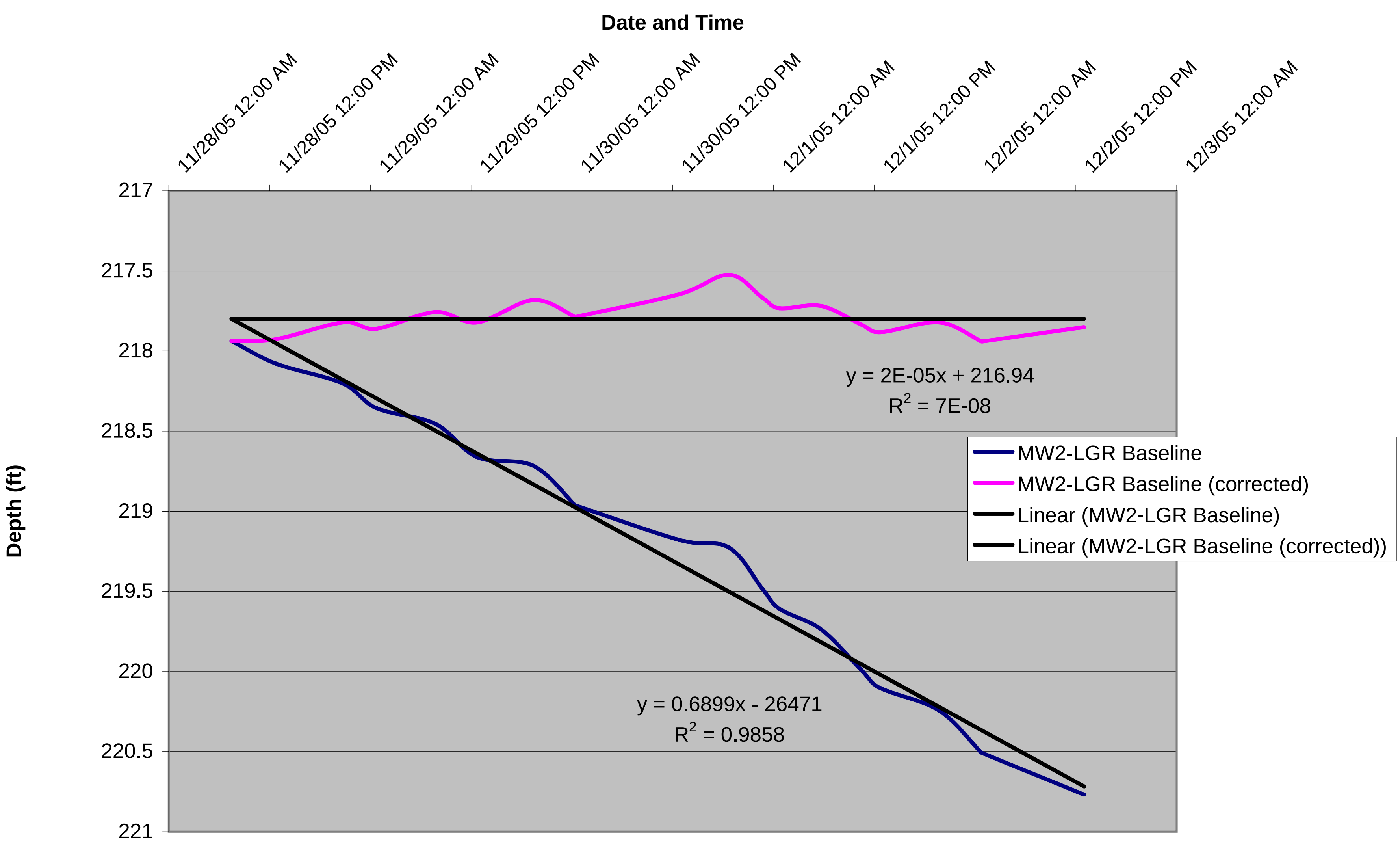

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Figure A.14
Regional Trend of MW2-CC

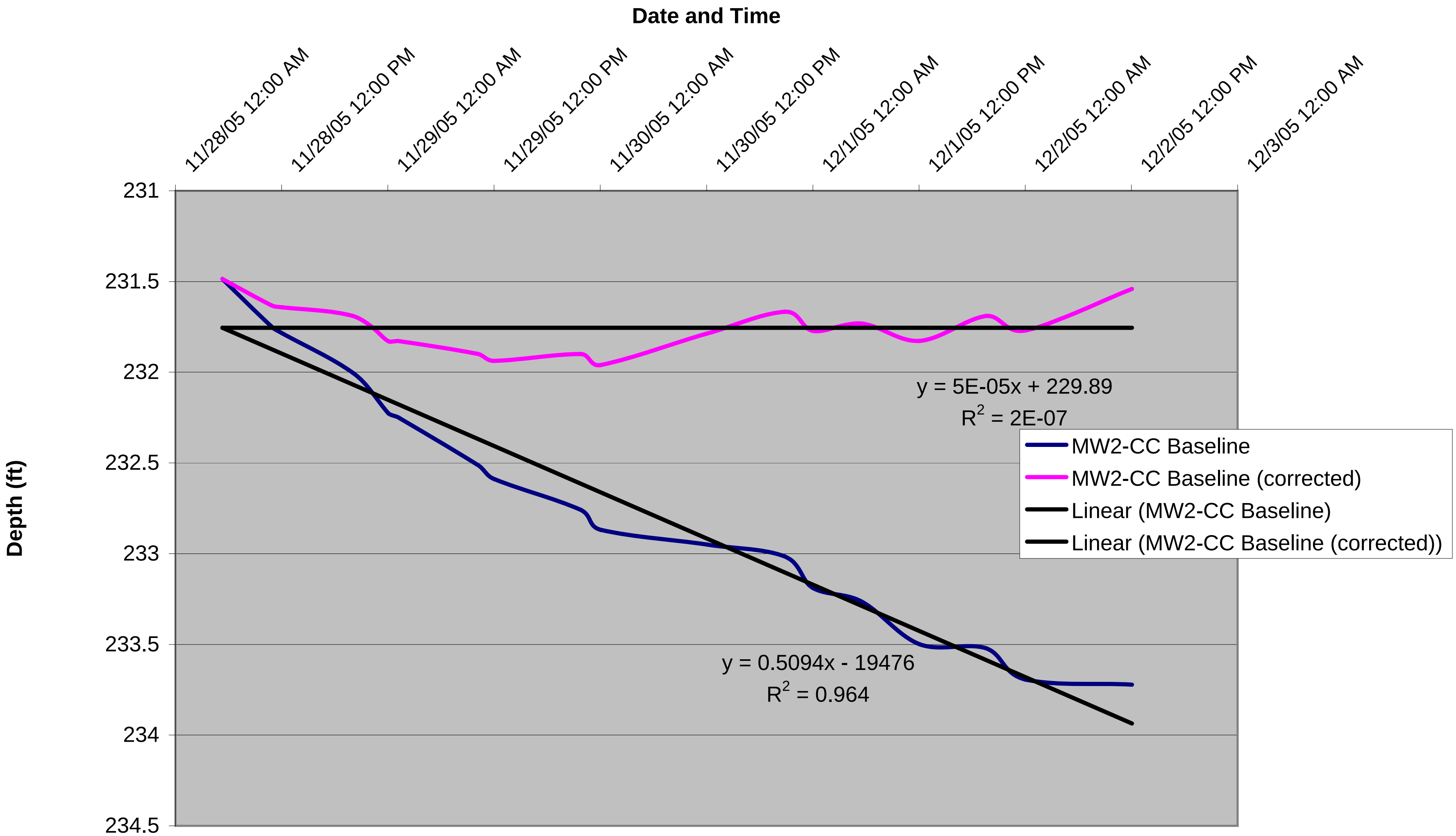

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Figure A.15
Regional Trend of MW4-LGR

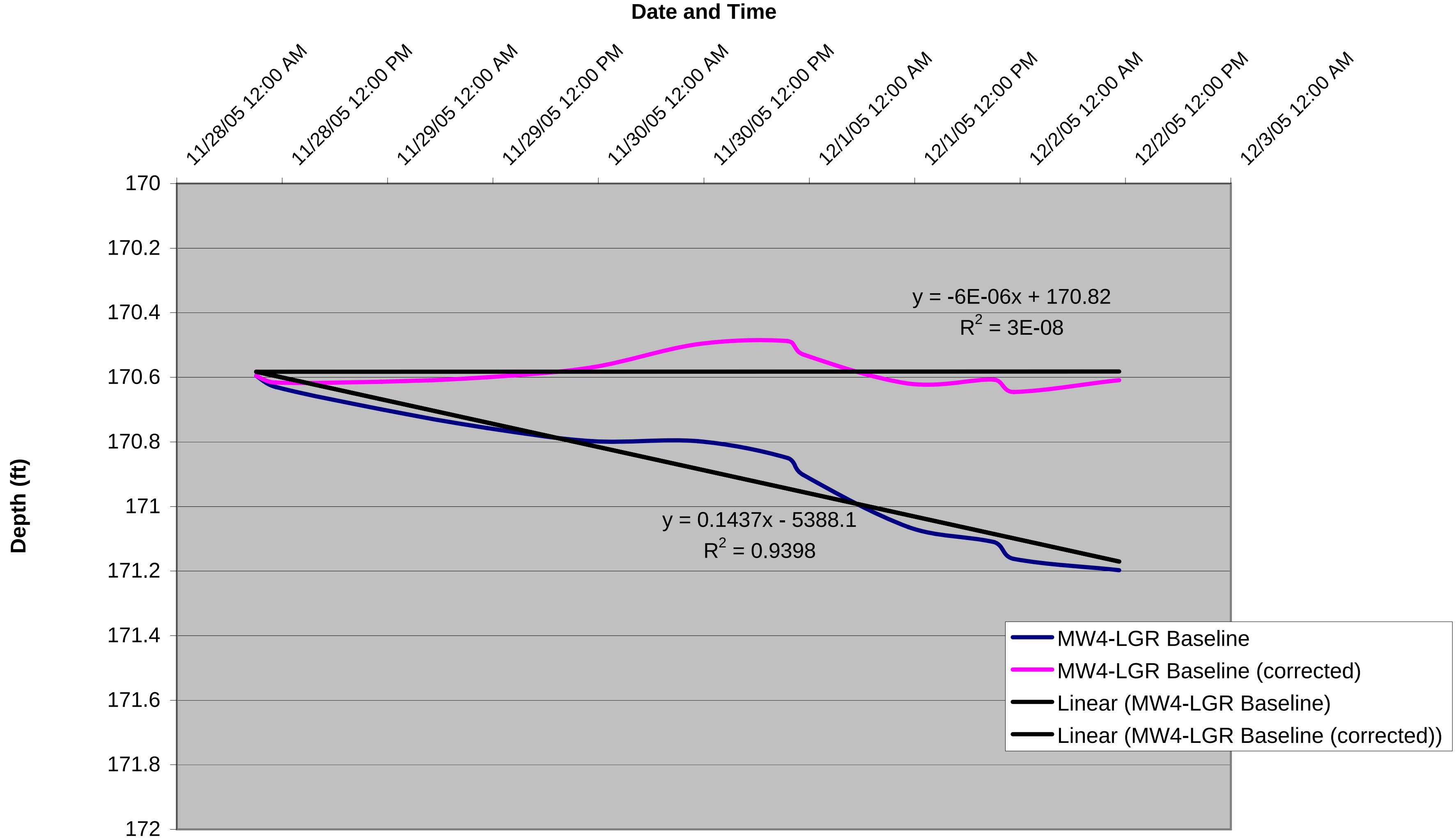

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Figure A.16
Regional Trend of MW5-LGR

