2010 Update

Three-Tiered
Long Term Monitoring Network
Optimization Evaluation

Prepared for:

Camp Stanley Storage Activity
Boerne, Texas

November 2010

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GEOSCIENTIST CERTIFICATION

2010 Update for
Three-Tiered
Long Term Monitoring Network
Optimization Evaluation

For

Department of the Army
Camp Stanley Storage Activity
Boerne, Texas

I, W. Scott Pearson, P.G., hereby certify that the Updated Three-Tiered Long Term Monitoring Network Optimization Evaluation for the Camp Stanley Storage Activity installation in Boerne, Texas accurately represents the site conditions of the subject area. This certification is limited only to geoscientific products contained in the subject report and is made on the basis of written and verbal information provided by the CSSA Environmental Office, laboratory data provided by APPL Laboratory, DHL Laboratory, and Severn Trent Laboratory, and field data obtained during ongoing groundwater monitoring conducted at the site, and is true and accurate to the best of my knowledge and belief.

W. Scott Pearson, P.G.
State of Texas
Geology License No. 2186

Nov. 18, 2010
Date

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ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Engineering and the Environment
AOC	area of concern
BDCME	bromodichloromethane
BZME	toluene
BS	Bexar Shale
CC	Cow Creek
cm/sec	centimeters per second
COC	contaminant of concern
CSSA	Camp Stanley Storage Area
DCE	dichloroethene
DQO	data quality objective
ESRI	Environmental Systems Research Institute, Inc.
FM	Farm to Market Road
GIS	geographical information system
gpd	gallon per day
gpm	gallon per minute
HCSM	hydrogeologic conceptual site model
IH	Interstate Highway
LCY	loose cubic yards
LGR	Lower Glen Rose
LTM	long-term monitoring
µg/L	microgram(s) per liter
MCL	maximum contaminant level
NS	north to south cross section
Pb	lead
PCE	tetrachloroethene
PQL	practical quantitation limit
PZ	piezometer
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RMU	rifle management unit
SWMU	solid waste management unit
SVE	soil vapor extraction
TBME	bromoform
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
UGR	Upper Glen Rose
USEPA	United States Environmental Protection Agency

USGS	United States Geological Survey
VC	vinyl chloride
VEW	vapor extraction well
VLF	very low frequency
VOC	volatile organic compound
WB	Westbay™-equipped well
WE	west to east cross section

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EXECUTIVE SUMMARY

Since volatile organic compounds (VOCs) were first reported in CSSA groundwater in 1991, the U.S. Army has enacted a prolific groundwater monitoring program to delineate two VOC plumes originating from CSSA. Numerous on-post wells and privately-held off-post wells have been incorporated into a VOC detection and delineation network that was routinely sampled on a quarterly basis. By 2004, approximately 88 on- and off-post wells were regularly sampled on a quarterly basis to develop a large statistical database. By 2004, it became evident that most wells sampled contained VOC concentrations well below the federally-mandated Maximum Contaminant Levels (MCLs) for the target VOCs. At that time, CSSA initiated a Long Term Monitoring Optimization (LTMO) process to evaluate if statistical and spatial parameters would support a reduction in sampling locations and/or sampling frequencies without sacrificing the monitoring objectives.

In 2005, Parsons used validated analytical data spanning from 1992 through December 2004 from the monitoring well network to perform a Three-Tiered LTMO evaluation. The evaluation includes a "qualitative" analysis performed by geologists and chemists familiar with the site, followed by a temporal (statistical) evaluation of the data to identify trends. The final tier of the analysis is a spatial evaluation to determine the individual contribution that single well and its data make to the overall monitoring network. The findings of the three-tiered evaluations are combined into a final recommendation for adjusting the sampling locations and sampling frequency.

The 2005 LTMO for the on-post and off-post wells recommended a refined monitoring program consisting of the 84 wells that would be sampled less frequently (33 wells sampled biennially, 28 sampled annually, 16 sampled semi-annually, and 7 sampled quarterly) than before but still adequate to address the primary monitoring objectives. The recommendations included reducing the number of sampling events for the four Westbay™ multi-port wells (44 zones) from monthly to semi-annually. In effect, this would the sampling frequency of Westbay Zones from 528 to 88 events per year. Implementation of these recommendations for the monitoring program at CSSA would reduce the number of on- and off-post sampling events per year by approximately 57 percent and the WB sampling events per year by approximately 88 percent.

In 2005, the Environmental Protection Agency (EPA) and Texas Commission on Environmental Quality (TCEQ) approved the use of the LTMO recommendations for on-post monitoring wells and the Westbay multi-port wells. However, at that time, the TCEQ had reservations for implementing the off-post LTMO, and suggested that CSSA continue to follow the current approved off-post sampling program. The on-post LTMO recommendations were implemented beginning December 2005. An additional change to the LTMO sampling frequency was made in 2009 to provide for an additional 9-month "snapshot" event. This "snapshot", in which all on- and off-post wells were sampled, was adopted to provide an area-wide status of the two plumes. The 9-month sampling interval was selected to provide long-term assurance that seasonal changes associated with the hydrologic cycle were taken into consideration.

In 2007, CSSA began a "Bioreactor" treatability study at the SWMU B-3. This study involved the establishment of an extraction well network to provide contaminated water to the

Bioreactor to augment solvent de-chlorination. Groundwater monitoring associated with this study has a separate sampling plan/schedule and is not included in this LTMO study. Numerous sumps, monitoring wells and four Westbay multi-level wells are included with the SWMU B-3 Bioreactor study.

This report provides an update to the original 2005 LTMO report. An additional four years of analytical data from the existing and new wells were added to the three-tiered evaluation to determine if there had been changes in trends and if the sampling frequency could be further refined. By 2009, the monitoring network had grown to 111 wells which included new monitoring wells drilled at CSSA, and new off-post wells incorporated into the network. The same qualitative, temporal/statistical, and spatial evaluations were conducted to provide recommendations to further enhance or streamline the monitoring network.

Overall, since on-post LTMO was implemented, there has been no discernible increasing or decreasing trend in size or concentration with either CSSA VOC plume. In 2009, the combined three-tiered evaluation streamlined the on- and off-post monitoring network to better implement the 9-month sampling strategy. Further modifications to the CSSA groundwater monitoring plan for off-post include taking the wells that are currently sampled either annually or semi-annually and change their schedule to a 9-month frequency only. Select wells that are near the plume centers or are sentry wells will also be continued at a semi-annual frequency as well. The on-post potable water supply wells and key off-post wells will continue to be sampled on a quarterly basis. All off-post wells will also continue to be evaluated by the approved Off-Post Wells Data Quality Objectives (DQOs) that dictate sampling frequencies and remedial actions based upon the VOC concentrations detected in a given well. At all times, the DQOs will supersede the recommended LTMO sampling frequency if conditions change.

This refined on and off-post monitoring network would result in an average of 154.4 well-sampling events per year (76 on-post and 78.4 off-post), compared to 209 well-sampling events per year (100 on-post and 109 off-post) under the current (2005 LTMO) monitoring program. Reducing Westbay sampling from semi-annually every 9-months would reduce the number of sampling events from an average 294 events per year to 223.6 events per year.

Implementing these recommendations would reduce on- and off-post sampling events by 24 percent and 28 percent, respectively. Likewise the reduction of Westbay sampling would result in a 19 percent decrease in sampling events. Overall, the recommendations of the 2010 LTMO update will reduce the CSSA groundwater monitoring frequency by 24 percent.

SECTION 1
INTRODUCTION

Groundwater monitoring programs have two primary objectives (U.S. Environmental Protection Agency [USEPA], 1994; Gibbons, 1994):

1. Evaluate long-term temporal trends in contaminant concentrations at one or more points within or outside of the remediation zone, as a means of monitoring the performance of the remedial measure (*temporal objective*); and
2. Evaluate the extent to which contaminant migration is occurring, particularly if a potential exposure point for a susceptible receptor exists (*spatial objective*).

The relative success of any remediation system and its components (including the monitoring network) must be judged based on the degree to which it achieves the stated objectives of the system. Designing an effective groundwater monitoring program involves locating monitoring points and developing a site-specific strategy for groundwater sampling and analysis to maximize the amount of relevant information that can be obtained while minimizing incremental costs. Relevant information is that required to effectively address the temporal and spatial objectives of monitoring. The effectiveness of a monitoring network in achieving these two primary objectives can be evaluated quantitatively using statistical techniques. In addition, there may be other important considerations associated with a particular monitoring network that are most appropriately addressed through a qualitative assessment of the network. The qualitative evaluation may consider such factors as hydrostratigraphy, locations of potential receptor exposure points with respect to a dissolved contaminant plume, and the direction(s) and rate(s) of contaminant migration.

This report presents a description and evaluation of the groundwater monitoring program associated with the Camp Stanley Storage Activity (CSSA) in Boerne, Texas. A 111-well monitoring network containing 153 sampling points was evaluated to identify potential opportunities to streamline monitoring activities while still maintaining an effective monitoring program. A three-tiered approach, consisting of a qualitative evaluation, an evaluation of temporal trends in contaminant concentrations, and a statistical spatial analysis, was conducted to assess the degree to which the monitoring network addresses each of the two primary objectives of monitoring, and other important considerations. Results of the three evaluations were combined and used to assess the optimal frequency of monitoring and the spatial distribution of the components of the monitoring network, and were also used to develop recommendations for optimizing the monitoring program at CSSA.

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SECTION 2
SITE BACKGROUND INFORMATION

The location, operational history, geology, and hydrogeology of CSSA are briefly described in the following subsections.

2.1 SITE DESCRIPTION

2.1.1 Site Background

CSSA is an active installation located in Bexar County, approximately 19 miles northwest of downtown San Antonio, Texas. Its higher headquarters is the McAlester Army Ammunition Plant in McAlester, Oklahoma. The mission of CSSA is the receipt, storage, and issuance of ordnance materiel as well as quality assurance testing and maintenance of military weapons and ammunition. Because of its ordnance mission, CSSA is a restricted-access facility.