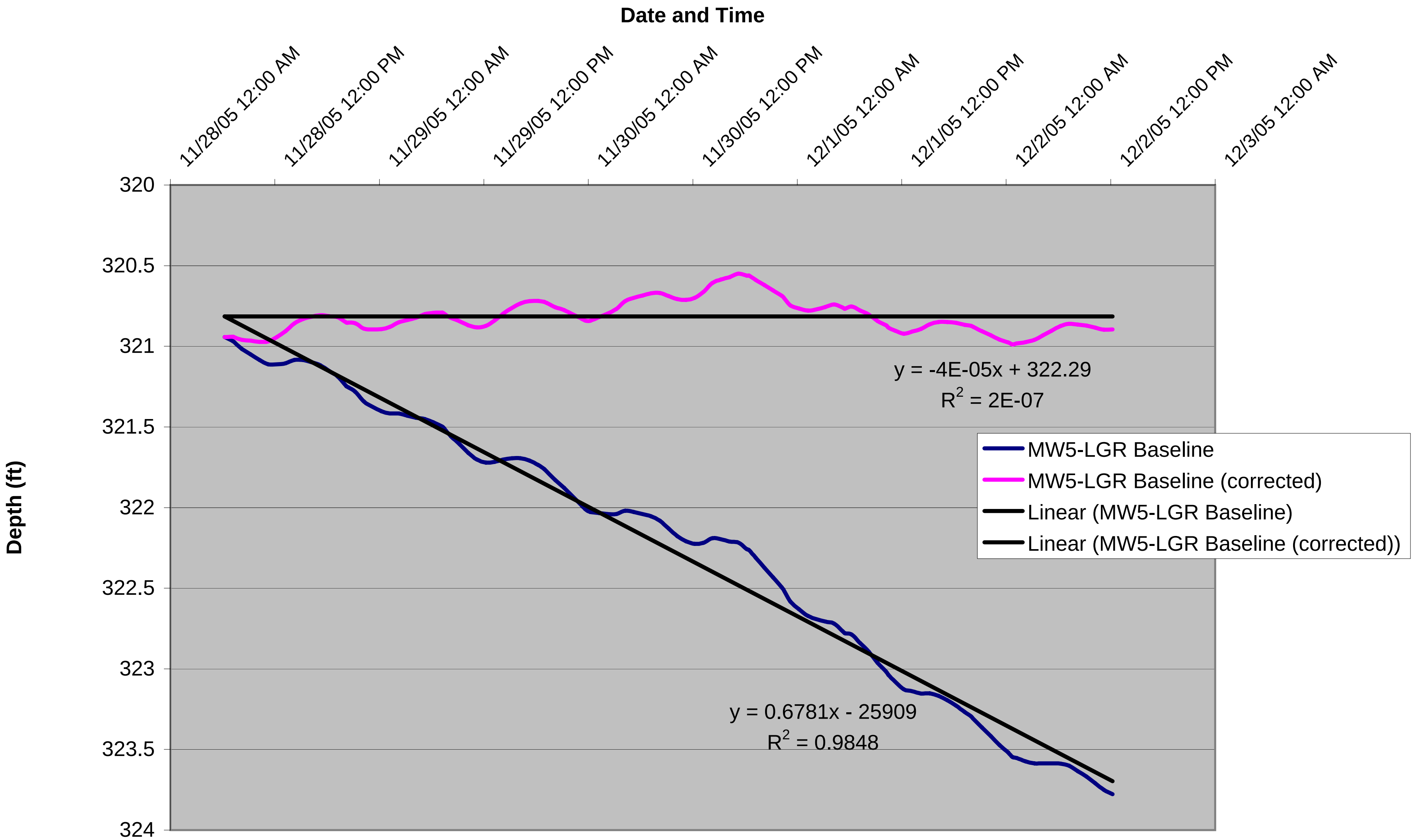

Figure A.17
Regional Trend of MW9-LGR

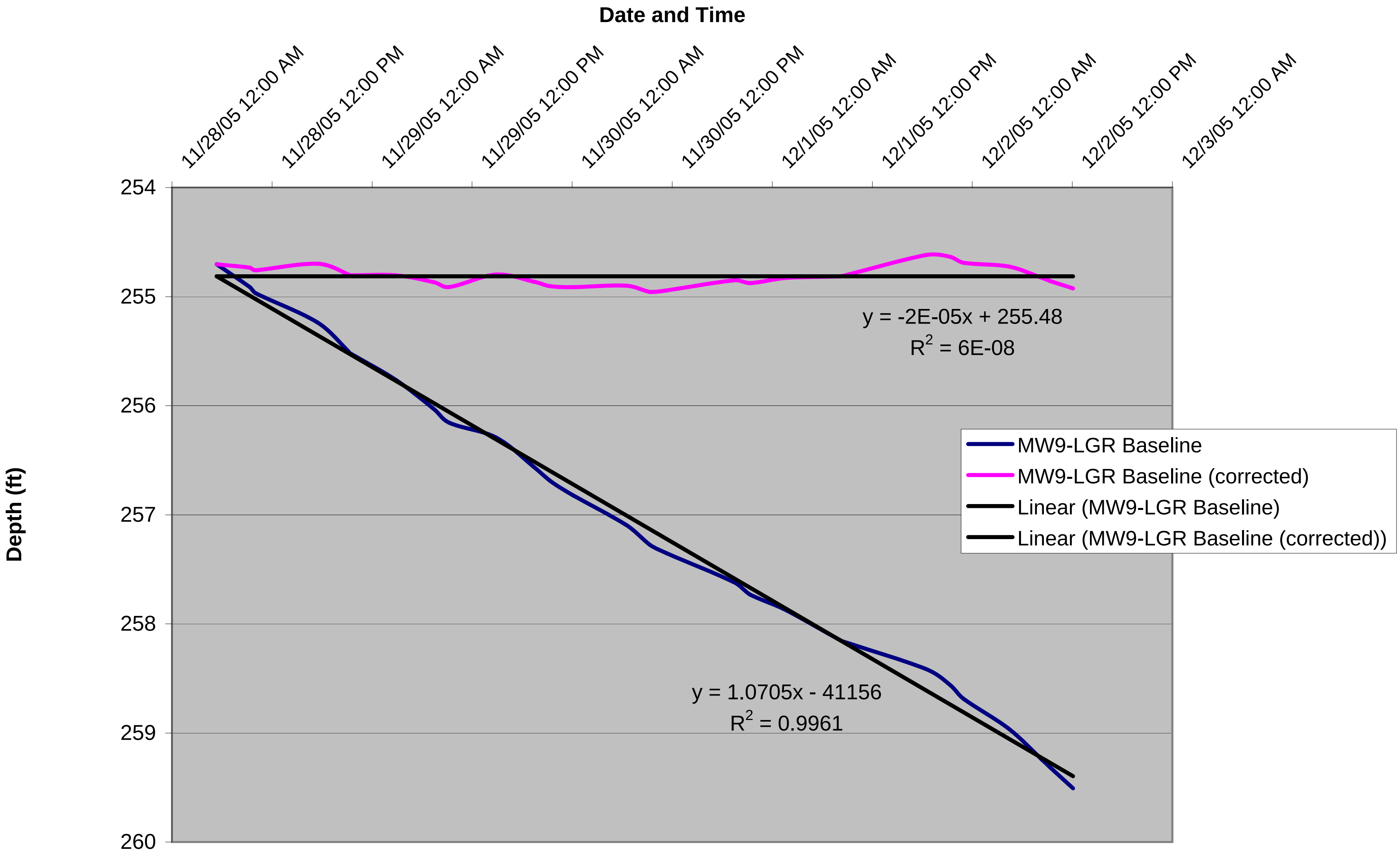

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Figure A.18
Regional Trend of MW9-BS

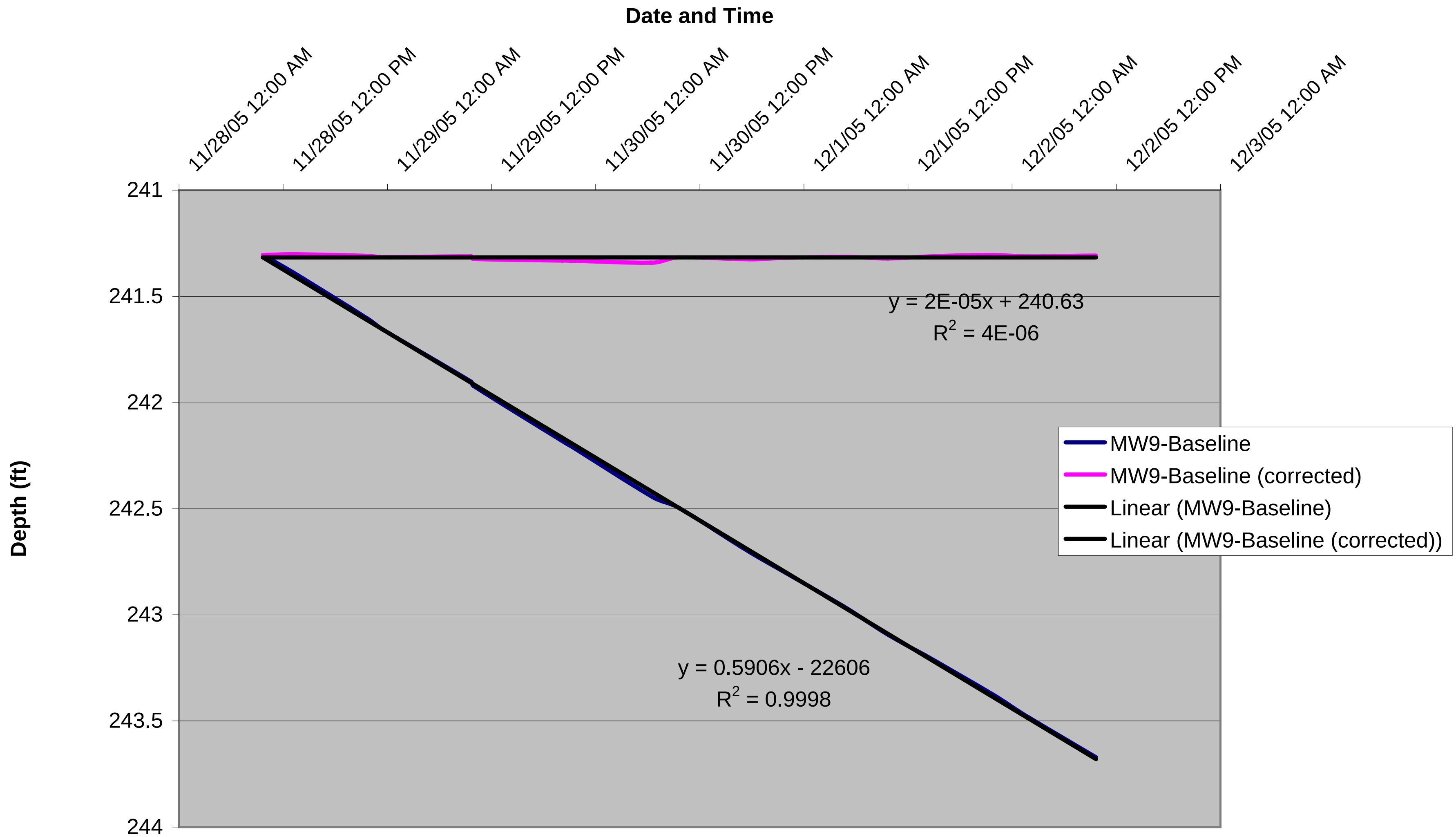

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Figure A.19
Regional Trend of MW9-CC

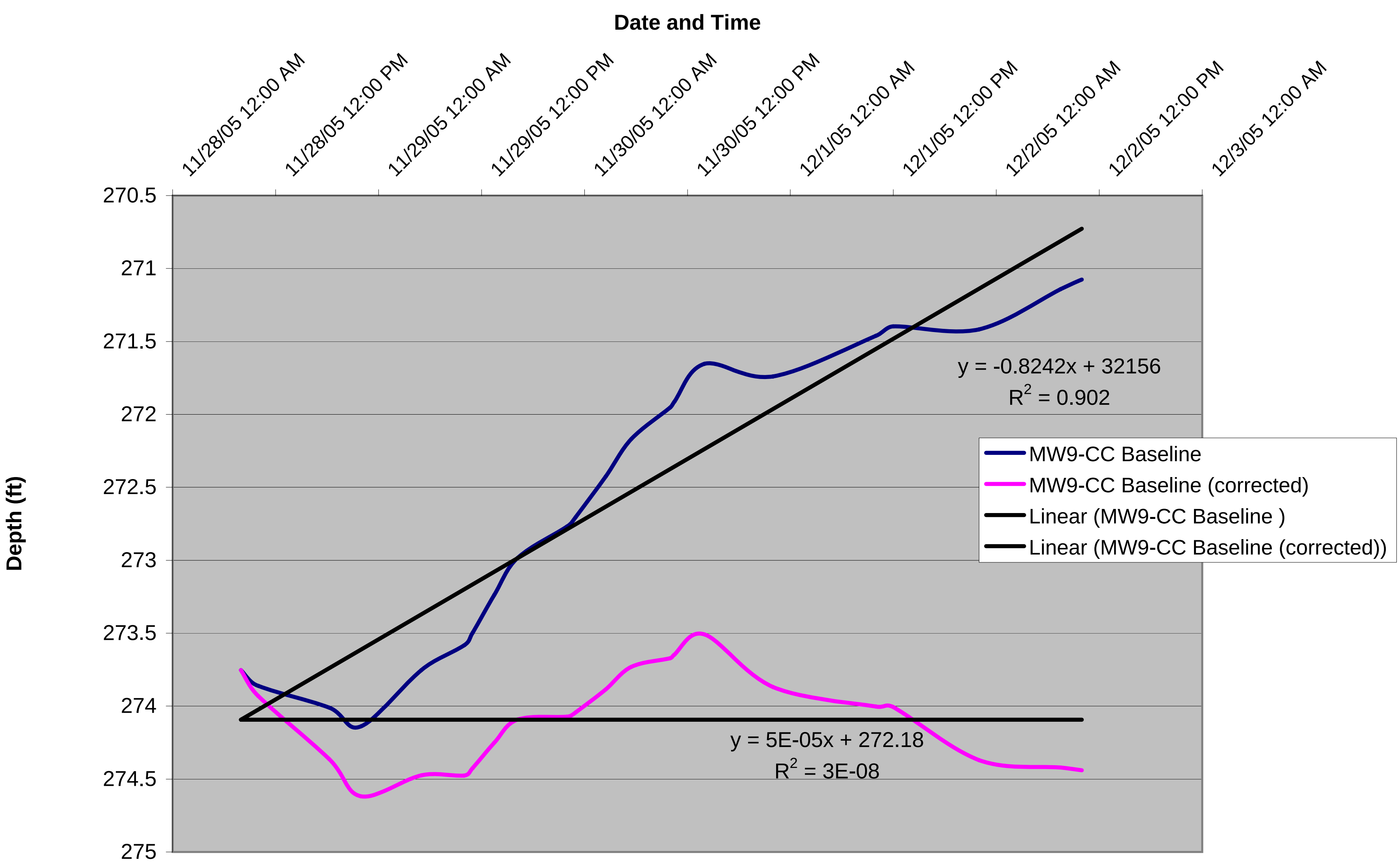

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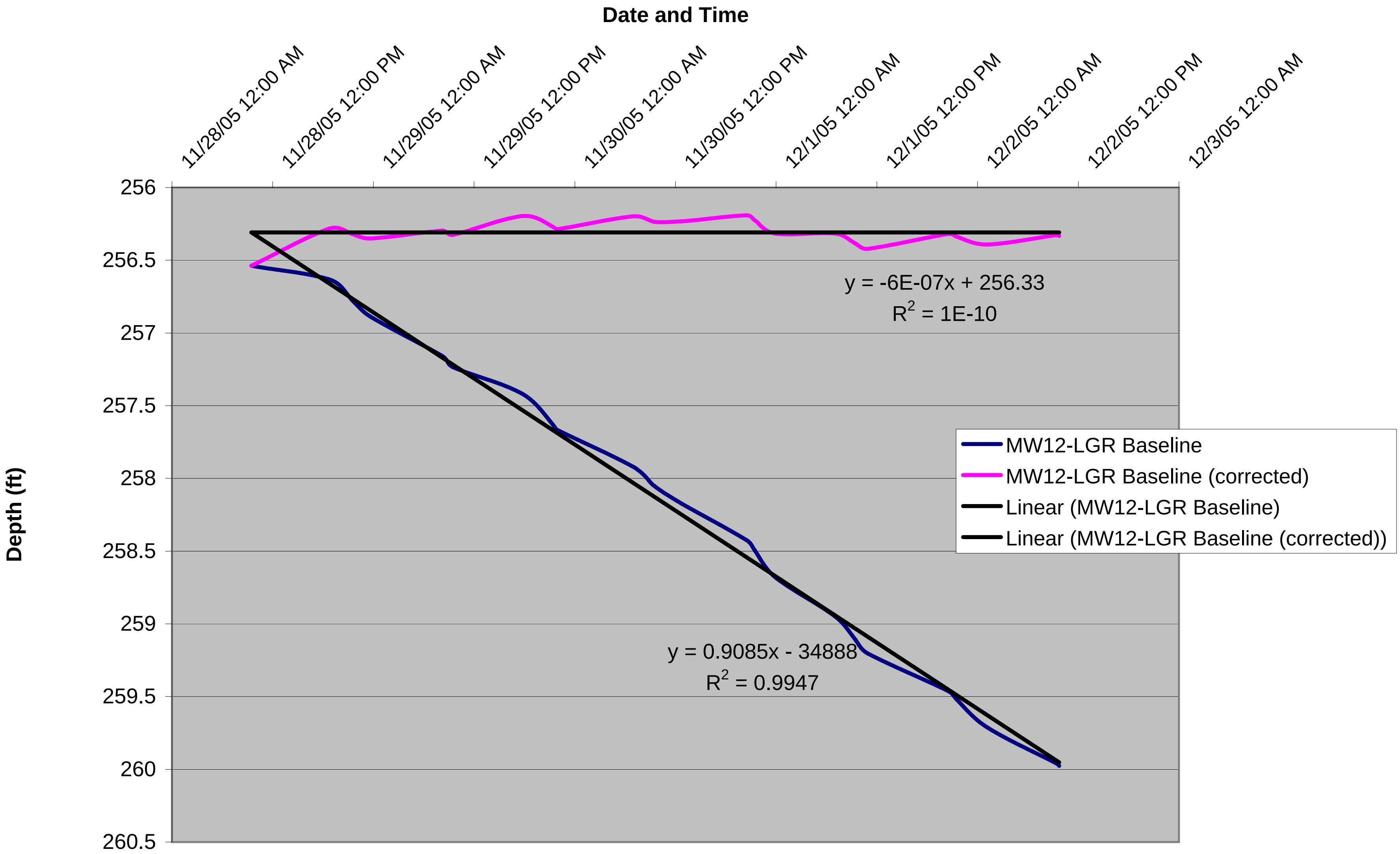
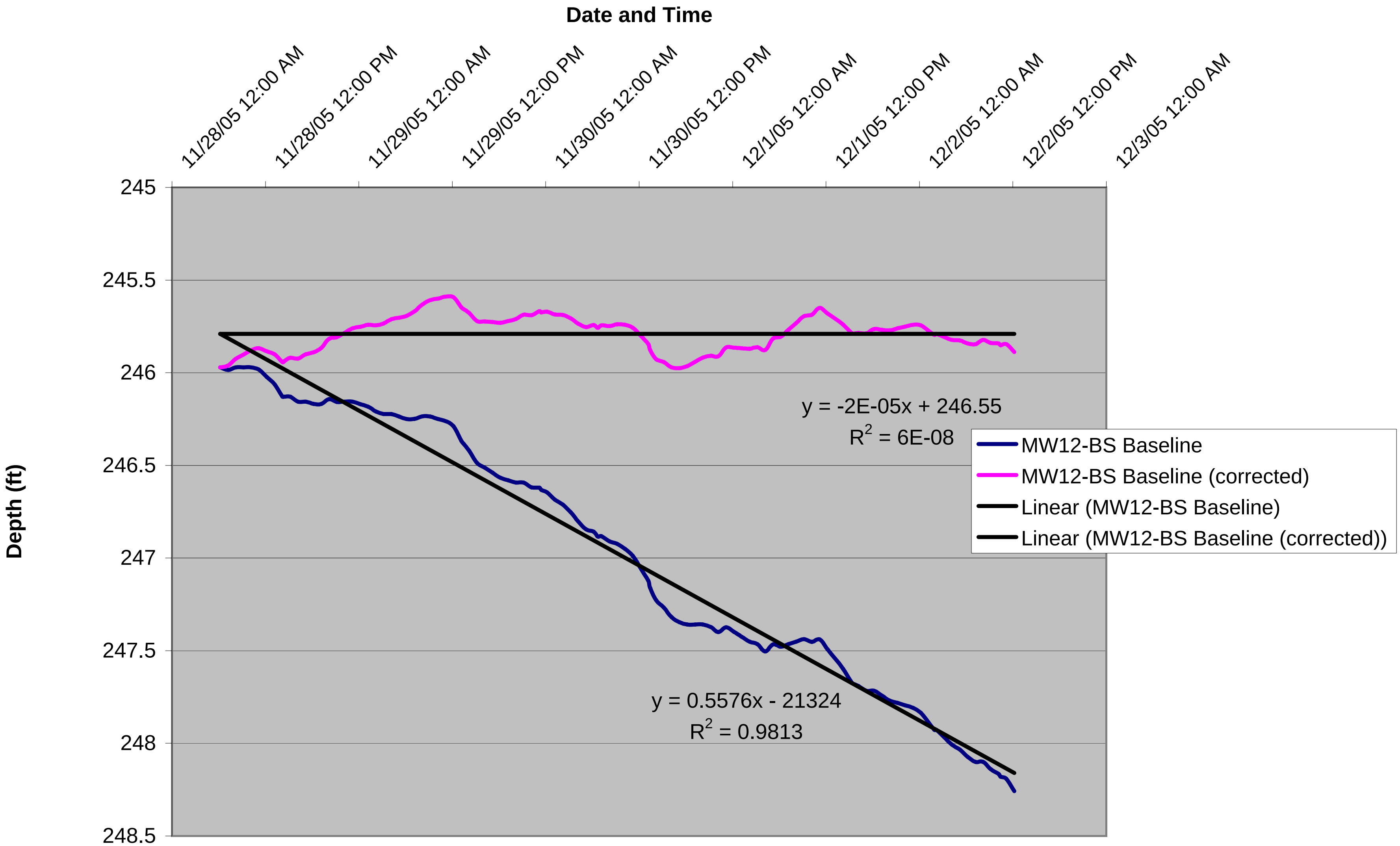
Figure A.20
Regional Trend of MW12-LGR