CSSA consists of 4,004 acres immediately east of Farm to Market Road (FM) 3351, and approximately half a mile east of Interstate Highway (IH) 10 (**Figure 2.1**). Camp Bullis borders CSSA on the north, east, and southeast. The land on which CSSA is located was used for ranching and agriculture until the early 1900s. Six tracts of land were purchased by the U.S. Government during 1906 and 1907 and designated the Leon Springs Military Reservation, which later evolved into Camp Stanley.

Land south and west of CSSA is primarily residential or used for ranching. Nearby communities and subdivisions include Leon Springs, Leon Springs Villa, Hidden Springs Estates, The Dominion, Fair Oaks Ranch, and Jackson Woods. Ranching and agricultural land is intermingled with the developed communities. The IH 10 and Ralph Fair Road intersection includes separate commercial businesses. A strip center at the northwest corner of CSSA also contains businesses that serve the city of Fair Oaks Ranch.

2.1.2 Investigative and Remedial Activities

A total of 84 sites, consisting of 39 solid waste management units (SWMU), 40 areas of concern (AOC), and five rifle management units (RMU) were identified at CSSA in previous investigations. Analytical data suggest that tetrachloroethene (PCE), trichloroethene (TCE), and *cis*-1,2-dichloroethene (DCE) are the primary contaminants of concern (COC) in groundwater, and that metals are the primary COC in soil. As of November 2010, a total of 51 SWMU and/or AOC sites have been closed. Over 72 sites have been investigated, and remediation is currently being conducted at 14 sites. However, only three sites investigated are considered to be likely sources for the groundwater contamination within the Middle Trinity aquifer. These include two SWMUs (B-3 and O-1) located near well CS-16 and AOC-65 located near the SW corner of the post (**Figure 2.2**). In addition to these VOC source areas, one metals source area, well CS-9, has been identified. Monitoring suggests the area of impact is immediately around the wellbore and the metals impact in ground water has not spread appreciably. Additional information on these site investigations is included in the CSSA Environmental Encyclopedia; specifically the *Groundwater Investigation and Associated Source Characterizations Report, SWMU B-3 Characterization* (Parsons 1996), *Interim/Stabilization Measures and Partial Facility Closure*

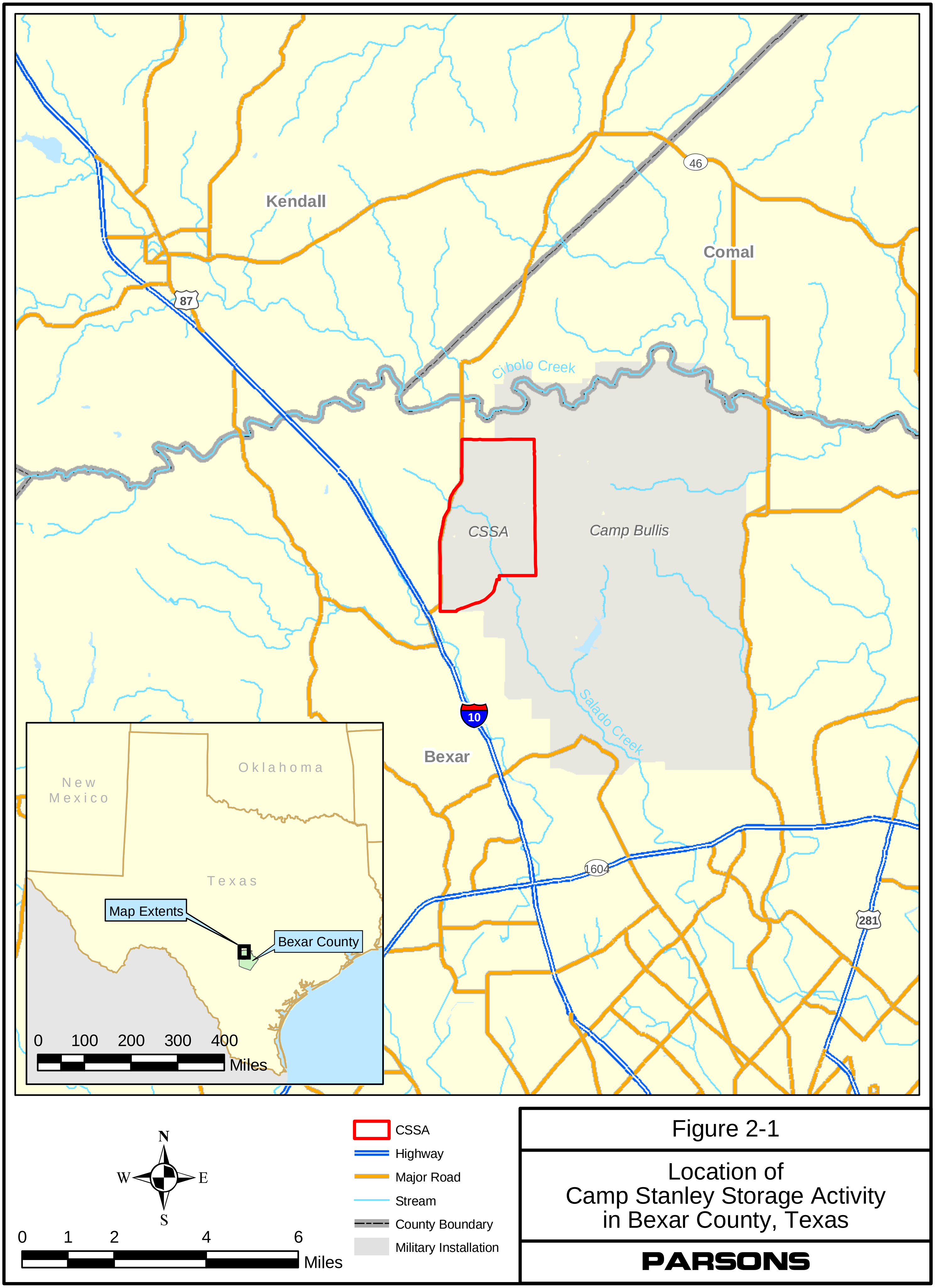
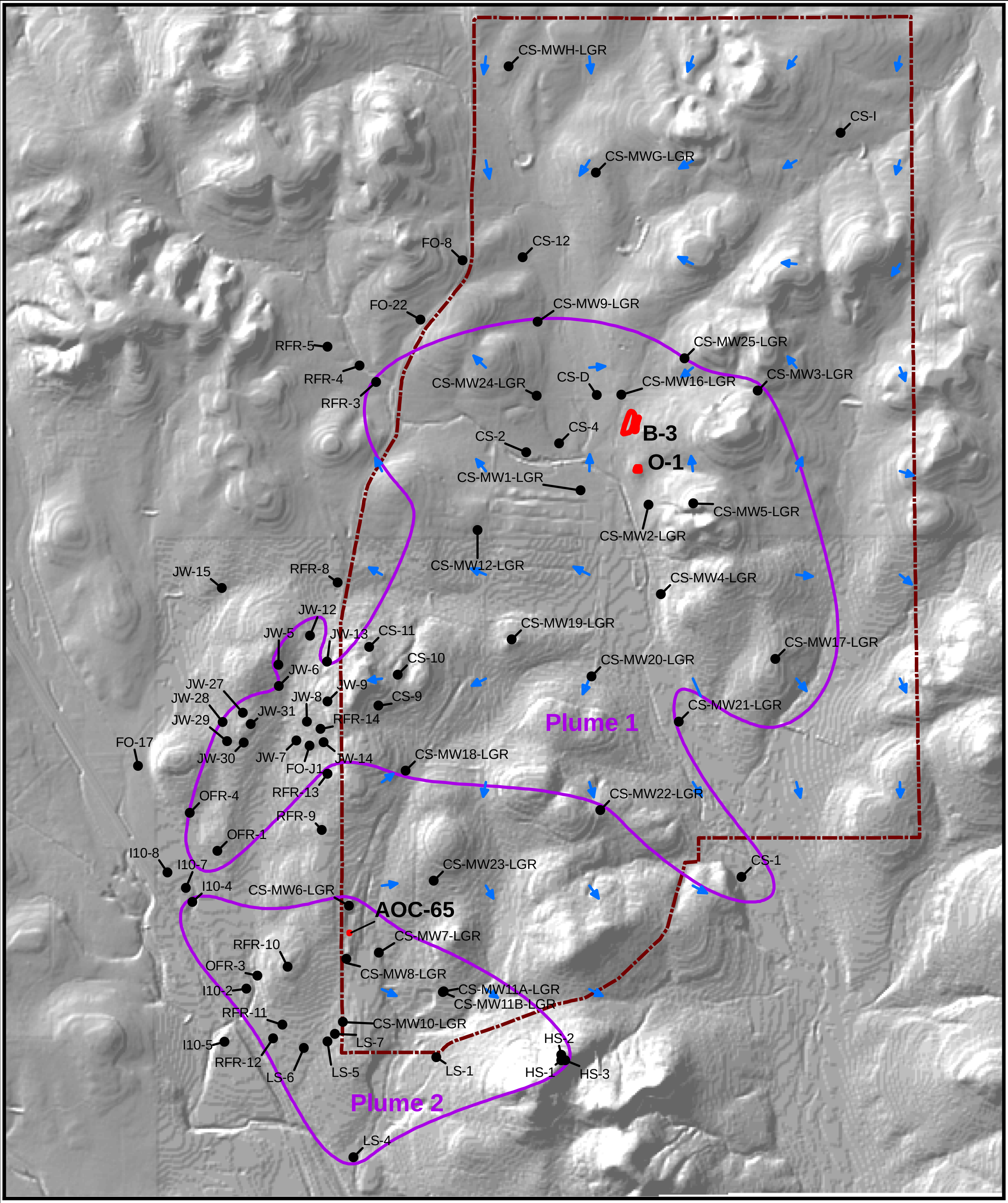


Figure 2-1

Location of
Camp Stanley Storage Activity
in Bexar County, Texas

PARSONS



N
W E
S

- LGR Zone Wells
- Groundwater Flow Direction (Dec 09)
- Approximate Extent of PCE Plume
- Source Areas
- CSSA Boundary

2,500 1,250 0 2,500 Feet

Figure 2.2

General Site Features

Camp Stanley Storage Activity

PARSONS

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Report for SWMU O-1 (Parsons, 2000) and *AOC 65 Interim Removal Action Report* (Parsons 2003). The CSSA Environmental Encyclopedia is maintained as the Administrative Record for CSSA under provisions of the Administrative Order on Consent issued to CSSA on May 5, 1999, pursuant to §3008(h) of the Safe Drinking Water Act (SDWA). The CSSA Environmental Encyclopedia is available in hard copy format and on the internet at www.stanley.army.mil.

SWMU B-3 was a trenched landfill area thought to have been used primarily for garbage disposal and trash incineration. In 1991, chlorinated hydrocarbons were detected in groundwater from well CS-16 approximately 500 feet north-northwest of SWMU B-3. The concentrations were above drinking water standards and prompted several investigations aimed at identifying possible source areas that could have contributed to the contamination. Various investigations including geophysical surveying, surface and subsurface soil sampling, and soil gas sampling, indicated PCE and TCE were present at SWMU B-3. The presence of these chlorinated hydrocarbons indicated SWMU B-3 as a likely source area for the contamination detected in well CS-16.

Removal actions performed at SWMU B-3 include the excavation/disposal of soil impacted by volatile organic compounds (VOCs). Three drums with PCE labels were removed from the easternmost trench (trench 6) and disposed off-site along with 732 loose cubic yards (LCY) of hazardous media and 1,242 LCY of Class 2 non-hazardous materials. In addition, over 5,500 LCY of cover soil were properly characterized and remain stockpiled at the site.

Soil vapor extraction (SVE) pilot tests and treatability were performed at SWMU B-3 before and after the removal actions. Based on initial SVE pilot tests and the first 12 months of operations and maintenance, removal of approximately 290 pounds of VOCs occurred. Based on these findings, SVE appeared to be an effective method for removing VOCs from the SWMU B-3 trenches, but did not appear to reduce impact to groundwater in the area.

A second site identified as a possible source of contamination was the oxidation pond, also referred to as SWMU O-1. The pond, located approximately 210 feet south of SWMU B-3 was constructed in 1975. Waste fluids from CSSA industrial operations were trucked to the oxidation pond for evaporation. These wastes included spent solvent from the Building 90 solvent vats. The pond liner was damaged during site closure. No records are available to indicate whether or not disposal of the sludge or residue contained in the oxidation pond occurred before damage to the liner. Due to its proximity to contaminated well CS-16, investigations were initiated at SWMU O-1 in 1995. Surface geophysical surveys, soil sampling and soil gas surveys were performed. Approximately 80 LCY of soil material were excavated during the liner investigation. A field treatability study was initiated to test the efficacy of electrokinetic treatment on metals contamination. Additional soil was excavated and removed in November 1999 and in 2000. Surface and subsurface soil was transported and disposed of off-site. The excavation area was backfilled and a low-permeability clay liner was constructed over the site. Six inches of topsoil were placed on top of the clay liner, and a vegetative surface was established on the topsoil. Texas Commission on Environmental Quality (TCEQ) approved a partial facility closure of the surface soil zone located within the boundaries of SWMU O-1 in April 2002.

The third site identified as a groundwater VOC source area was AOC-65. This site is located at the southwest corner of the post and included two sub-slab, concrete-lined vaults located inside Building 90 as well as associated drain lines and ditches extending west from the building. A metal vat was installed in the western vault prior to 1966 and removed in 1995. The vat was used for cleaning ordnance materials with chlorinated liquid solvents, such as PCE and TCE. In 1995, after removal of the solvent vat, a metal plate was welded over the concrete vault. At the same time, use of PCE and TCE solvents were replaced by citrus-based cleaners. The use of the second vault, located within the middle of Building 90, is not known. It was backfilled and capped with concrete at an unknown date. Building 90 continues to be used for weapons cleaning and maintenance.

A soil gas survey, performed in January and February 2001, revealed a PCE plume in the soil beneath and to the south and west of Building 90 (*AOC-65 Soil Gas Survey Results, January - February 2001* [Parsons, 2001]). Soil borings were advanced and sampled and monitoring wells were installed and sampled. The soil gas survey indicated the presence of a PCE contaminant plume underlying Building 90 and extending primarily to the west and southwest from the building. Based on sampling results, it appears the lateral extent of the PCE plume in the soil gas is generally confined to the immediate vicinity of Building 90. Soil in the area where the drainage line from Building 90 meets the drainage ditch contained the highest COC concentrations. However, in the bedrock samples (21.0 to 21.5 feet below ground surface), concentrations only slightly exceeded background. Groundwater samples collected from both inside and outside the soil-gas survey plume contained PCE.

Geophysical investigations were performed to identify subsurface features such as fractures, faults, and karst dissolution that may be controlling the migration of contaminants. Identification of these features was used to direct installation of piezometers (PZ)s and an SVE system near Building 90. The geophysical methods utilized at AOC-65 include electrical resistivity, microgravity, very low frequency (VLF), EM, shear-wave seismic reflection, induced polarization (IP), and spontaneous potential (SP). These methods were selected based on their ability to detect changes in physical properties associated with fractures, faults, and karst features. The surveys were implemented in a phased approach with the results of one phase providing direction for subsequent phases. Removal of near-surface contamination and the installation of two SVE systems were conducted. Geologic correlations from core and geophysical logs indicate at least three faults cross the AOC-65 area.

After near-surface soil was removed along the former drain line and ditch, engineering controls were constructed to minimize the amount of precipitation recharge infiltrating the source zone.

2.2 GEOLOGY AND HYDROGEOLOGY

2.2.1 Geology

The oldest and deepest known rocks in the CSSA area are Paleozoic age (225 to 570 million years ago) schists of the Ouachita structural belt. They underlie the predominant carbonate lithology of the Edwards Plateau. The Cretaceous age sediments were deposited as onlapping sequences on a submerged marine plain and, according to well logs and outcrop observations, these sediments thicken to the southeast. The Cretaceous System stratigraphy includes the Trinity Group Travis Peak Formation shallow marine deposits. The Travis Peak Formation attains a maximum thickness of about 940 ft and is divided into five members, in ascending order: the Hosston Sand, the Sligo Limestone, the Hammett Shale, the Cow Creek (CC) Limestone, and the Hensell Sand (and Bexar Shale (BS) facies). Overlying the Travis Peak

Formation, but still a part of the Cretaceous-age Trinity Group, is the Glen Rose Limestone. For this study, the units of interest are the Glen Rose Limestone, BS, and CC Limestone that form the Middle Trinity aquifer.

The Hammett Shale, which overlies the Sligo Limestone, has an average thickness of 60 feet. It is composed of dark blue to gray fossiliferous, calcareous, and dolomitic shale, pinches out to the north of CSSA and attains a maximum thickness of 80 feet to the south. Above the Hammett Shale is the CC Limestone, which is a massive fossiliferous, white to gray, shaley to dolomitic limestone that attains a maximum thickness of 90 feet down dip in the area. The youngest member of the Travis Peak Formation is the Hensell Sand, locally known as the BS. The shale thickness averages 60-80 feet, and is composed of silty dolomite, marl, calcareous shale, and shaley limestone, and thins by interfingering into the Glen Rose Formation.

The upper member of the Trinity Group is the Glen Rose Limestone. The Glen Rose Limestone was deposited over the Travis Peak BS and represents a thick sequence of shallow water marine shelf deposits. This formation is divided into upper and lower members. At CSSA, the Glen Rose is exposed at the surface and in stream valleys.

The Upper Glen Rose (UGR) consists of beds of blue shale, limestone, and marly limestone with occasional gypsum beds (Hammond, 1984). Based on well log information, the thickness of the upper member reaches 500 feet in Bexar County. The UGR is located at the surface over much of CSSA, while the thickness of this member at CSSA is estimated from well logs to be between 20 and 150 feet.

The Lower Glen Rose (LGR), underlying the UGR, consists of a massive fossiliferous limestone, grading upward into thin beds of limestone, marl, and shale (Ashworth, 1983). The lower member, according to area well logs, is approximately 300 feet thick at CSSA. Isolated areas of reef rock have also been identified in the LGR. The boundary between the upper and lower members of the Glen Rose Limestone is defined by a widespread fossil stratigraphic marker known as the Corbula bed (*Corbula martinae*) (Whitney, 1952). The Corbula bed is 0.5-5 feet thick and contains small pelecypod clamshells, which are three to five millimeters in diameter. Presence of Corbula fossils indicates a slightly more saline depositional environment than fossils found above and below the Corbula. A gypsum bed has also been identified near the Corbula bed.

2.2.2 Hydrogeology

The geologic units present at CSSA were informally divided into hydrostratigraphic units to provide a framework for describing the local hydrogeology. Three aquifers are present in the area of CSSA: the Upper, Middle, and Lower Trinity. The Travis Peak Formation and the Glen Rose Formation are the principal water-bearing units. Only the Middle and Upper Trinity aquifers are addressed for this study.

The following hydrostratigraphic descriptions are based on work performed by the USGS, in which the UGR member has been informally divided into five mappable units within Camp Bullis and CSSA. For this report, the UGR Limestone has been subdivided into five mappable intervals (UGR[A-E]). Exposures of units UGR(A, B, and C) are limited to the very highest elevations within the post. The lower two units, UGR(D and E), comprise over 83 percent of the outcrop at CSSA.