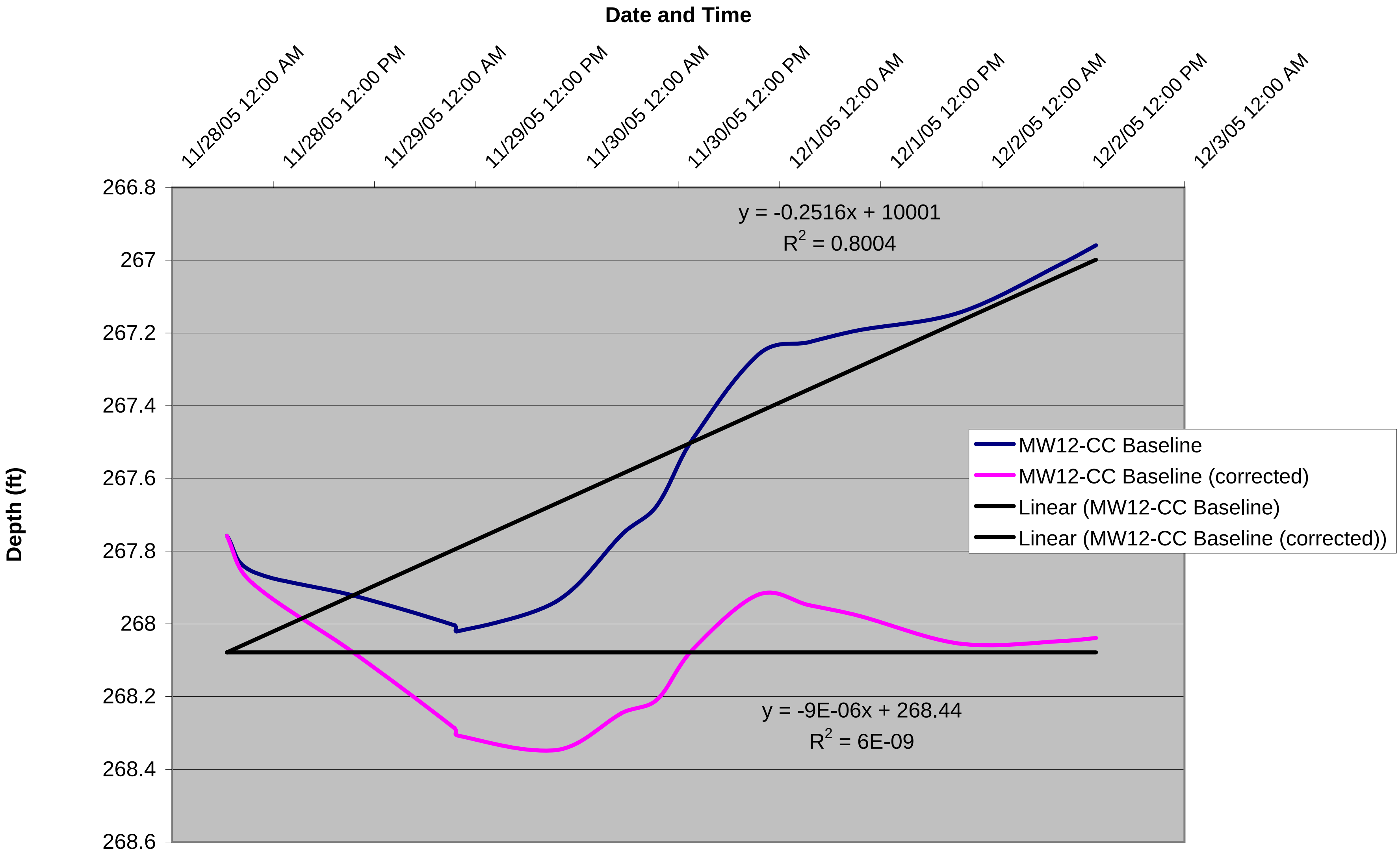
J:\744\744223 B3 & AOC65\12000-Pumping Tests\Data from FTP\Observation Wells EXCEL_conversions\MW12-LGR.xls

Figure A.21
Regional Trend of MW12-BS



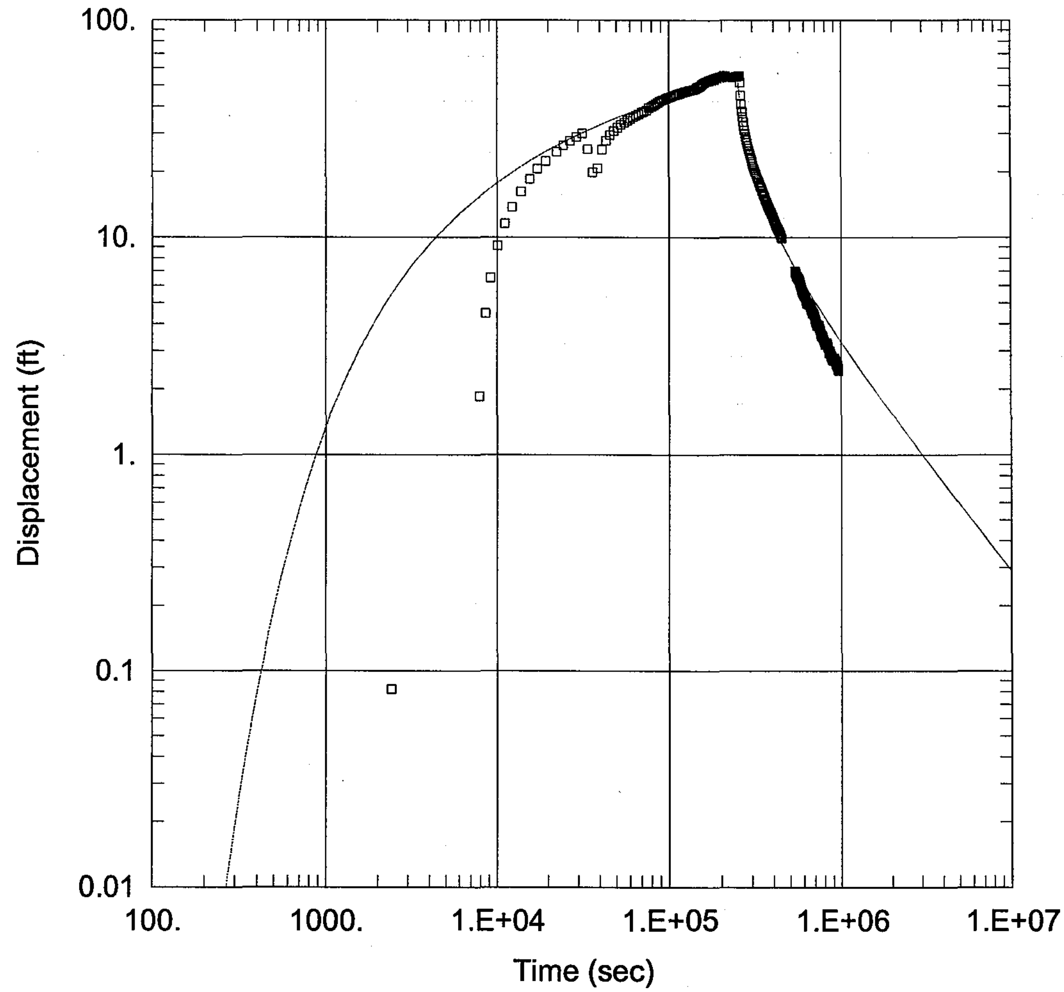
J:\744\744223 B3 & AOC65\12000-Pumping Tests\Data from FTP\Observation Wells EXCEL_conversions\MW12-BS.xls

Figure A.22
Regional Trend of MW12-CC



J:\744\744223 B3 & AOC65\12000-Pumping Tests\Data from FTP\Observation Wells EXCEL_conversions\MW12-CC.xls

APPENDIX B
CS- MW16-CC PUMPING/RECOVERY TEST AQTESOLVTM GRAPH AND REPORT



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\WB5CC1.AQT
Date: 06/22/06 Time: 14:04:14

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

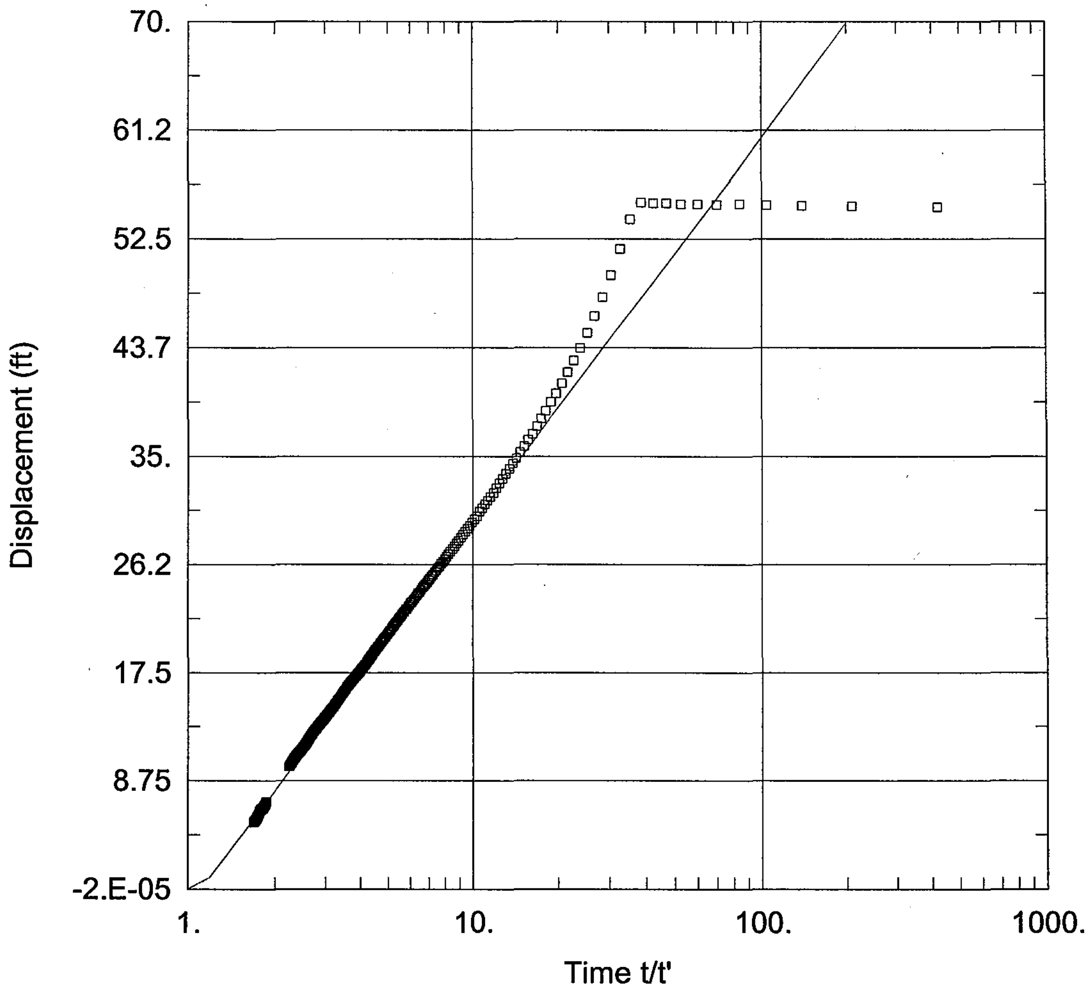
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CS-WB05-CC1	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 210.2 gal/day/ft
S = 3.215E-05



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\WB5CC1.AQT
Date: 06/20/06 Time: 15:24:28