Interval UGR(A) is approximately 120 feet thick composed of alternating and interfingering medium-bedded mudstone to packstone, with evaporates occurring locally. Interval UGR(A) has been referred to as the "cavernous zone" (GVA, 2000) because of an abundance of caves in the interval. Interval UGR(A) crops out only atop Schasse Hill within the confines of CSSA. Interval UGR(B) is a 120- to 150-feet-thick interval similar to Interval UGR(A) but with appreciably less cave development and thus less permeability than the overlying interval. Overall, intervals A and B are indistinguishable based on lithology. Interval UGR(B) crops out only atop some of the larger hills (Schasse Hill, Wells Hill, and Steele Hill) within the confines of CSSA. Groundwater occurring within intervals A and B is laterally discontinuous and is not likely to be hydraulically connected to the known VOC source areas. Limited recharge to the zone is through direct precipitation on the outcrop and recharge from Interval UGR(A), and much of that water is believed to be lost to seeps along the base of the outcrop. Some groundwater may leak vertically to lower strata where the outcrop is bisected by faults or fractures.

Interval UGR(C) is a solution zone approximately 10 to 20-feet thick. Like the underlying Interval UGR(E) at the base of the UGR, it was originally an evaporite bed. It is composed of yellow-to-white calcareous mud with some very thin mudstone layers interspersed with a tendency to form broad, valley-like slopes. Interval UGR(C) only crops out along the slopes of the larger hills (Schasse, Wells, and Steele) within the confines of CSSA.

Interval UGR(D) is 135 to 180 feet thick and composed of alternating beds of wackestone, packstone, and marl. Because of its high mud content, the 135 to 180-foot thick Interval UGR(D) (between the two solutioned evaporite beds (Intervals UGR [C] and UGR [E] and known locally as a "fossiliferous zone") generally has low porosity and permeability, with some local exceptions. In a few locations, some cavern porosity can be seen in outcrops along fractures. Interval UGR(D) crops out over most of CSSA (77.5 percent coverage). Most of the developed areas at CSSA are on the Interval UGR(D) outcrop. Likewise, most of the waste management activities that have occurred at CSSA are also within this interval. However, most of the more permeable zones near the top of the unit have been eroded from CSSA, and occur only near the top of hills where less development and waste management activities have occurred. Significant recharge to the zone is through direct precipitation on the outcrop and recharge from overlying intervals. This is the first pervasive stratum across the facility that lends itself to lateral groundwater movement without being cropped out by the intersecting land surface. A significant volume of groundwater is assumed to leak vertically to lower strata where the outcrop is bisected by faults or fractures. This unit has been investigated in depth by RFI activities and groundwater investigations, as well as the background soils study prepared in the Second Revision to Evaluation of Background Metals Concentrations in Soils and Bedrock (Parsons, 2002a). Groundwater contamination is known to exist within this interval near the source areas of Plumes 1 and 2.

Interval UGR(E) is a 7- to 10-foot thick solution zone that was originally an evaporite bed, but that has subsequently been dissolved, leaving behind a calcareous mud. The Corbula bed lies at the base of this interval and marks the geologic contact between the UGR and LGR Limestone. The Corbula bed is a thin to very-thin-bedded grainstone. As with Interval UGR(C), this solutioned evaporite bed, which includes the Corbula bed at its base, appears to intercept the downward seepage of water. The interval acts as a lateral conduit for flow, as demonstrated by seeps observable at the surface in outcrop. Groundwater contamination is known to exist within this interval near the source areas of Plumes 1 and 2. The vapor extraction wells (VEW) at B-3 and the shallow PZs (-2, -4, and -6) at AOC-65 are mostly completed within this depth interval, and groundwater concentrations from these wells indicate concentrations greater than those in the main plume within the LGR. At B-3 (Plume 1), *cis*-1,2-DCE has been reported in excess of 27,000 µg/L, and nearly 3,000 µg/L of PCE were reported. At AOC-65 (Plume 2), lesser concentrations of PCE, generally ranging between 30 µg/L and 60 µg/L, are found in the underlying LGR units. However, near the source area, 30,000 µg/L of PCE were reported in UGR strata.

In the Hydrogeologic Conceptual Site Model (HCSM), the LGR Limestone has been informally divided into six intervals LGR(A-F), as described below from youngest to oldest (Parsons, 2008).

Exposures of unit LGR(A) are limited to the basal portion of Salado Creek and its tributaries in the central portion of the post (covering 10.8 percent of CSSA's surface). The remaining older units do not crop out within the post. Interval LGR(A) is defined as the uppermost 50-foot sequence of LGR deposits throughout the CSSA area. The unit is characterized by alternating layers of pale yellow mudstone, wackestones, and packstones.

The top of Interval LGR(B) ranges between 30 to 50 feet beneath the UGR/LGR contact, and the interval is between 30 and 50 feet thick. The interval is characterized as a whitish fossiliferous packstone and grainstone that is evident both in lithologic and geophysical logs. During much of the year, the main aquifer level is well below the elevation of this interval. During these times, groundwater will tend to perch within this zone. Large sinkholes and other solution features have formed in this zone.

Over much of CSSA, Interval LGR(C) exists as a 60-70-foot thick sequence of thin and medium-bedded mudstones below the more permeable grain-supported limestones of Interval LGR(B). The mudstones are described as alternating layers of tannish-brown and greenish-gray bioturbated muds with a low percentage allochemical constituents (*e.g.*, fossils). The rock is competent and highly styolitic (susceptible to diagenetic pressure solutioning). Interval LGR(C) also includes some significant reef structures to the north and south.

Interval LGR(D) is a 65-70-foot thick unit of rock that is characterized by a unique resistivity signature with respect to the overlying and underlying rocks. The change generally represents two resistive packstone layers divided by a less resistive mudstone. The upper and lower packstone layers tend to be approximately 25 feet thick, and are described as interbedded fossiliferous wackestones and packstones that are pale yellow to white in color. The middle layer is more characteristic of a bioturbated mudstone that is tan in color. The localized vugs associated with moldic porosity (fabric selective) can store and transmit limited amounts of groundwater.

Interval LGR(E) is a 50-60-foot layer of tan and light brown wackestones with intermittent thin fossiliferous layers and grain-supported rock. The unit is fairly unremarkable, except for the presence of a notable vuggy packstone layer located at the base of the interval.

Interval LGR(F) comprises the main groundwater production zone within the LGR throughout CSSA. Interval LGR(F) is composed of a 45 to 55-foot reef complex, the lateral extent of which appears to be under the entire confines of CSSA. The occurrence of this reef has been well documented within boreholes drilled at CSSA and neighboring areas. The interval is described as a white to tan, very fossiliferous packstone/grainstone with high fabric selective moldic porosity. The interval is characterized by its relatively low gamma response and high resistivity response. The vuggy porosity left as a result of fossil dissolution has resulted in voids that range from several millimeters to 5 centimeters in size. In some locations, the basal 15 feet of the interval has a pronounced increase in mud content, and a color change to pale brown.

The primary permeability of Interval LGR(F) is moldic (fabric selective) porosity. Extensive testing through packer tests and discrete interval groundwater sampling indicate that the interval is capable of yielding groundwater in excess of 75 gallons per minute (gpm). Where not fabric selective porosity exists in the form of developed fractures, karst, or small caverns, groundwater production can easily exceed 150 to 300 gpm. For the monitoring well program, this interval has been the focus of the investigations where typically the basal 25 feet of the aquifer are monitored for the occurrence of contamination.

The BS has been subdivided into two intervals BS(A-B), as described below from youngest to oldest. As expected, these subunits can be quite variable over the extent of CSSA. The BS forms a relatively impermeable aquitard for the overlying LGR water bearing zones. What, if any, vertical water movement in the BS is anticipated to be through fractures and faults only. CSSA currently has four monitoring wells completed in the BS. For the purposes of this model, Interval BS(A) is defined as the uppermost 25-30-foot sequence of BS deposits throughout the HCSM area. The unit is characterized by alternating layers of pale yellow mudstone, wackestones, and packstones. The BS(A) interval appears to have low porosity and permeability with only not fabric selective fracture porosity evident and no known cavern development. Beneath much of CSSA, the top of interval BS(B) is denoted by a large increase in gamma counts, which peaks and quickly declines. An approximately 10 to 15-feet-thick oyster bioherm also appears to be predominant at the top of BS(B). The basal 20 feet of the BS consists of a platy, fissile mudstone with an olive gray appearance. At this depth the unit is more characteristic of a shale bed with few allochems, and a very low porosity. The BS(B) interval appears to have low porosity and permeability with only not fabric selective fracture porosity evident and no known cavern development.

The CC has been subdivided into two intervals, CC(A-B), as described below from youngest to oldest. Interval CC(A) is defined as the uppermost 50-55-foot sequence of CC deposits throughout the area. The unit is characterized by alternating layers of white and light gray packstones and grainstones. Portions of this interval can be quite permeable from either moldic (fabric selective) porosity or not fabric porosity in the form of dissolutioned vugs, voids, or fractures. Moderate to large amounts of groundwater can be expected to be produced from this interval. This zone has been identified as an interval of interest with respect to groundwater monitoring at CSSA.

The basal 20 feet of the CC Limestone represents a conformable transition with the underlying Hammett Shale. The grainstones and packstones of unit CC(A) grade into a soft olive gray silty mudstone designated unit CC(B). The contact is transitional, with numerous interbeddings between soft shaley members and more competent limestone rock. Bedding units range from a few inches to several feet in thickness. The contact with the Hammett Shale below CC(B) has been defined typically as the greatest gamma peak below the base of the BS.

Historical water level data at CSSA show that the typical groundwater flow gradient is toward the south, with directional variations ranging from the southwest to the southeast, depending on the level of recharge. During extended periods of drought, the flow direction reflects a greater westerly component of flow.