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

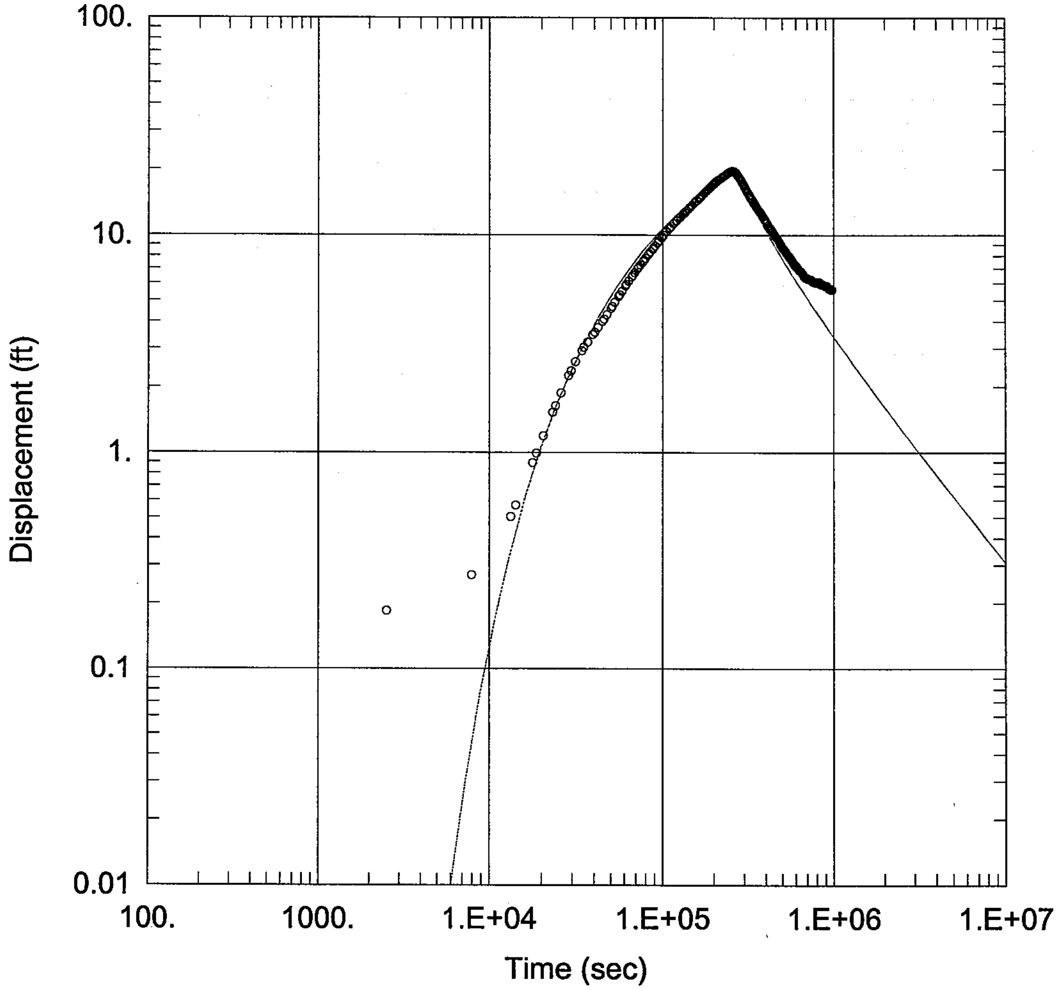
Observation Wells

Well Name	X (ft)	Y (ft)
▫ CS-WB05-CC1	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 182.5 gal/day/ft
S' = 1.11



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\MW1CC.AQT
Date: 06/22/06 Time: 14:04:30

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

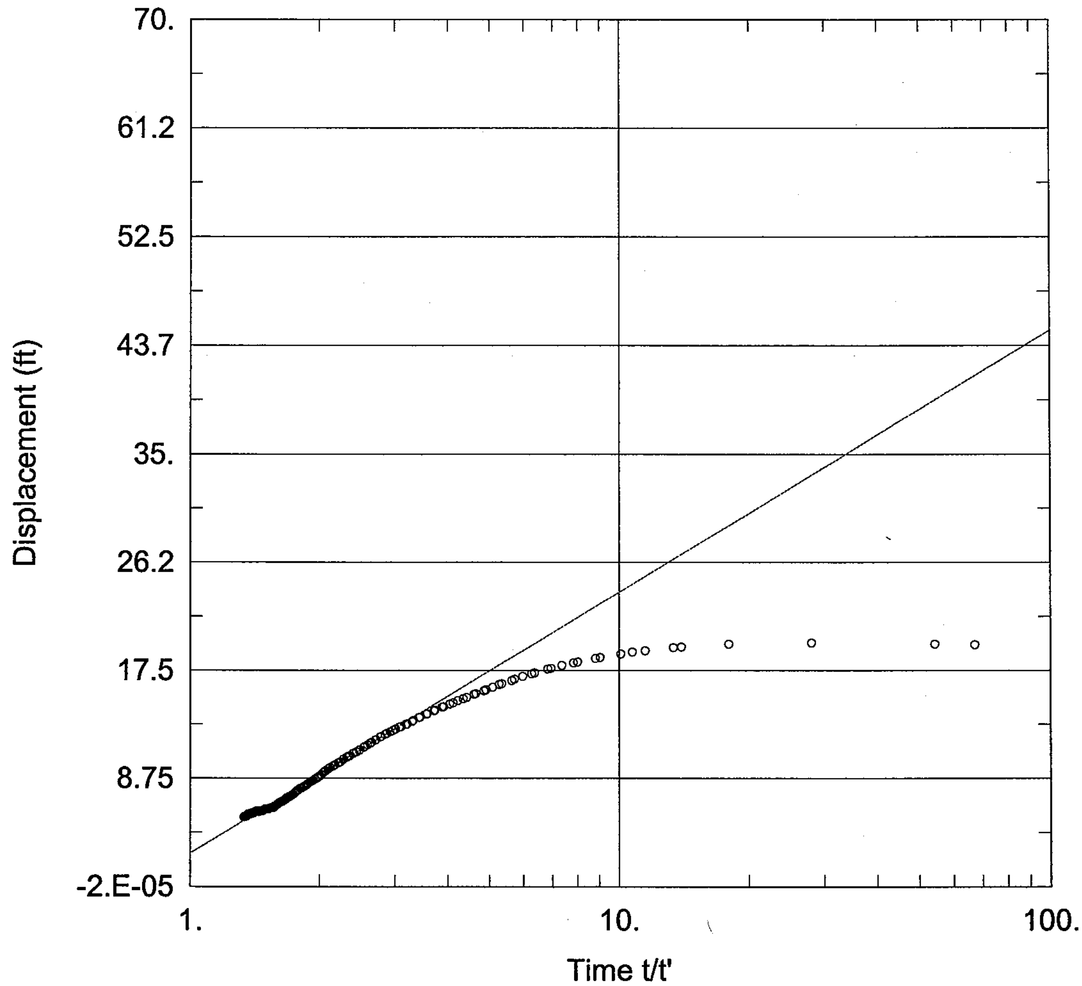
Observation Wells

Well Name	X (ft)	Y (ft)
○ CS-MW1-CC	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 197.1 gal/day/ft
S = 1.017E-05



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\16CC4OBS.AQT
Date: 06/20/06 Time: 15:51:25

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

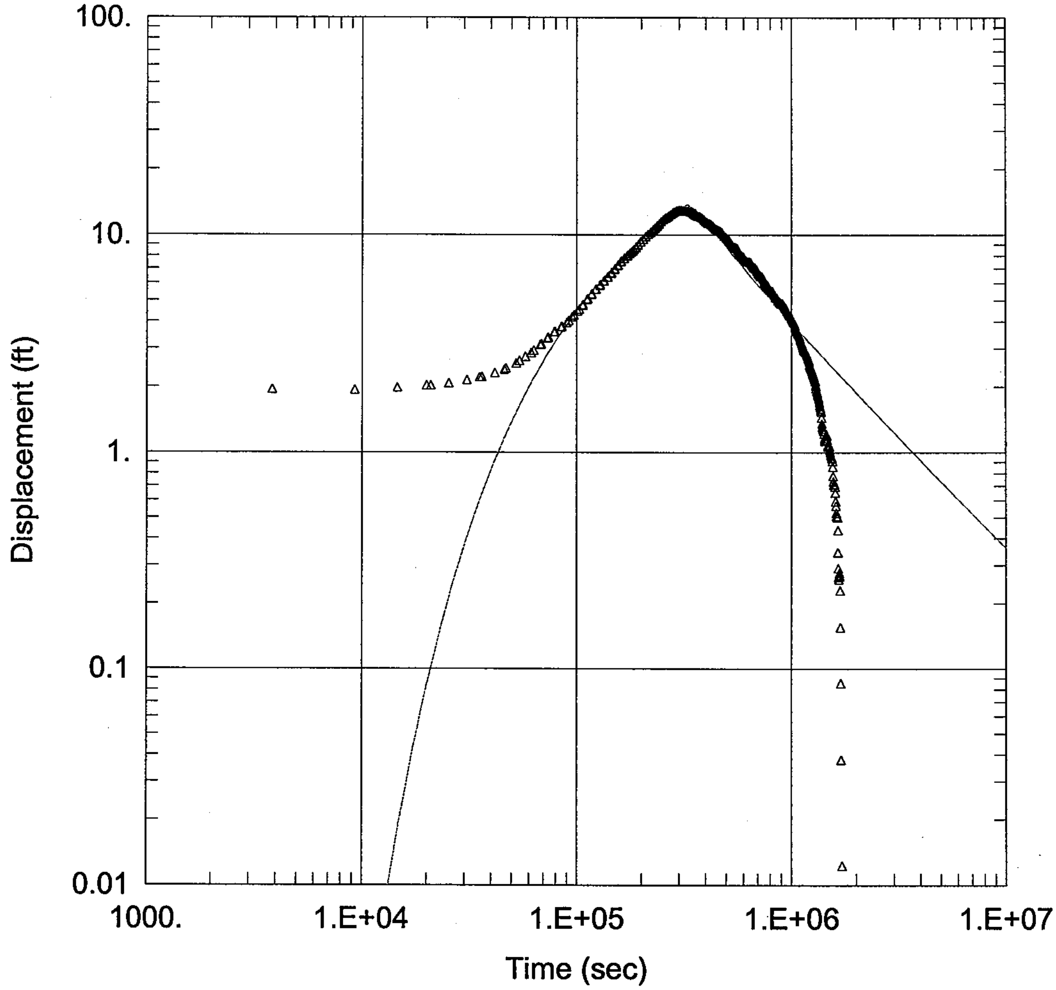
Observation Wells

Well Name	X (ft)	Y (ft)
○ CS-MW1-CC	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 267.5 gal/day/ft
S' = 0.7474



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\MW2CC.AQT
Date: 06/22/06 Time: 14:04:21

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

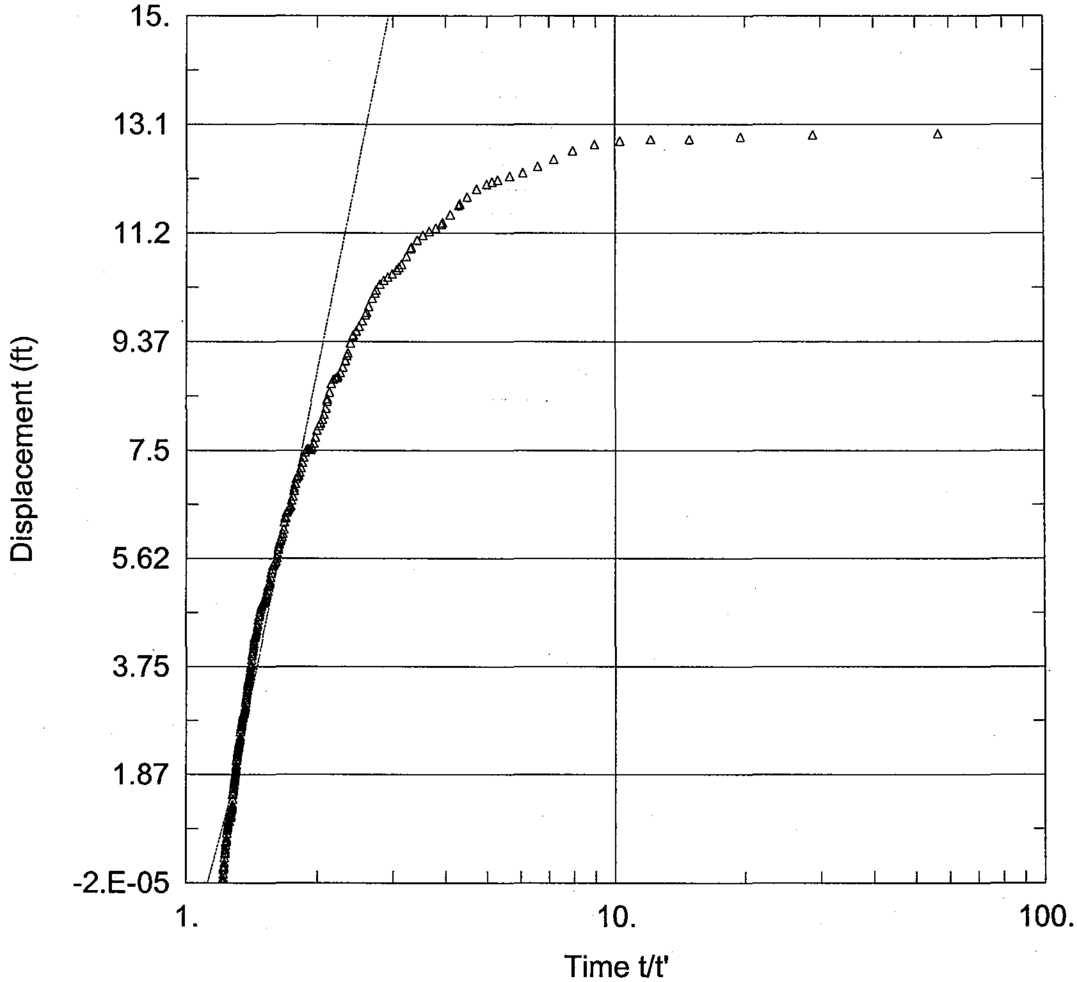
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-MW2-CC	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 210. gal/day/ft
S = 1.94E-05



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\MW2CC.AQT
Date: 06/27/06 Time: 12:07:52

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

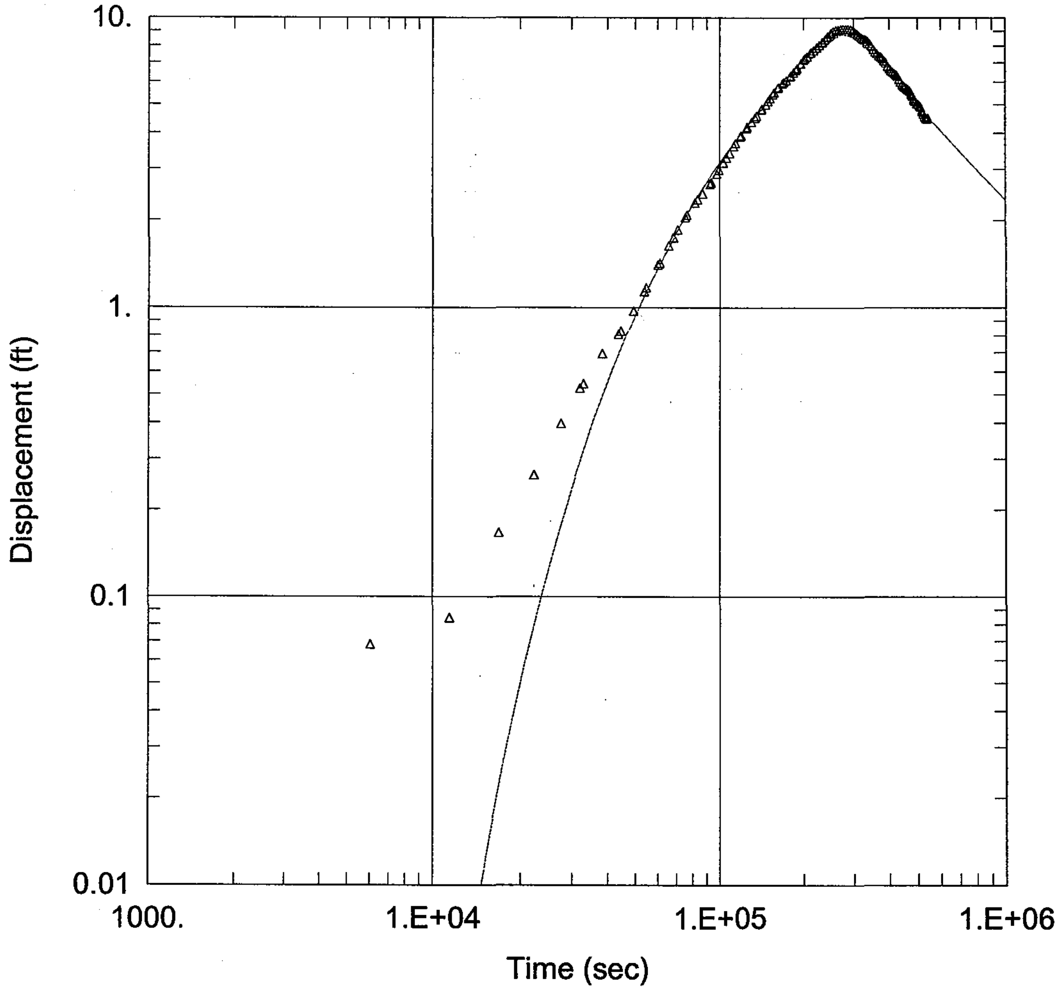
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-MW2-CC	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 157.5 gal/day/ft
S' = 1.15



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\MW12CC.AQT
Date: 06/22/06 Time: 14:04:41

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

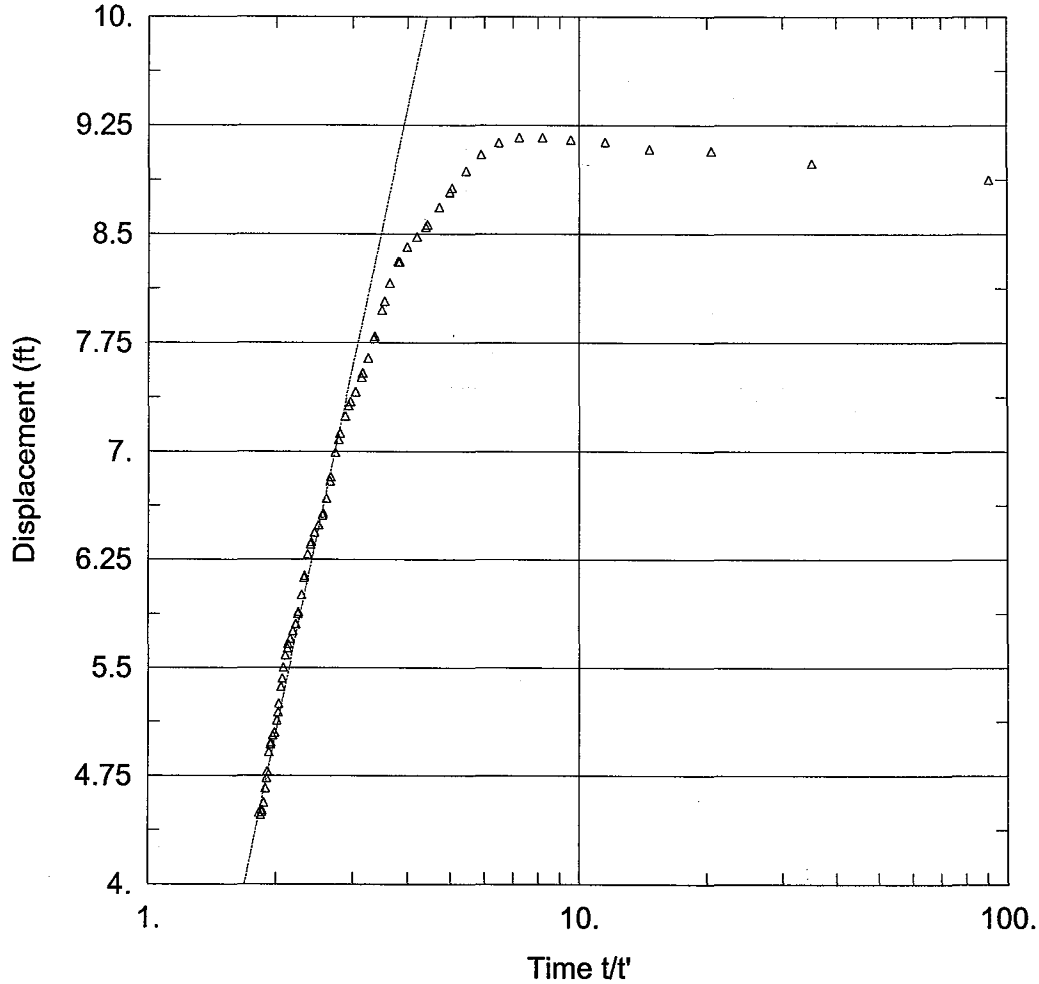
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-MW12-CC	1.76E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 272.1 gal/day/ft
S = 8.691E-06



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\MW12CC.AQT
Date: 06/20/06 Time: 15:48:56

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

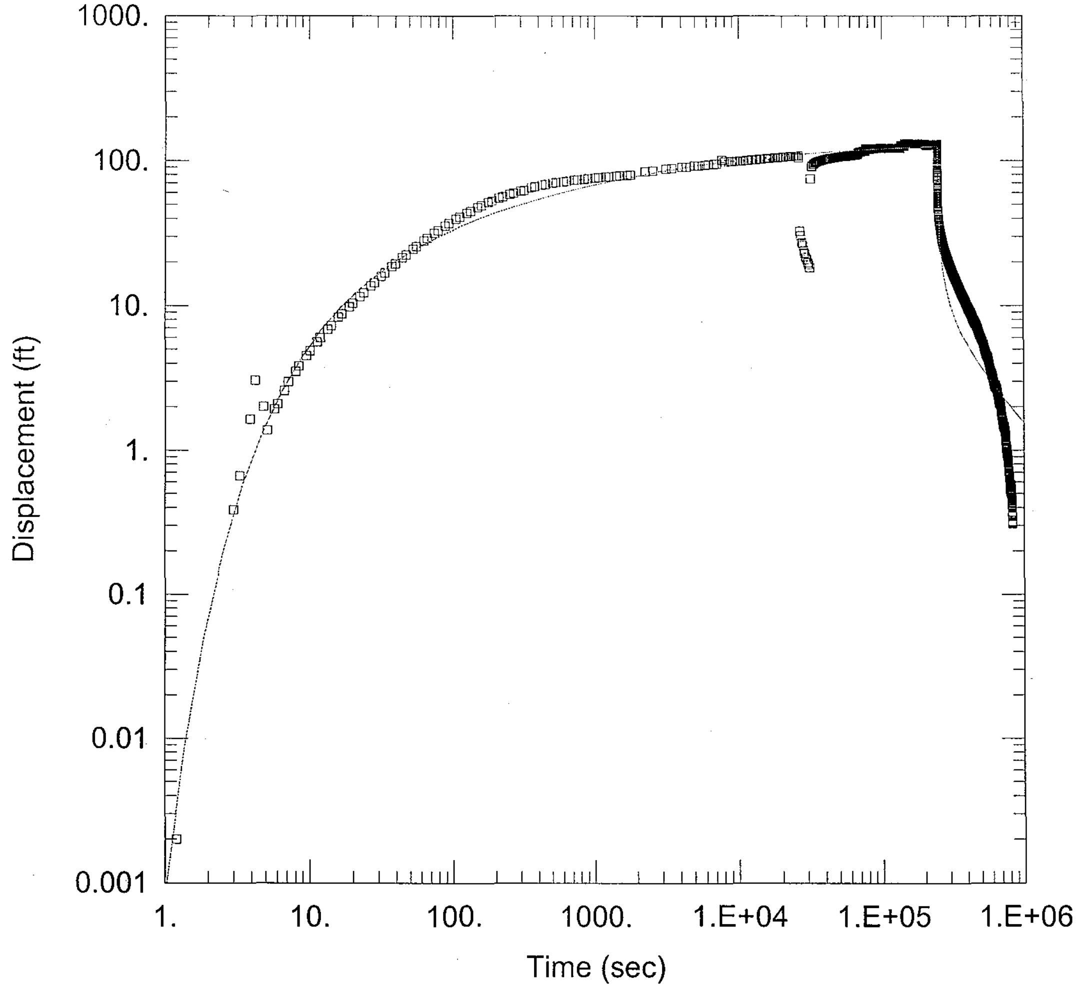
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-MW12-CC	1.76E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 394.4 gal/day/ft
S' = 0.8886



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\16CC.AQT
Date: 06/27/06 Time: 15:00:13

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16CC	1.763E+006	1.078E+007

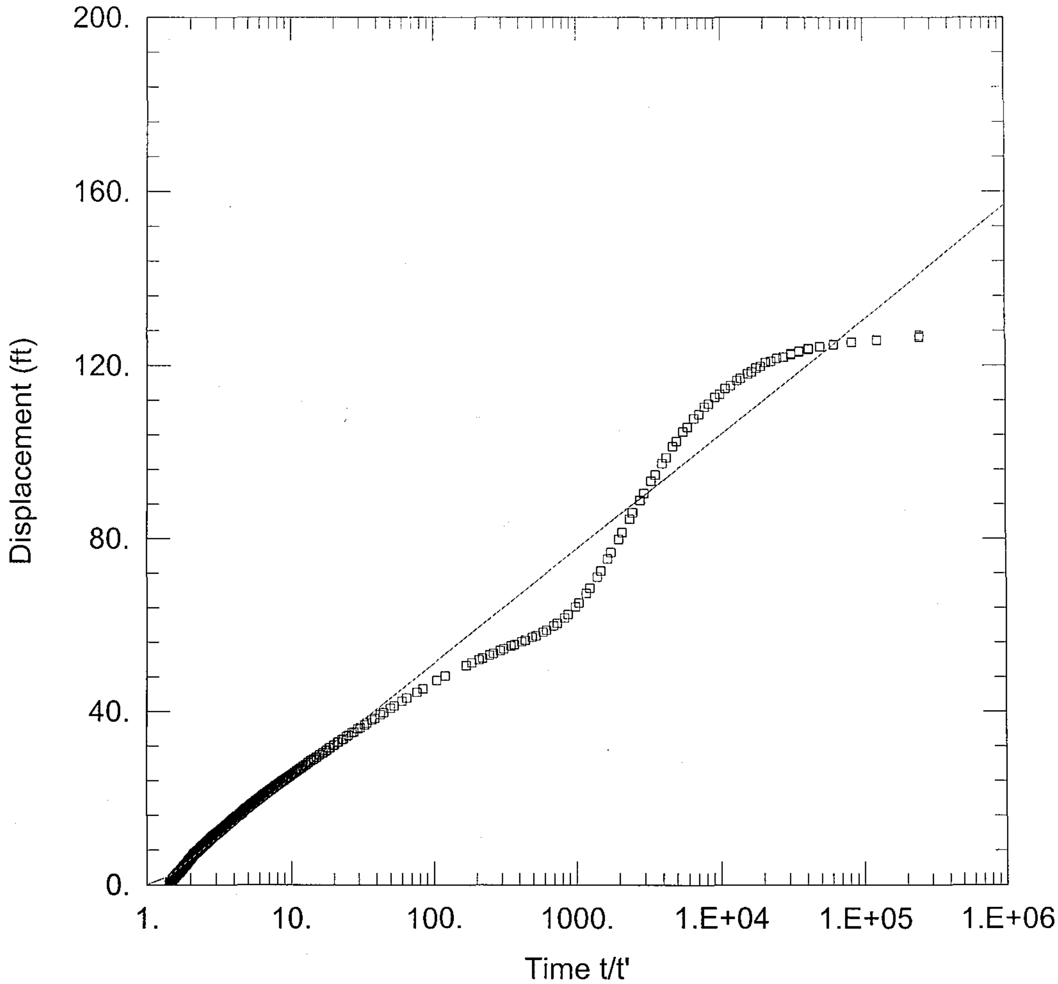
Observation Wells

Well Name	X (ft)	Y (ft)
□ 16cc	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 446.7 gal/day/ft
S = 0.1933



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\16CC.AQT
Date: 06/27/06 Time: 15:01:24

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16CC	1.763E+006	1.078E+007

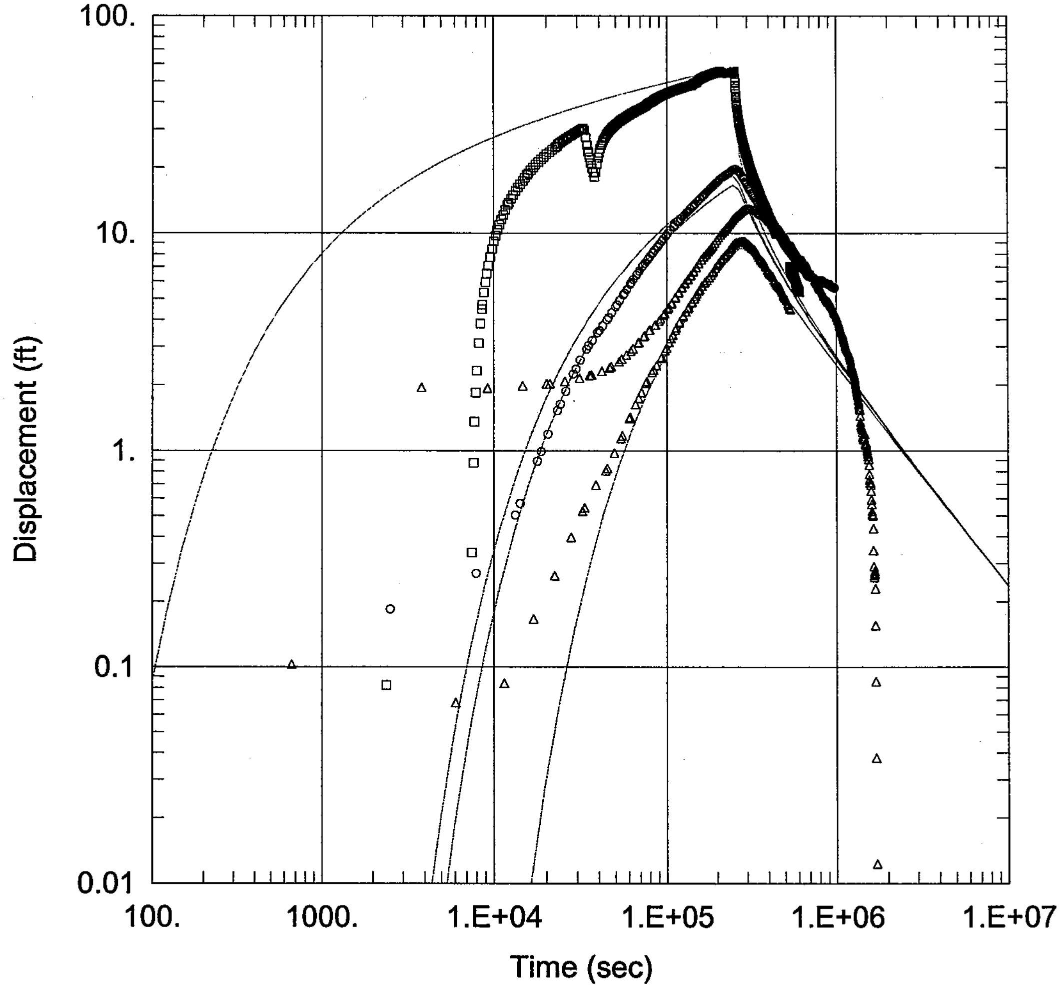
Observation Wells

Well Name	X (ft)	Y (ft)
▫ 16cc	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 213.2 gal/day/ft
S' = 1.189



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\16CC4OBS.AQT
Date: 06/22/06 Time: 14:07:59