Potentiometric surface maps from previous monitoring events indicate highly varying flow directions in the LGR. From December 2002 through December 2009, the overall direction of groundwater flow is predominately to the south-southeast. Groundwater flow in this unit is apparently influenced by groundwater mounding in the vicinity of well CS-MW4-LGR. Groundwater appears to move in several directions from this groundwater mound, which may be the result of well CS-MW4-LGR intersecting a significant recharge feature. The proximity of CS-MW4-LGR to Salado Creek is possibly the cause of a consistently higher potentiometric surface near this well. Until further control points are established, this mounding effect remains one of the most notable features of the groundwater surface. **Figure 2.2** shows the general groundwater flow in the LGR zone at CSSA.

Hydraulic conductivity and transmissivity data were gathered from pumping tests conducted at drinking water wells present at CSSA. Additional hydraulic conductivity and transmissivity data were presented in prior publications. Published hydraulic conductivity values range from 1.4×10^{-3} to 3.5×10^{-3} cm/sec locally and range from 3.4×10^{-5} to 1.0×10^{-3} cm/sec regionally (Hammond, 1984). Site-specific hydraulic conductivity values ranged from 4.2×10^{-4} to 5.7×10^{-4} cm/sec (Parsons, 2002b). Published transmissivity values ranged from 5,740 to 16,110 gpd/feet locally and range from 240 to 3,220 gpd/feet regionally (Hammond, 1984). Site-specific transmissivity values range from 1,600 to 2,400 gpd/feet (Parsons, 2002b).

2.3 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

As a result of previous operations at SWMUs B-3, O-1 and AOC-65, releases of chlorinated VOCs to the environment have occurred within CSSA. These releases resulted in contamination of the UGR and LGR Limestone member of the middle Trinity Aquifer. Detections of solvent contamination (PCE, TCE and *cis*-1,2-DCE) were first reported in 1991. Starting in 1996, the first of 51 monitoring wells were installed. Well installation continued through April 2007. Off-post contamination was first reported by CSSA in 1999 at private well LS-7. Since that time, solvent contamination has been detected in 31 off-post private and public water supply wells. The U.S. Army installed GAC treatment systems at five off-post well locations where concentrations exceed 80 percent of the federal maximum contaminant level (MCL) (5 µg/L) for PCE and/or TCE.

The highest concentrations of the COCs PCE, TCE and/or *cis*-1,2-DCE occurred at on-post monitoring wells CS-D, CS-16-LGR, CS-MW16-CC, CS-MW1-LGR, CS-MW2-LGR, in various zones of the four WB wells and in wells near Building 90 (AOC-65-MW2A, AOC-65-PZ01-LGR, AOC-65-MW1-LGR, AOC-65-PZ05-LGR, and AOC-65-MW1-LGR). Detections occurred at concentrations below the MCL on-post in wells CS-MW9-LGR to the north, CS-MW5-LGR and CS-MW17-LGR to the east, CS-1 to the southeast, CS-MW10-LGR to the southwest, and CS-9, CS-10, and CS-MW18-LGR to the west. Well CS-1 is located on Camp Bullis, beyond the boundary of CSSA.

The highest concentrations of the COCs PCE, TCE, and/or *cis*-1,2-DCE detected off-post occur at wells OFR-3, RFR-10, RFR-11, LS-2, LS-6, and LS-7. These wells are located approximately 1,000 to 2,000 feet from the CSSA southwestern boundary. Detections at concentrations below the MCL have been reported in off-post wells JW-29 located approximately 4,000 feet to the west, I10-2 located approximately 4,200 feet to the southwest, LS-4 located approximately 4,200 feet to the south, and HS-2 located approximately 1,200 feet to the south.

The groundwater plume associated with SWMUs O-1 and B-3 exists in the north-central area of the post (Plume 1) and has migrated off-post to the south and west. The groundwater plume associated with AOC-65 at the southwestern boundary of the post (Plume 2) has migrated off-post and has impacted off-post drinking water sources. These plumes are the focus of this Monitoring Network Optimization (MNO) evaluation. The COCs for both plumes include PCE, TCE, and *cis*-1,2-DCE. Groundwater contamination is most widespread within the LGR water-bearing unit. Although the highest concentrations of VOCs have been found in the UGR, previous investigations demonstrated that largest aerial extent of VOC impact resides within the LGR.

Within Plume 1, concentrations above the MCL for PCE and/or TCE are detected in wells CS-D, CS-MW1-LGR, CS-MW2-LGR, and the CS-MW16 cluster. Concentrations in excess of 200 µg/L for PCE and/or TCE have been reported at CS-D, CS-16-LGR, CS-MW16-CC, and multi-port wells at SWMU B-3. This plume has advectively migrated southward to CS-1 (on Camp Bullis), and west-southwest toward the CSSA drinking water well CS-10 (CS-9 and CS-11 are currently inactive), and to several off-post public and private wells. Over most of the plume area, contaminant concentrations are below 1 µg/L. In contrast, little to no contamination is detected in the BS and impact to the CC is limited to the area immediately around CS-16.

Contamination at Plume 2 originated at or near AOC-65 and Building 90, and has spread southward and westward from CSSA. The highest concentrations of COCs were reported adjacent to the source area (30,000 µg/L) in CS-WB03-UGR-01, March 17, 2008. Within the CSSA boundary, concentrations in excess of 100 µg/L have been reported in perched groundwater intervals above the main aquifer body. However, once the main aquifer body is penetrated, lower VOC levels are reported. Off-post, concentrations in excess of the MCLs have been detected in private and public wells with open borehole completions. Concentrations exceeding 30 µg/L have been reported 1,200 feet west-southwest of CSSA at RFR-10. Vertical profiling within that well shows that discrete intervals within uncased upper strata contribute PCE concentrations at over 90 µg/L. Only sporadic, trace concentrations of solvents have been detected in BS and CC wells within Plume 2. The general extent of plumes 1 and 2 are shown on **Figure 2.1**. The groundwater monitoring program at CSSA is fully described in Section 3.

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SECTION 3
LONG-TERM MONITORING PROGRAM AT CSSA

The 2009 groundwater monitoring program at CSSA was examined to identify potential opportunities for streamlining monitoring activities while still maintaining an effective monitoring program. The 2009 monitoring program at CSSA is reviewed in the following subsections.

3.1 DESCRIPTION OF MONITORING PROGRAM

The CSSA groundwater monitoring program contains 111 wells, including on-post, off-post and Westbay (WB)-equipped wells. The WB wells have ports at multiple depths across the LGR, BS, and CC zones; the four wells have 46 distinct sampling locations that are considered separately for the LTMO analysis. Thus, the monitoring program examined in this 3-tiered LTMO evaluation includes 153 sampling locations (56 on-post wells, 51 Off-post wells, and 46 WB sampling locations in 4 wells). The objectives of the monitoring program at CSSA are presented in both the *Data Quality Objectives for the Groundwater Contamination Investigation,* (November, 2003) and in the CSSA *Off-post Groundwater Monitoring Response Plan* (June, 2002) and include, in part:

- Determine whether on- and off-post drinking water meets the standards for safe drinking water as prescribed under the USEPA and TCEQ rules;
- Determine if VOC concentrations in on-post and off-post drinking water wells exceed values stated in project data quality objectives (DQOs) and the CSSA off-post Monitoring Response Plan;
- Determine which formation(s) in the Middle Trinity Aquifer are impacted by VOC contaminants;
- Determine the impacts of rain events, drought conditions, and groundwater recharge on concentrations and migration of VOCs in the aquifer and vadose zone.

The CSSA Groundwater Monitoring Program wells and their associated current (2009) monitoring frequencies were identified from the Quarterly Groundwater Monitoring Reports available in Volume 5 of the CSSA Environmental Encyclopedia and subsequent review by site hydrogeologist Scott Pearson. Well information is listed in **Table 3.1**, including the hydrogeologic zone (as described in Section 2.2), current sampling frequency (as of December 2009), the first and most recent sampling events, well zone and well classification. Wells are classified into the following groups for the statistical analyses:

- LGR: Monitoring wells screened in the LGR Zone
- CC: Monitoring wells screened in the CC Zone
- BS: Monitoring wells screened in the BS Zone
- OPBH: On-post Open Boreholes screened across multiple hydrogeologic units
- OffBH: Off-post Open Boreholes screened across multiple hydrogeologic units
- AOC/WB: AOC-65 area wells and piezometers and WB Wells.