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

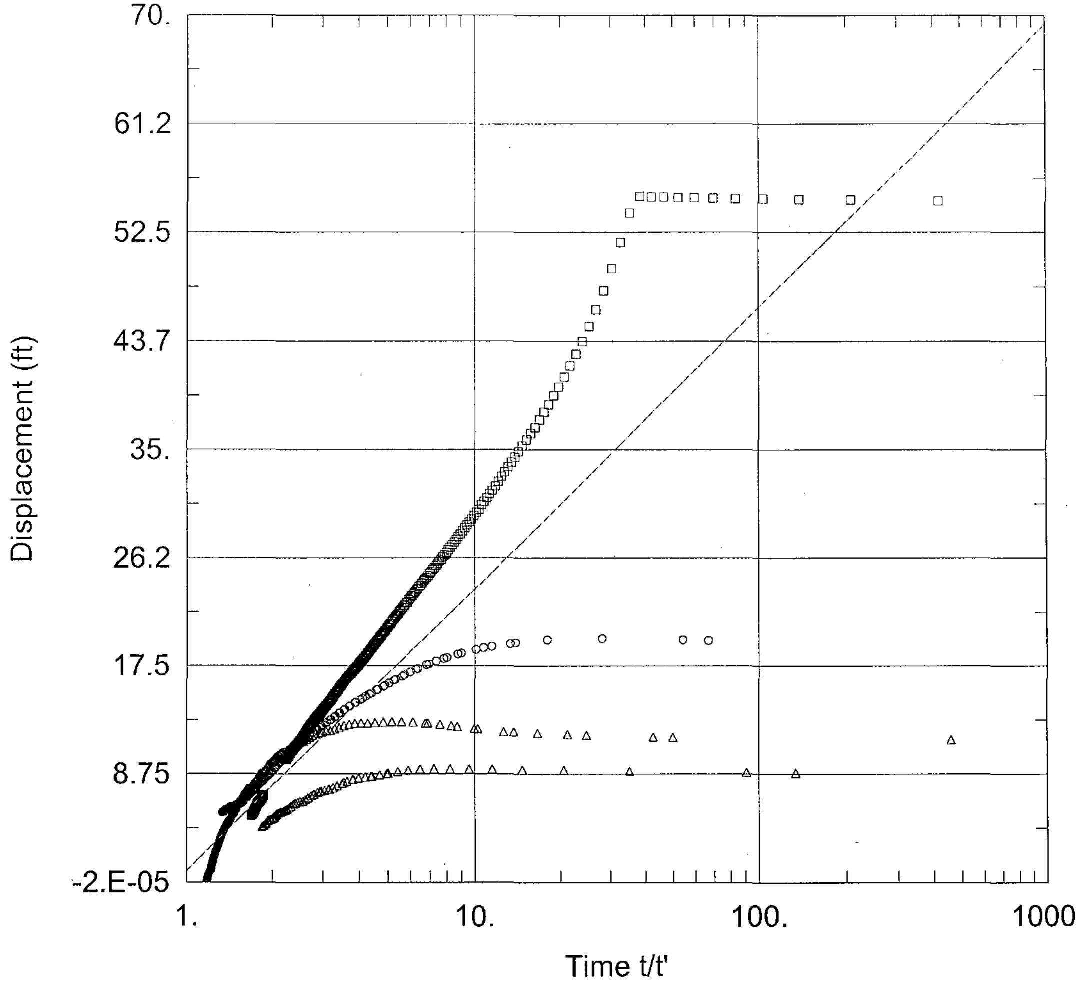
Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

Observation Wells

Well Name	X (ft)	Y (ft)
□ CS-WB05-CC1	1.763E+006	1.078E+007
○ CS-MW1-CC	1.762E+006	1.078E+007
△ CS-MW12-CC	1.76E+006	1.078E+007
△ CS-MW2-CC	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined T = 255.9 gal/day/ft
Solution Method: Theis S = 9.172E-06



CSSA - WELL CS-MW16-CC PUMPING TEST

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16CC\16CC4OBS.AQT
Date: 06/27/06 Time: 15:21:51

PROJECT INFORMATION

Company: Parsons
Client: CSSA
Project: 744223
Test Location: CSSA
Test Well: CS-MW16--CC
Test Date: 12/7/2005

AQUIFER DATA

Saturated Thickness: 75. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
CS-MW16-CC	1.763E+006	1.078E+007

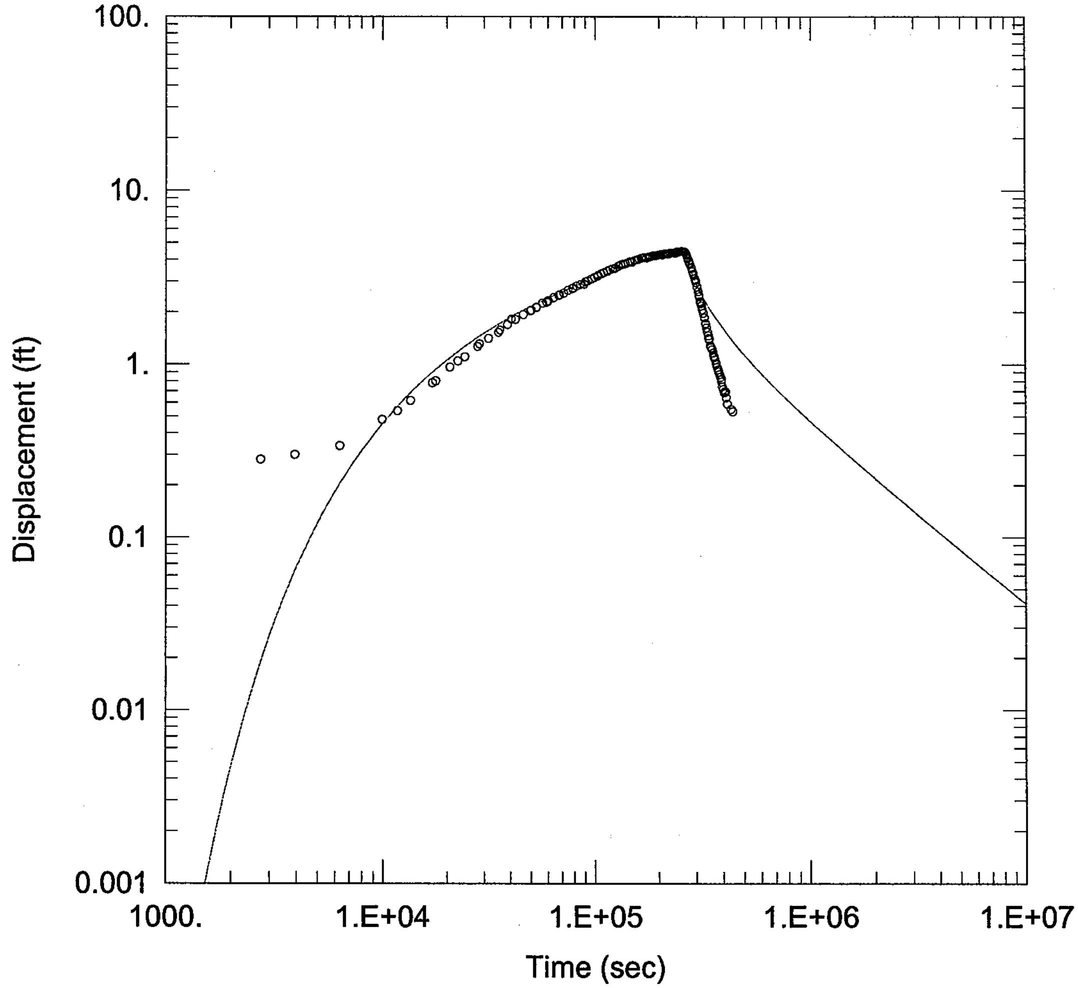
Observation Wells

Well Name	X (ft)	Y (ft)
□ CS-WB05-CC1	1.763E+006	1.078E+007
○ CS-MW1-CC	1.762E+006	1.078E+007
△ CS-MW12-CC	1.76E+006	1.078E+007
△ CS-MW2-CC	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined T = 248.4 gal/day/ft
Solution Method: Theis Recovery S' = 0.9112

APPENDIX C
CS- MW16-LGR PUMPING/RECOVERY TEST AQTESOLVTM GRAPH AND REPORT



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\B3MW1.AQT
Date: 06/23/06 Time: 15:30:59

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

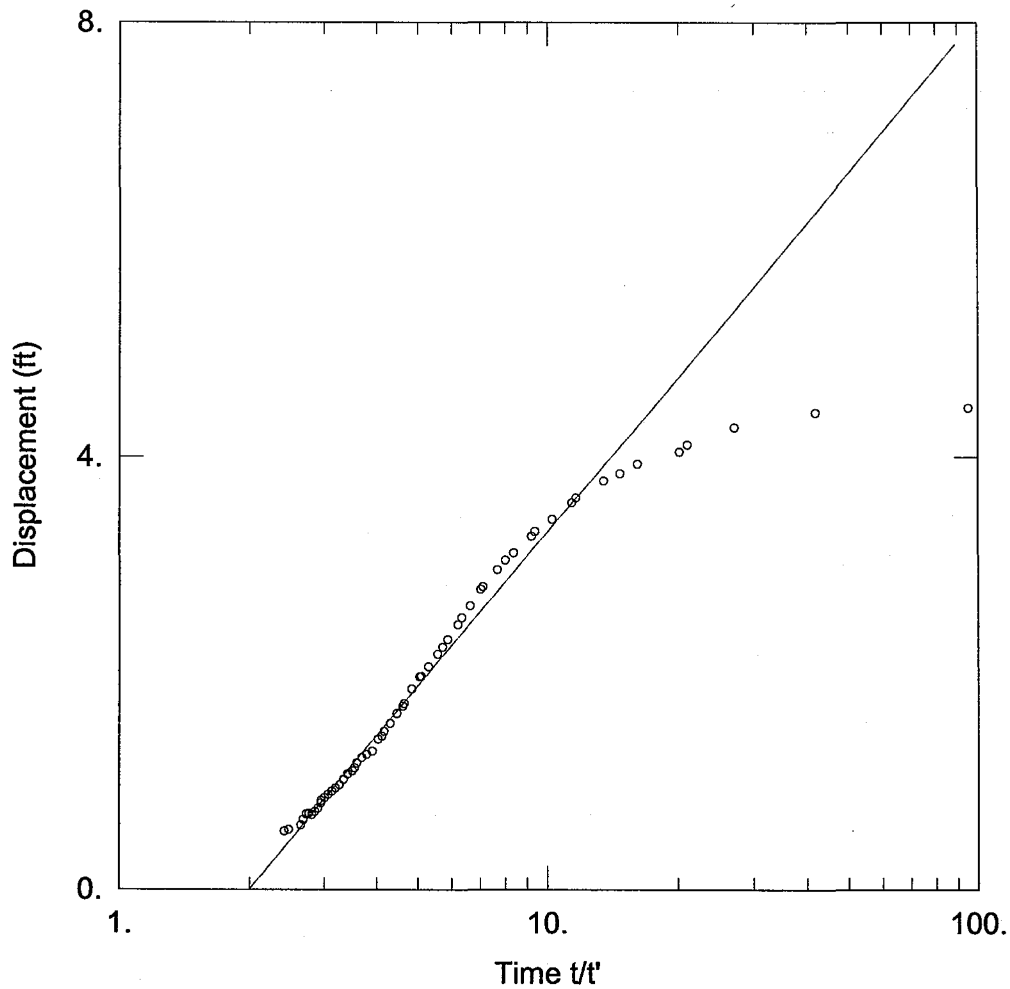
Observation Wells

Well Name	X (ft)	Y (ft)
∘ B3-MW1	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 726.8 gal/day/ft
S = 4.245E-06



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\B3MW1.AQT
Date: 06/23/06 Time: 16:34:04

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

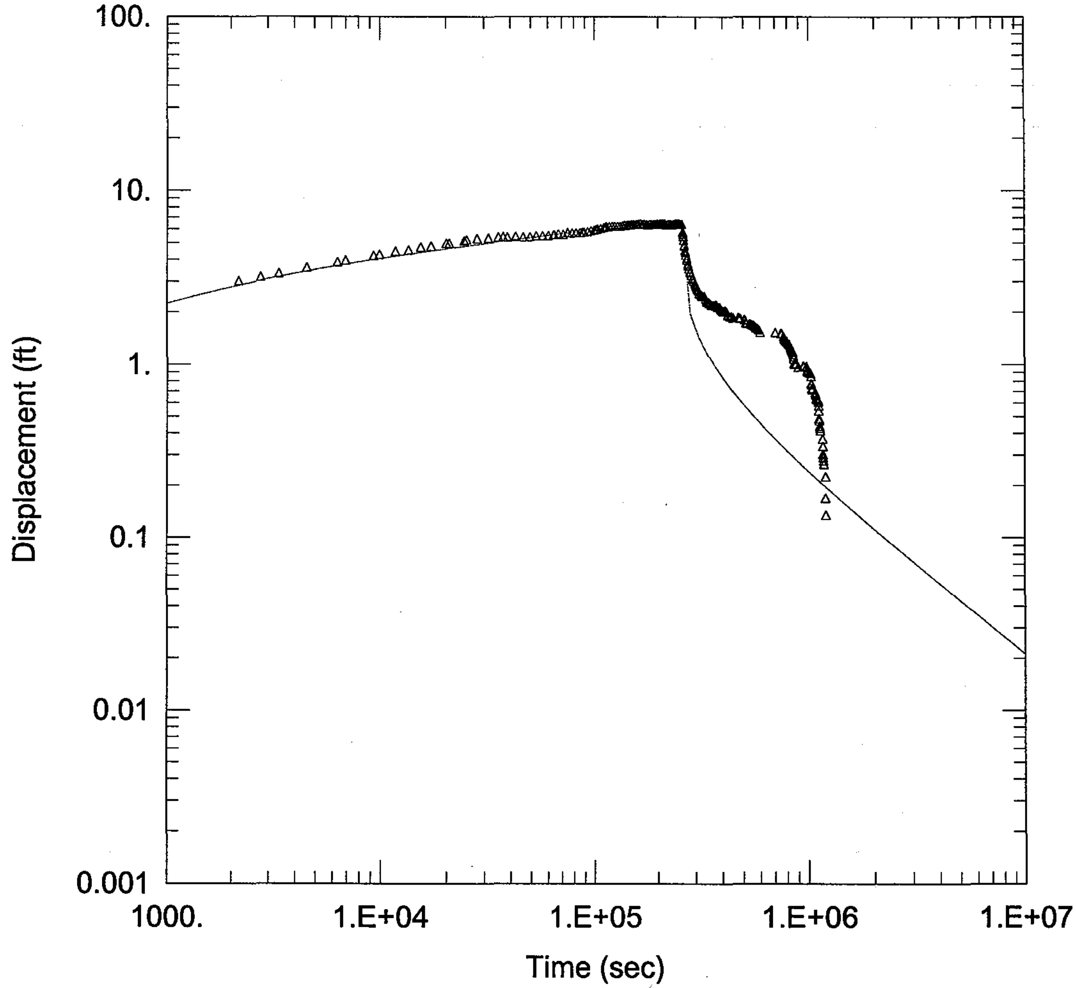
Observation Wells

Well Name	X (ft)	Y (ft)
◦ B3-MW1	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 558. gal/day/ft
S' = 2.001



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\CSD.AQT
Date: 06/23/06 Time: 15:49:58

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

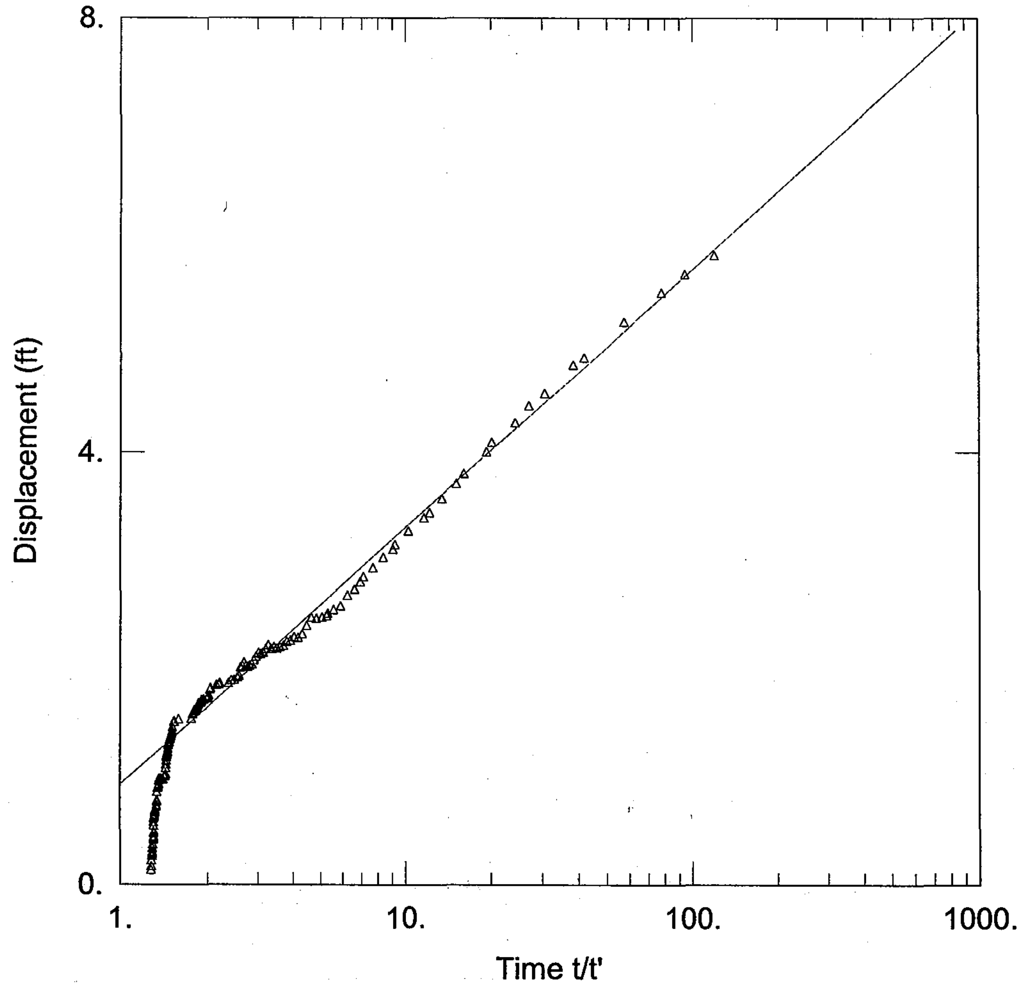
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-D	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1423.4 gal/day/ft
S = 1.544E-06



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\CSD.AQT
Date: 06/23/06 Time: 16:34:58

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

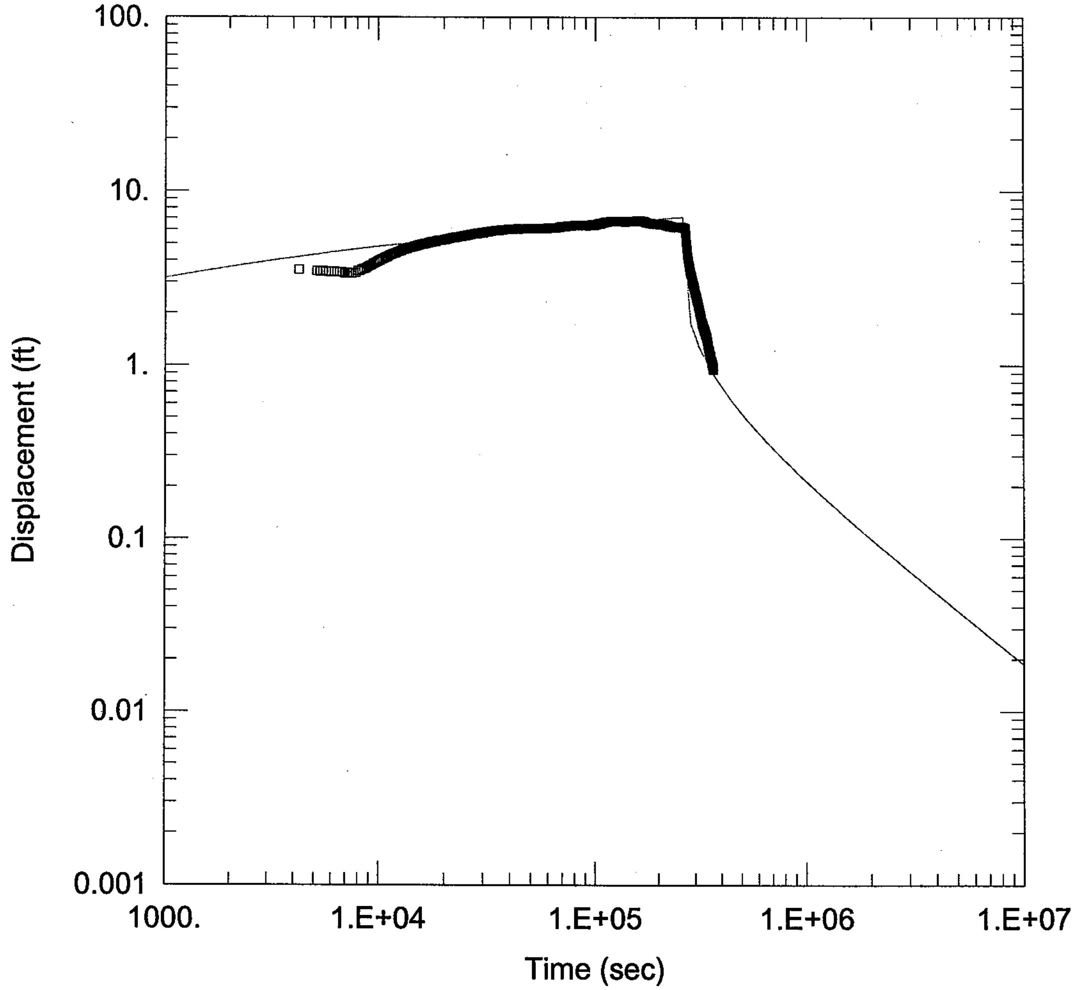
Observation Wells

Well Name	X (ft)	Y (ft)
△ CS-D	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 1108.7 gal/day/ft
S' = 0.4099



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\WB54A.AQT
Date: 06/23/06 Time: 15:53:06

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

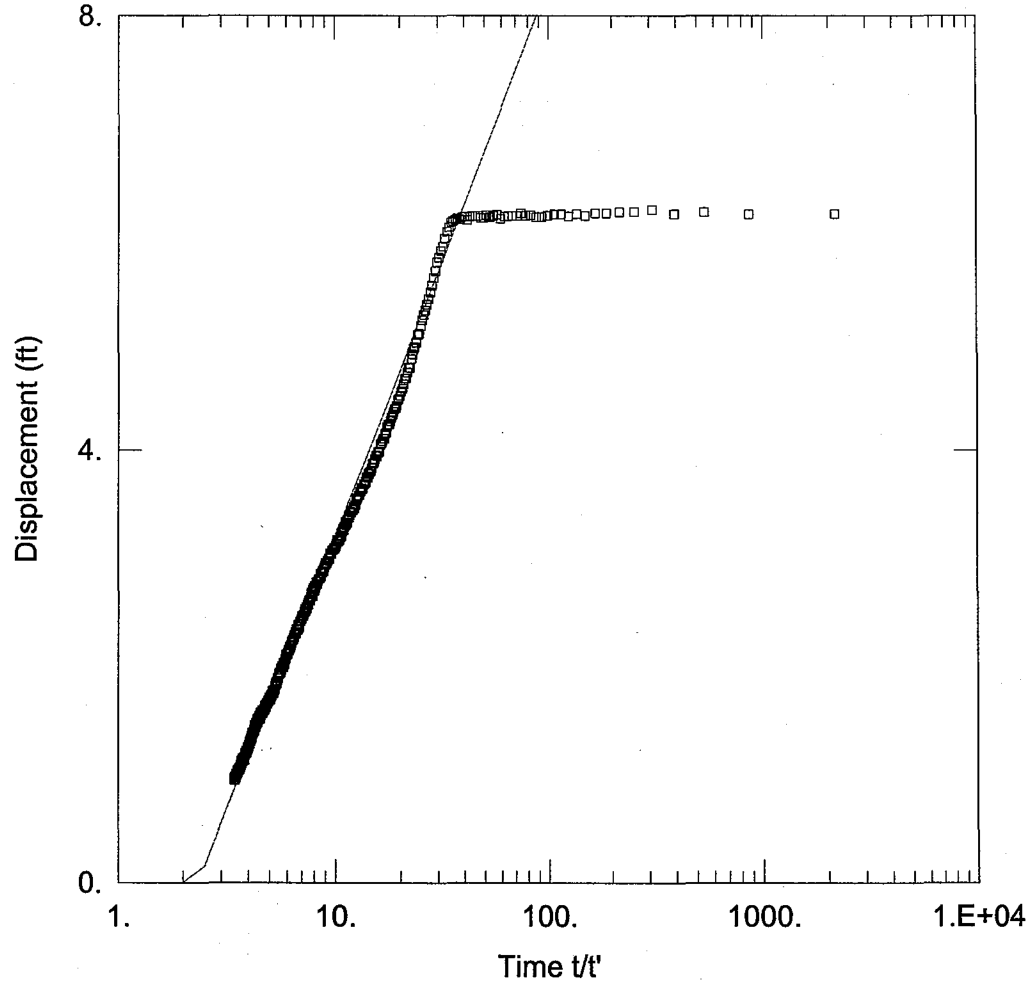
Observation Wells

Well Name	X (ft)	Y (ft)
□ WB5-4A	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1602.9 gal/day/ft
S = 7.703E-09



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\WB54A.AQT
Date: 06/23/06 Time: 16:35:50

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

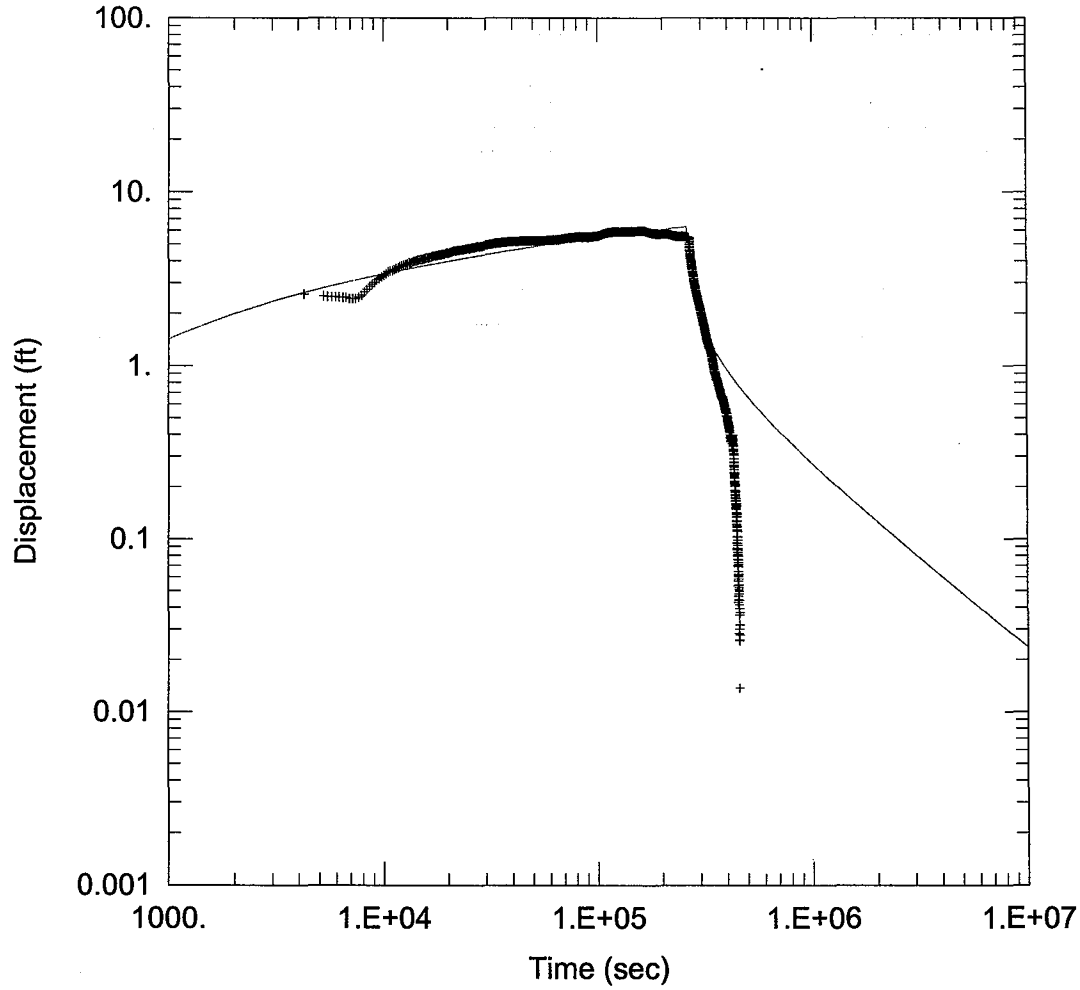
Observation Wells

Well Name	X (ft)	Y (ft)
□ WB5-4A	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 519.3 gal/day/ft
S' = 2.346



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\WB54B.AQT
Date: 06/23/06 Time: 15:53:55

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

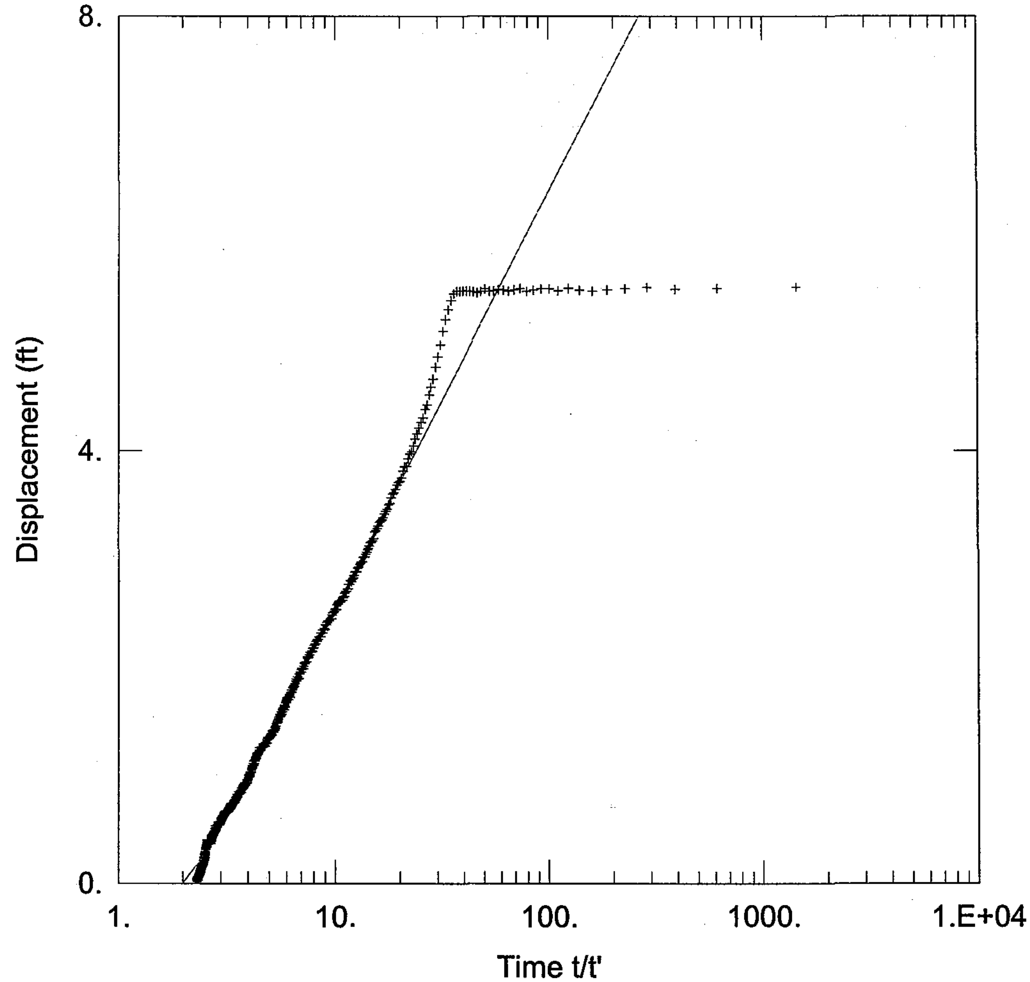
Observation Wells

Well Name	X (ft)	Y (ft)
+ WB5-4B	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1267.9 gal/day/ft
S = 1.219E-07