TABLE 3.1
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
On Post Monitoring Wells					
AOC65-MW1	UGR(D)	Sample after major rain event	6/10/04	12/2/04	AOC/WB[a/]
AOC65-MW2A	UGR(D)	Sample after major rain event	6/10/04	12/2/04	AOC/WB
AOC65-PZ01-LGR	LGR(B)	Exclude	7/19/02	8/24/04	AOC/WB
AOC65-PZ02-LGR	UGR(D)	Exclude	7/19/02	6/10/04	AOC/WB
AOC65-PZ03-LGR	LGR(B)	Exclude	6/5/03	8/24/04	AOC/WB
AOC65-PZ04-LGR	UGR(D)	Exclude	6/5/03	6/10/04	AOC/WB
AOC65-PZ05-LGR	LGR(B)	Exclude	7/30/02	6/10/04	AOC/WB
AOC65-PZ06-LGR	UGR(D)	Exclude	6/5/03	6/10/04	AOC/WB
CS-1	LGR(D), LGR(E), LGR(F), BS(A), BS(B), CC(A),	Quarterly	8/9/91	12/14/09	OPBH[b/]
CS-10	LGR(F), BS(A), BS(B), CC(A), CC(B)	Quarterly	8/9/91	12/14/09	OPBH
CS-11	LGR(C), LGR(D), LGR(E), LGR(F), BS(A), BS(B),	Exclude (No pump)	8/9/91	6/9/09	OPBH
CS-12	LGR(D), LGR(E), LGR(F), BS(A), BS(B), CC(A),	Quarterly	3/25/09	12/14/09	OPBH
CS-2	LGR(E), LGR(F), BS(A)	Every 9 months	11/3/92	12/9/09	OPBH
CS-3	LGR(E), LGR(F), BS(A)	Exclude	11/4/92	12/16/99	OPBH
CS-4	LGR(E)	Semi-annually	12/4/91	12/9/09	OPBH
CS-9	LGR(E), LGR(F), BS(A), BS(B), CC(A)	Quarterly	8/9/91	12/14/09	OPBH
CS-D	LGR(D), LGR(E), LGR(F)	Semi-annually	12/4/91	12/9/09	OPBH
CS-I	LGR(E), LGR(F)	Every 9 months	11/4/92	3/16/09	OPBH
CS-MW10-CC	CC(A)	Biennially	12/13/01	12/8/09	CC[c/]
CS-MW10-LGR	LGR(F)	Every 9 months	12/13/01	12/8/09	LGR[d/]
CS-MW11A-LGR	LGR(F)	Semi-annually	6/17/03	12/8/09	LGR
CS-MW11B-LGR	LGR(B)	Semi-annually	6/17/03	3/12/08	LGR
CS-MW12-BS	BS(A)	Biennially	12/16/02	12/11/09	BS[e/]
CS-MW12-CC	CC(A)	Biennially	12/16/02	12/11/09	CC
CS-MW12-LGR	LGR(F)	Every 9 months	12/16/02	12/11/09	LGR
CS-MW16-CC	CC(A)	Semi-annually	9/16/03	12/14/09	CC
CS-MW16-LGR	LGR(E), LGR(F)	Semi-annually	9/30/94	12/14/09	OPBH
CS-MW17-LGR	LGR(F)	Every 9 months	9/12/02	12/16/09	LGR
CS-MW18-LGR	LGR(F)	Semi-annually	9/12/02	12/17/09	LGR
CS-MW19-LGR	LGR(F)	Semi-annually	9/12/02	12/17/09	LGR
CS-MW1-BS	BS(A)	Biennially	3/25/03	12/10/09	BS
CS-MW1-CC	CC(A)	Biennially	3/25/03	12/10/09	CC
CS-MW1-LGR	LGR(F)	Semi-annually	9/8/99	12/10/09	LGR

TABLE 3.1
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
CS-MW20-LGR	LGR(F)	Quarterly until new LTMO	10/18/06	12/10/09	LGR
CS-MW21-LGR	LGR(F)	Quarterly until new LTMO	6/7/07	12/10/09	LGR
CS-MW22-LGR	LGR(F)	Quarterly until new LTMO	6/7/07	12/10/09	LGR
CS-MW23-LGR	LGR(F)	Quarterly until new LTMO	6/5/07	12/8/09	LGR
CS-MW24-LGR	LGR(F)	Quarterly until new LTMO	12/26/06	12/9/09	LGR
CS-MW25-LGR	LGR(F)	Quarterly until new LTMO	6/5/07	12/16/09	LGR
CS-MW2-CC	CC(A)	Biennially	6/17/03	12/10/09	CC
CS-MW2-LGR	LGR(F)	Semi-annually	9/9/99	12/10/09	LGR
CS-MW3-LGR	LGR(F)	Semi-annually	6/14/01	12/16/09	LGR
CS-MW4-LGR	LGR(F)	Semi-annually	6/14/01	12/9/09	LGR
CS-MW5-LGR	LGR(F)	Semi-annually	6/14/01	12/9/09	LGR
CS-MW6-BS	BS(A)	Biennially	6/13/01	12/15/09	BS
CS-MW6-CC	CC(A)	Biennially	6/13/01	12/15/09	CC
CS-MW6-LGR	LGR(F)	Semi-annually	6/13/01	12/15/09	LGR
CS-MW7-CC	CC(A)	Biennially	9/13/01	12/8/09	CC
CS-MW7-LGR	LGR(F)	Semi-annually	9/13/01	12/8/09	LGR
CS-MW8-CC	CC(A)	Biennially	6/14/01	12/8/09	CC
CS-MW8-LGR	LGR(F)	Every 9 months	6/12/01	12/8/09	LGR
CS-MW9-BS	BS(A)	Biennially	6/14/01	12/16/09	BS
CS-MW9-CC	CC(A)	Biennially	6/14/01	12/16/09	CC
CS-MW9-LGR	LGR(F)	Semi-annually	6/14/01	12/16/09	LGR
CS-MWG-LGR	LGR(C), LGR(D), LGR(E)	Every 9 months	11/3/92	12/16/09	OPBH
CS-MWH-LGR	LGR(F)	Biennially	11/4/92	12/7/09	LGR
Off Post Monitoring Wells					
DOM-2	LGR, CC	Exclude (No Power at Well)	9/19/01	3/6/08	OffBH[f/]
FO-17	LGR, CC	Annually	3/19/02	6/2/09	OffBH
FO-22	LGR, CC	Annually	9/18/01	3/4/09	OffBH
FO-8	LGR, CC	Annually	3/19/02	3/4/09	OffBH
FO-J1	LGR, CC	Qtrly, 1 year thru Dec. 10	9/18/01	12/1/09	OffBH
HS-1	LGR, CC	Quarterly	9/19/06	12/2/09	OffBH
HS-2	LGR, CC	Qtrly, 1 year thru June 10	12/19/01	12/2/09	OffBH
HS-3	LGR, CC	Annually	12/19/01	6/3/09	OffBH
I10-2	LGR, CC	Annually	9/19/01	3/3/09	OffBH
I10-4	LGR, CC	Quarterly	12/19/01	12/2/09	OffBH
I10-5	LGR, CC	Annually	12/6/02	3/4/09	OffBH
I10-7	LGR, CC	Qtrly, 1 year thru Dec. 10	3/21/02	12/3/09	OffBH
I10-8	LGR, CC	Annually	12/19/05	12/2/09	OffBH
JW-12	LGR, CC	Access agreement expired	9/18/01	6/5/09	OffBH
JW-13	LGR, CC	Annually	9/19/01	6/5/09	OffBH
JW-14	LGR, CC	Qtrly, due to location	9/18/01	12/1/09	OffBH
JW-15	LGR, CC	Annually	6/21/05	3/4/09	OffBH
JW-26	LGR, CC	Declined Access	3/21/02	12/13/06	OffBH
JW-27	LGR, CC	Annually	6/12/03	3/4/09	OffBH
JW-28	LGR, CC	Qtrly, due to location	9/10/03	12/3/09	OffBH
JW-29	LGR, CC	Qtrly, due to location	6/11/03	12/2/09	OffBH
JW-30	LGR, CC	Qtrly, due to location	9/8/99	12/2/09	OffBH

TABLE 3.1
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
JW-31	LGR, CC	Qtrly, 1 year thru Dec. 10	12/1/09	12/1/09	OffBH
JW-5	LGR, CC	Annually	6/22/05	3/5/09	OffBH
JW-6	LGR, CC	Annually	9/19/01	6/2/09	OffBH
JW-7	LGR, CC	Qtrly, 1 year thru Dec. 10	9/8/03	12/14/09	OffBH
JW-8	LGR, CC	Qtrly, 1 year thru Dec. 10	6/18/03	12/1/09	OffBH
JW-9	LGR, CC	Annually	9/18/01	3/3/09	OffBH
LS-1	LGR, CC	Quarterly	9/17/01	12/2/09	OffBH
LS-2	LGR, CC	Well is offline, to be plugged	8/1/01	6/21/06	OffBH
LS-3	LGR, CC	Well is offline, to be plugged	8/1/01	3/21/07	OffBH
LS-4	LGR, CC	Annually	9/17/01	12/2/09	OffBH
LS-5	LGR, CC	Qtrly, 1 year thru Dec. 10	8/1/01	11/30/09	OffBH
LS-6	LGR, CC	Qtrly, 1 year thru Dec. 10	8/1/01	11/30/09	OffBH
LS-7	LGR, CC	Qtrly, 1 year thru Dec. 10	12/13/99	11/30/09	OffBH
OFR-1	LGR, CC	Qtrly, 1 year thru Dec. 10	12/20/01	12/1/09	OffBH
OFR-2	LGR, CC	Exclude (Plugged.)	3/18/02	3/20/06	OffBH
OFR-3	LGR, CC	Qtrly, 1 year thru Dec. 10	10/25/01	11/30/09	OffBH
OFR-4	LGR, CC	Annually	6/12/03	3/5/09	OffBH
RFR-10	LGR, CC	Qtrly, 1 year thru Dec. 10	9/19/01	11/30/09	OffBH
RFR-11	LGR, CC	Qtrly, 1 year thru Dec. 10	10/4/01	11/30/09	OffBH
RFR-12	LGR, CC	Annually	8/30/01	3/3/09	OffBH
RFR-13	LGR, CC	Annually	12/16/04	6/3/09	OffBH
RFR-14	LGR, CC	Qtrly, 1 year thru Sept. 10	3/23/06	12/3/09	OffBH
RFR-3	LGR, CC	Annually	9/8/99	12/3/09	OffBH
RFR-4	LGR, CC	Annually	3/10/04	12/3/09	OffBH
RFR-5	LGR, CC	Annually	3/10/04	12/3/09	OffBH
RFR-6	LGR, CC	Exclude (Plugged.)	9/19/01	12/15/04	OffBH
RFR-7	LGR, CC	Exclude (Plugged.)	9/19/01	12/19/05	OffBH
RFR-8	LGR, CC	Annually	9/8/99	6/3/09	OffBH
RFR-9	LGR, CC	Qtrly, 1 year thru Sept. 10	9/19/01	12/21/09	OffBH
WestBay Wells					
CS-WB01-LGR-01	LGR-01	Semi-annually	1/20/04	9/2/09	AOC/WB
CS-WB01-LGR-02	LGR-02	Semi-annually	1/20/04	9/2/09	AOC/WB
CS-WB01-LGR-03	LGR-03	Semi-annually	1/20/04	9/2/09	AOC/WB
CS-WB01-LGR-04	LGR-04	Semi-annually	1/20/04	9/2/09	AOC/WB
CS-WB01-LGR-05	LGR-05	Semi-annually	1/19/04	9/2/09	AOC/WB
CS-WB01-LGR-06	LGR-06	Semi-annually	1/19/04	9/2/09	AOC/WB
CS-WB01-LGR-07	LGR-07	Semi-annually	1/19/04	9/2/09	AOC/WB
CS-WB01-LGR-08	LGR-08	Semi-annually	1/19/04	9/2/09	AOC/WB
CS-WB01-LGR-09	LGR-09	Semi-annually	1/19/04	9/2/09	AOC/WB
CS-WB01-UGR-01	UGR-01	Semi-annually	11/18/04	12/2/04	AOC/WB
CS-WB02-LGR-01	LGR-01	Semi-annually	1/20/04	9/17/08	AOC/WB
CS-WB02-LGR-02	LGR-02	Semi-annually	4/16/04	10/3/07	AOC/WB
CS-WB02-LGR-03	LGR-03	Semi-annually	1/20/04	9/3/09	AOC/WB
CS-WB02-LGR-04	LGR-04	Semi-annually	1/20/04	9/3/09	AOC/WB
CS-WB02-LGR-05	LGR-05	Semi-annually	1/20/04	9/3/09	AOC/WB
CS-WB02-LGR-06	LGR-06	Semi-annually	1/20/04	9/3/09	AOC/WB
CS-WB02-LGR-07	LGR-07	Semi-annually	1/20/04	9/3/09	AOC/WB