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\WB54B.AQT
Date: 06/23/06 Time: 16:37:09

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

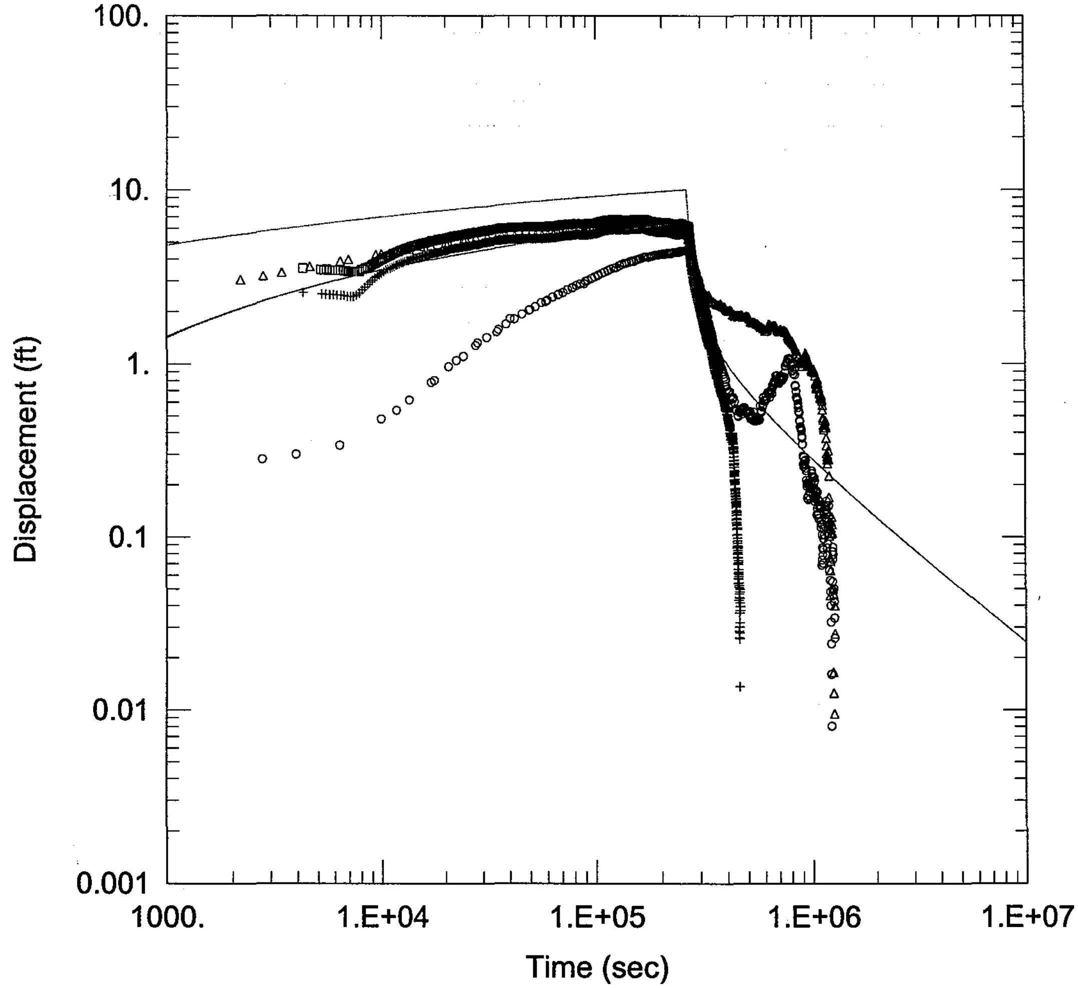
Observation Wells

Well Name	X (ft)	Y (ft)
+ WB5-4B	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 689.1 gal/day/ft
S' = 2.156



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\16LGRALL.AQT
Date: 06/23/06 Time: 15:29:18

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

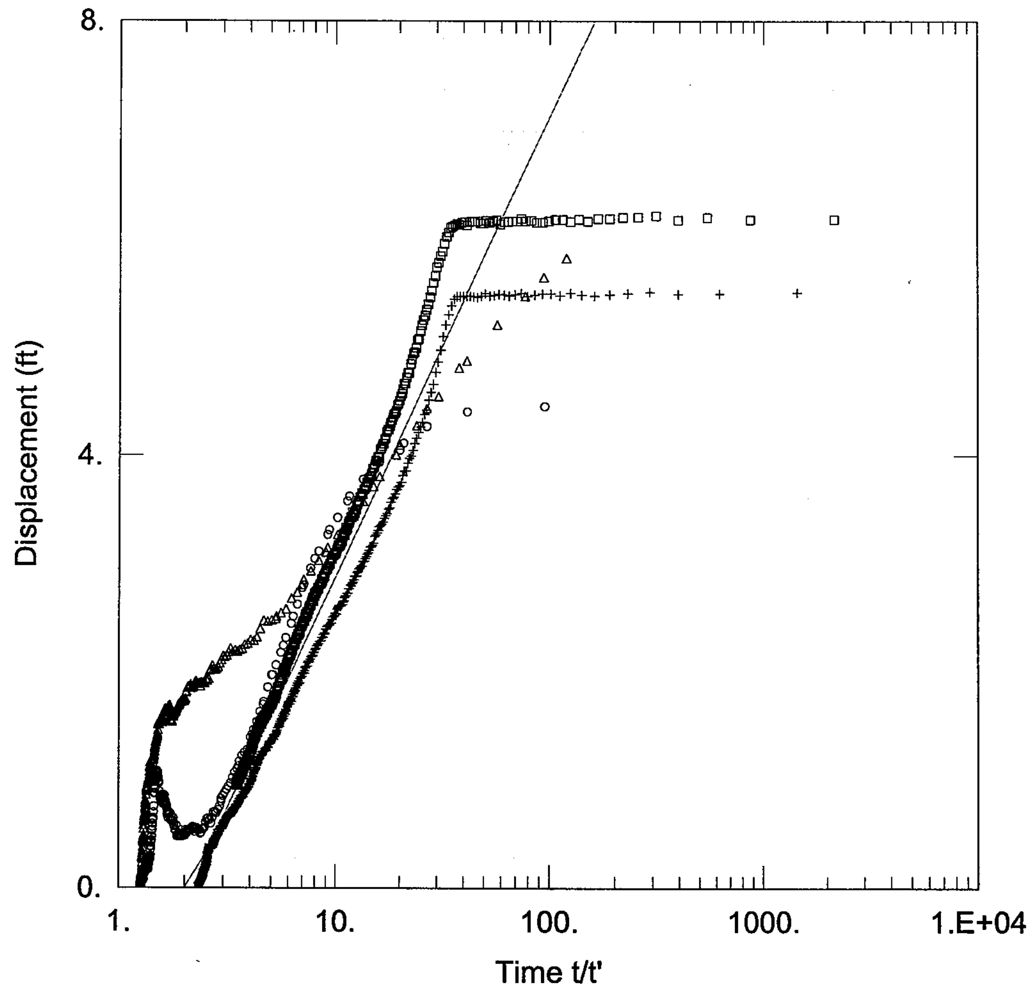
Observation Wells

Well Name	X (ft)	Y (ft)
□ WB5-4A	1.762E+006	1.078E+007
+ WB5-4B	1.762E+006	1.078E+007
○ B3-MW1	1.762E+006	1.078E+007
△ CS-D	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1219.5 gal/day/ft
S = 1.219E-07



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\16LGRALL.AQT
Date: 06/23/06 Time: 16:02:04

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

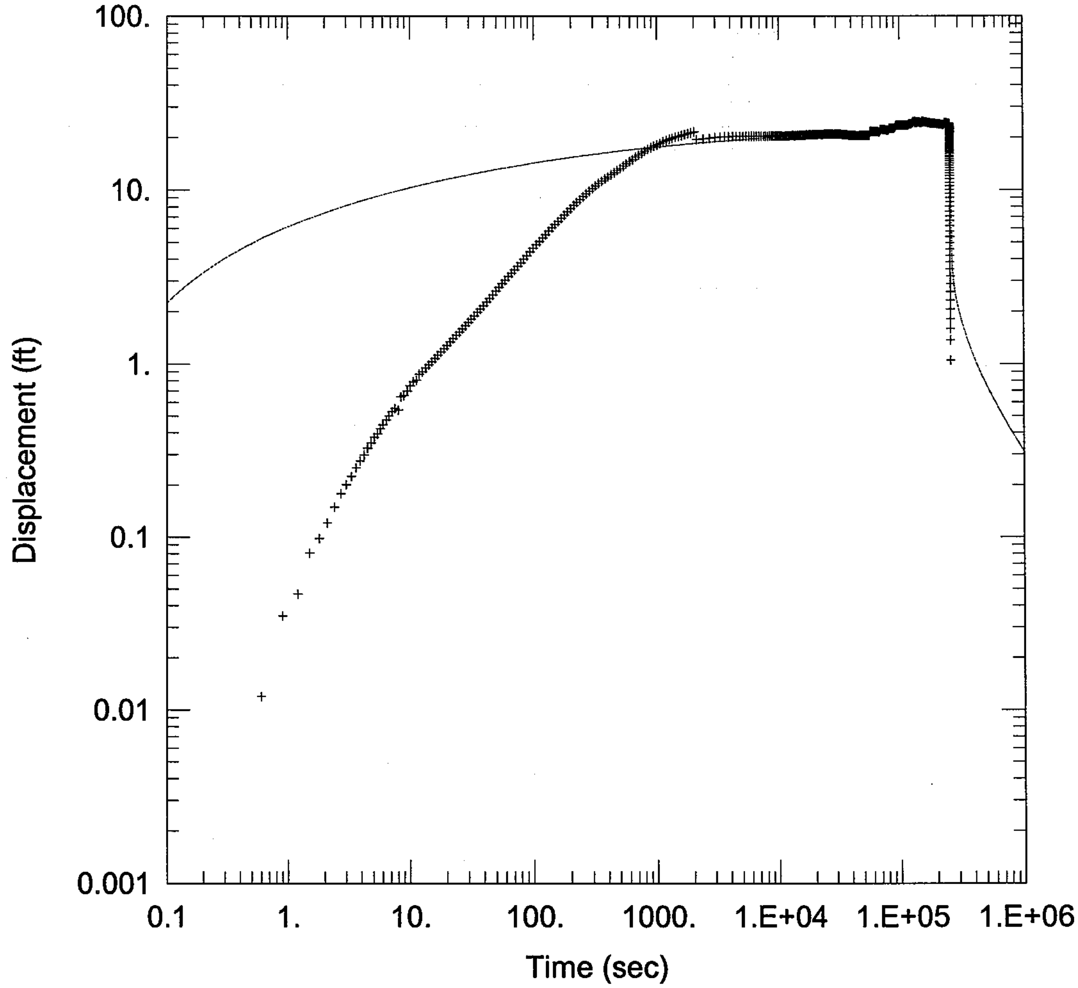
Observation Wells

Well Name	X (ft)	Y (ft)
□ WB5-4A	1.762E+006	1.078E+007
+ WB5-4B	1.762E+006	1.078E+007
○ B3-MW1	1.762E+006	1.078E+007
△ CS-D	1.762E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 621.5 gal/day/ft
S' = 2.109



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\16-LGR.AQT
Date: 06/23/06 Time: 15:24:46

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

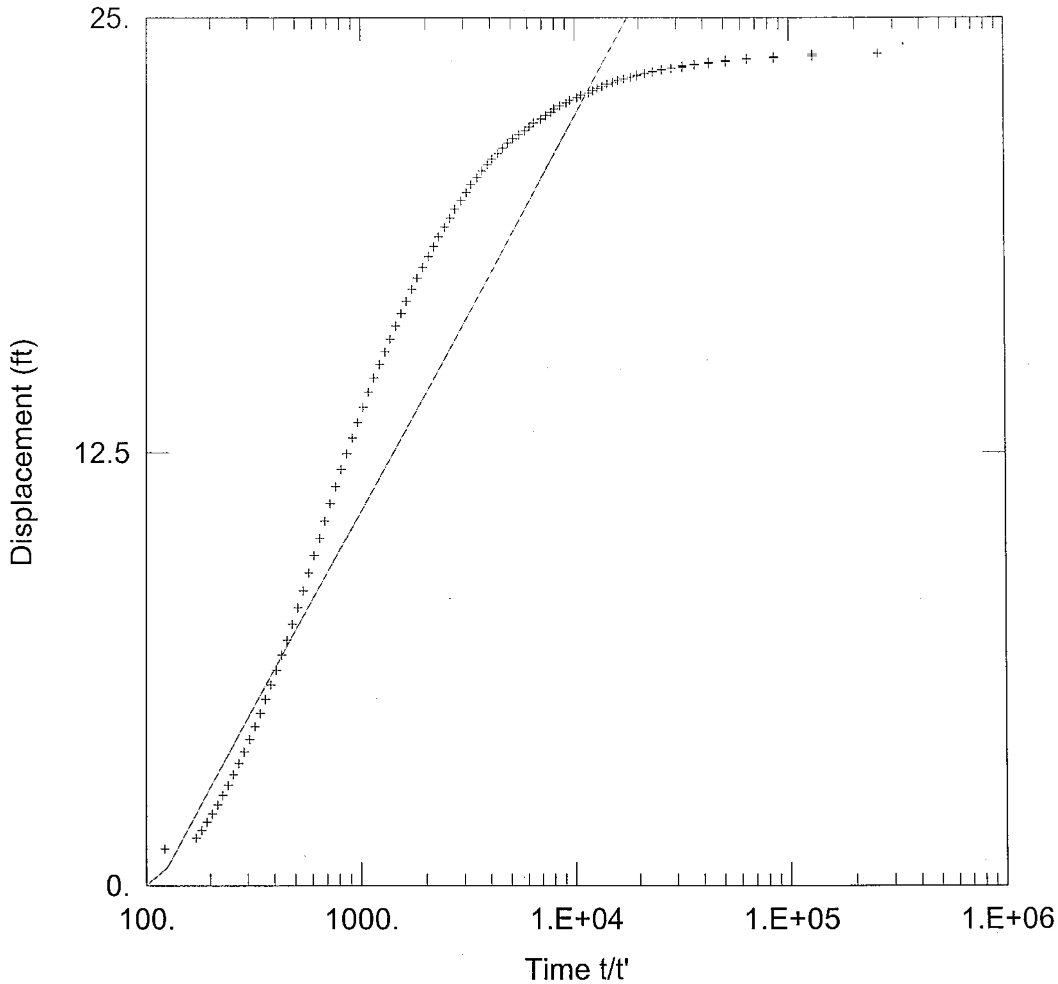
Observation Wells

Well Name	X (ft)	Y (ft)
+ 16lgr	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1095. gal/day/ft
S = 0.001219



WELL TEST ANALYSIS

Data Set: J:\744\744223~1\12000-~1\DATAFR~1\AQTESOLV\16LGR\16-LGR.AQT
Date: 06/27/06 Time: 17:07:17

AQUIFER DATA

Saturated Thickness: 111.5 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
16-LGR	1.763E+006	1.078E+007

Observation Wells

Well Name	X (ft)	Y (ft)
+ 16lgr	1.763E+006	1.078E+007

SOLUTION

Aquifer Model: Confined
Solution Method: Theis Recovery

T = 231.6 gal/day/ft
S' = 113.2