TABLE 3.1
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
CS-WB02-LGR-08	LGR-08	Semi-annually	1/20/04	9/3/09	AOC/WB
CS-WB02-LGR-09	LGR-09	Semi-annually	1/20/04	9/17/08	AOC/WB
CS-WB02-UGR-01	UGR-01	Semi-annually	7/2/04	12/2/04	AOC/WB
CS-WB03-LGR-01	LGR-01	Semi-annually	11/18/04	9/17/08	AOC/WB
CS-WB03-LGR-02	LGR-02	Semi-annually	11/30/04	10/4/07	AOC/WB
CS-WB03-LGR-03	LGR-03	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-04	LGR-04	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-05	LGR-05	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-06	LGR-06	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-07	LGR-07	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-08	LGR-08	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-LGR-09	LGR-09	Semi-annually	1/21/04	9/4/09	AOC/WB
CS-WB03-UGR-01	UGR-01	Semi-annually	11/18/04	3/10/09	AOC/WB
CS-WB04-BS-01	BS-01	Biennially	1/22/04	3/10/09	AOC/WB
CS-WB04-BS-02	BS-02	Biennially	1/22/04	3/10/09	AOC/WB
CS-WB04-CC-01	CC-01	Biennially	1/22/04	3/10/09	AOC/WB
CS-WB04-CC-02	CC-02	Biennially	1/22/04	3/10/09	AOC/WB
CS-WB04-CC-03	CC-03	Biennially	1/22/04	3/10/09	AOC/WB
CS-WB04-LGR-01	LGR-01	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-02	LGR-02	Semi-annually	5/12/04	3/19/08	AOC/WB
CS-WB04-LGR-03	LGR-03	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-04	LGR-04	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-06	LGR-06	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-07	LGR-07	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-08	LGR-08	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-09	LGR-09	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-10	LGR-10	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-LGR-11	LGR-11	Semi-annually	1/22/04	9/3/09	AOC/WB
CS-WB04-UGR-01	UGR-01	Semi-annually	11/18/04	11/18/04	AOC/WB

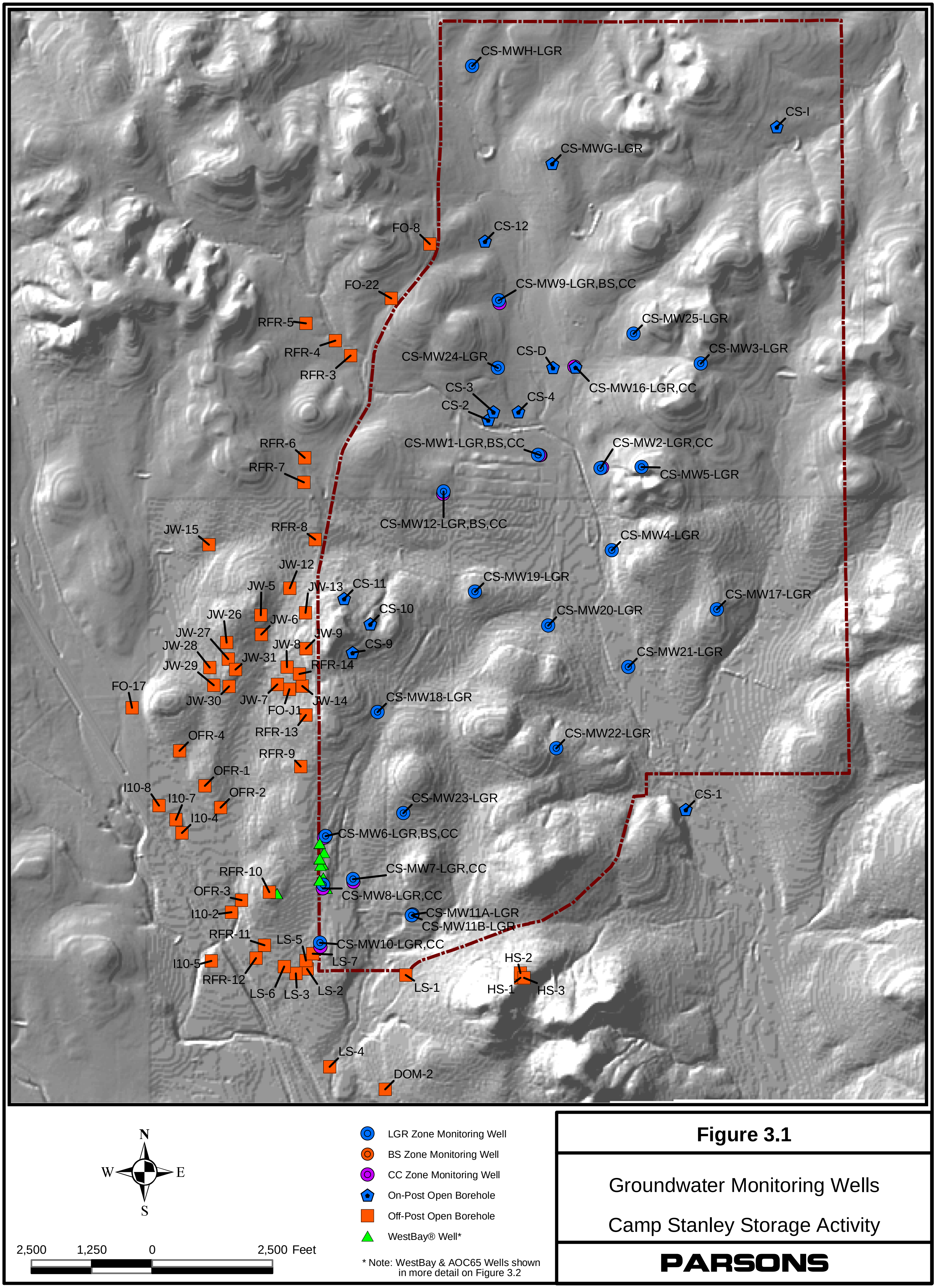
[a/] AOC/WB = AOC-65 area or WestBay-equipped well; included in vertical analysis.
[b/] OPBH = On Post Borehole; included in LGR zone analysis.
[c/] CC = Monitoring well screened in the Cow Creek zone.
[d/] LGR = Monitoring well screened in the LGR zone.
[e/] BS = Monitoring well screened in the Bexar Shale zone.
[f/] OffBH = Off Base Borehole; included in LGR zone analysis.

The 111 wells are shown on **Figures 3.1** and **3.2** classified by type of well. The most recent COC concentrations (December 2009) for each well are shown for zones LGR, BS, and CC in **Figures 3.3** through **3.5**, respectively. The on and off-post open boreholes are grouped into the LGR zone for this LTMO analysis. The typical well construction for the open borehole wells includes an open borehole completion through the LGR, BS, and CC portions of the aquifer with minimal surface casing. Historical results from on-post cluster wells indicate where COCs are detected in the LGR, the corresponding BS and CC wells are typically non-detect. Detections of COCs are generally confined to the LGR with the exception of the source area. Therefore, on and off-post open boreholes should be evaluated as LGR zones. The WB wells and area AOC-65 wells are considered separately from the LGR, BS, and CC zones because the data from these wells are "screening level" and not considered comparable to the validated chemical data from the other wells considered in the analysis.

The AOC-65 and WB wells are analyzed separately in a vertical cross-section analysis. The location of the two vertical cross sections (north to south and west to east) are shown on **Figure 3.2**. **Figures 3.6** and **3.7** display the vertical distribution of the most recent COC concentrations for wells in the north to south and west to east cross sections, respectively, along with their most recent sampling event.

3.2 SUMMARY OF ANALYTICAL DATA

In general, the CSSA groundwater plume is well-characterized both laterally and vertically. The groundwater monitoring program for this plume was evaluated using results for sampling events performed from 1991 through December 2009. The database was processed to remove duplicate data by retaining the maximum result for each duplicate sample pair. As discussed in Section 2.3, the COCs identified for CSSA include TCE, PCE, and cis-1,2-DCE. **Table 3.2** presents a summary of the occurrence of potential COCs in groundwater based on data collected from CSSA wells for all the sampling data. **Tables 3.3** through **3.8** show the summary statistics by well classification: LGR, on-post Open Boreholes (OPBH), CC, BS, Off-Post Open Borehole (OffBH), and Westbay/AOC-65 wells, respectively. **Tables 3.3** through **3.8** confirm that TCE, PCE, and *cis*-1,2-DCE are the main contaminants in groundwater beneath CSSA based on their widespread and relatively high (compared to their respective MCL) concentrations. Although it has been sampled less frequently than the primary COCs, lead (Pb) is of potential concern because of the relatively high percentage of and number of wells with detections. Other chemicals of potential concern include bromoform (TBME) and bromodichloromethane (BDCME) because of their action levels of zero. Toluene (BZME) detections occurred in screening level samples collected during discrete interval groundwater sampling during well installations and sporadically among definitive sampling events. Vinyl chloride (VC) has also been detected in Plume 1 ground water near SWMU B-3 and is an indicator that degradation of larger-chain chlorinated hydrocarbons is occurring. Although no wells used for this study have had exceedances of BZME or VC, both chemicals are of potential concern at CSSA, and are included in the temporal statistical analysis.



* Note: WestBay & AOC65 Wells shown in more detail on Figure 3.2

Figure 3.1

Groundwater Monitoring Wells

Camp Stanley Storage Activity

PARSONS

J:\746\746545_746546\01000 GW Mon\LTMO Update\GIS\mxds\Figure_3-1_groundwater_monitoring_wells.mxd - 7/13/2010 @ 11:20:50 AM

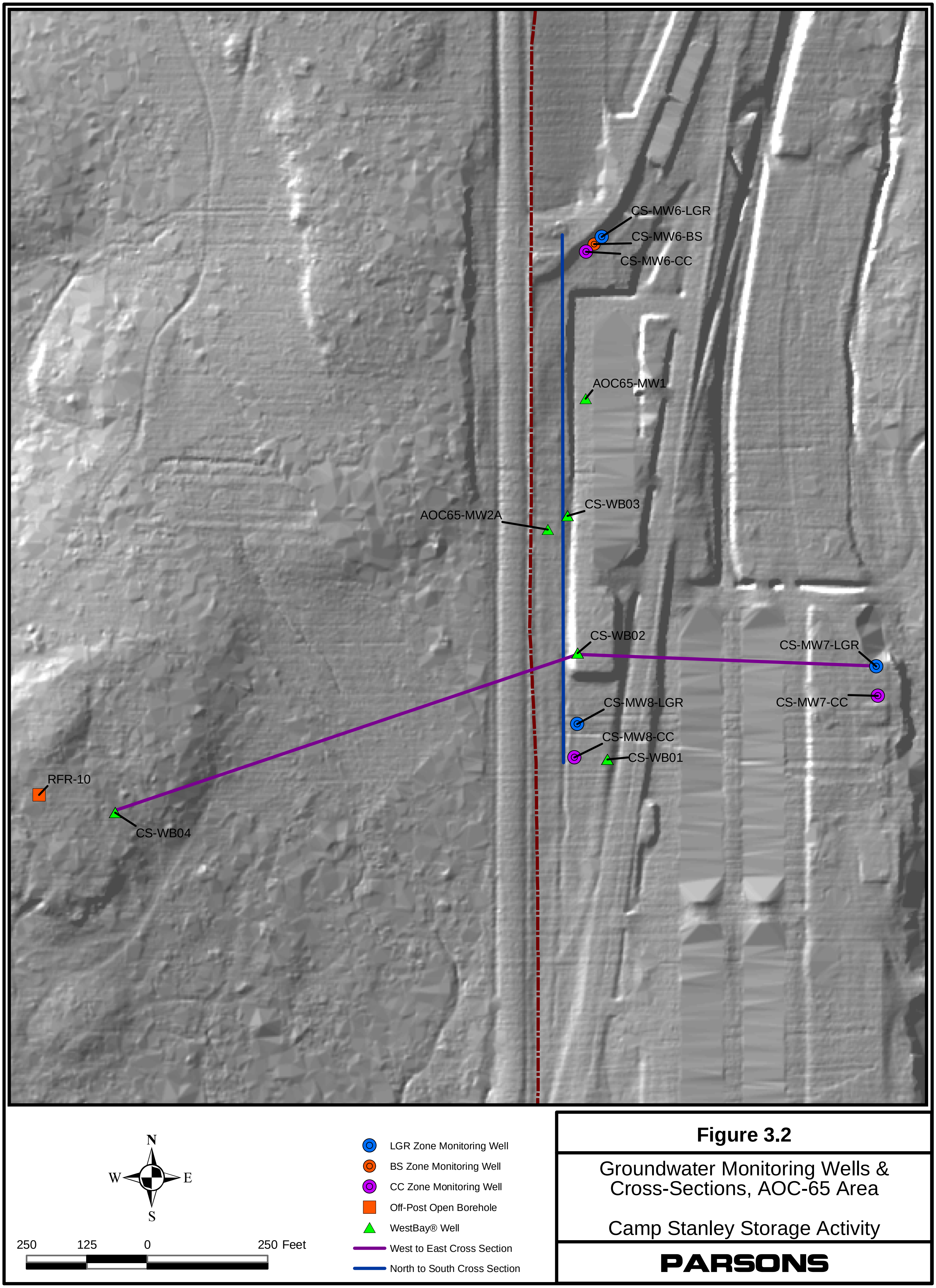


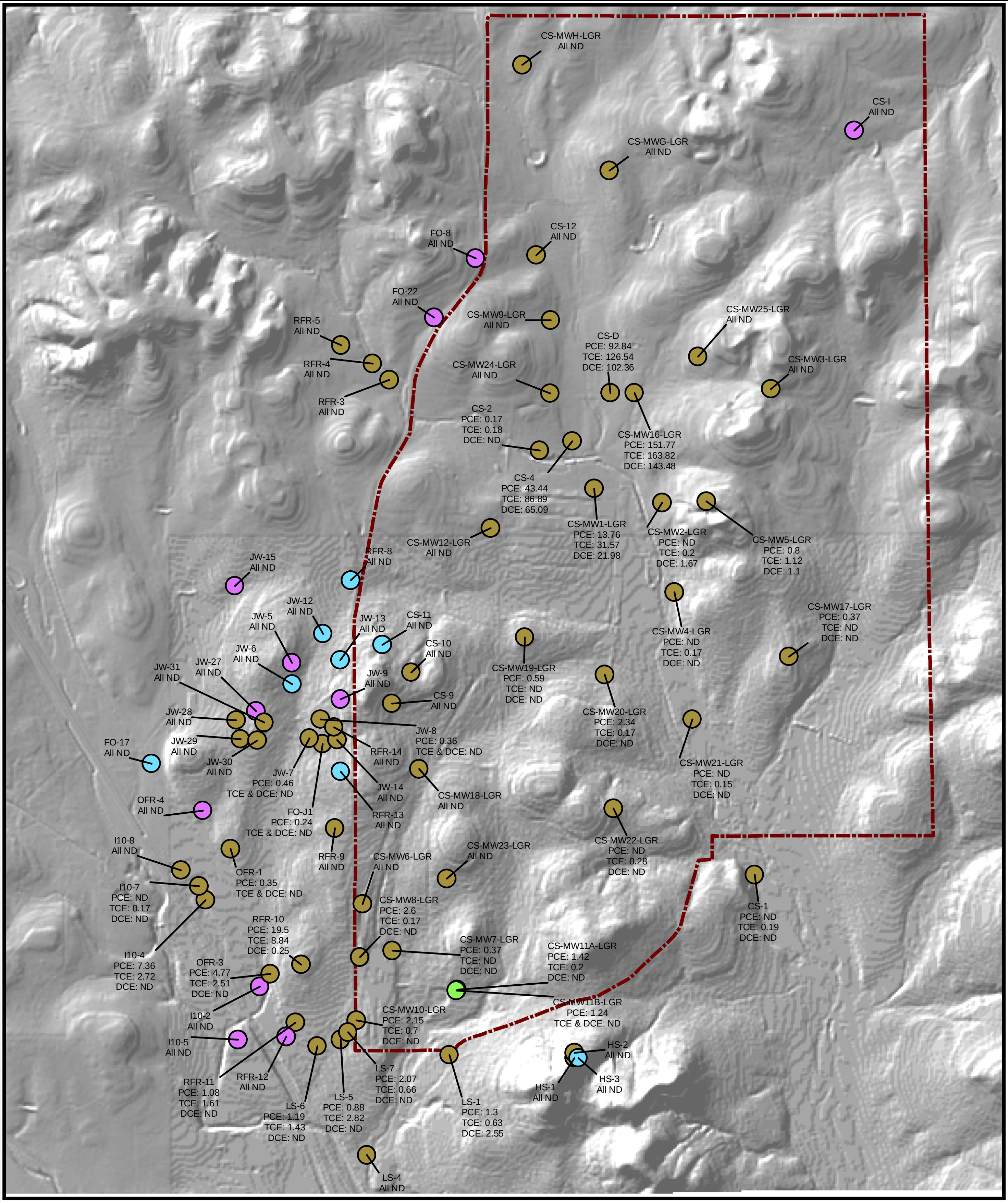
Figure 3.2

Groundwater Monitoring Wells & Cross-Sections, AOC-65 Area

Camp Stanley Storage Activity

PARSONS

J:\746\746545_746546\01000 GW Mon\LTMO Update\GIS\mxds\Figure_3-2_groundwater_monitoring_wells_AOC65area.mxd - 8/9/2010 @ 10:17:56 AM



N
W E
S

2,500 1,250 0 2,500 Feet

Most Recent Sampling Event

- 4Q 2009
- 2Q 2009
- 1Q 2009
- 1Q 2008

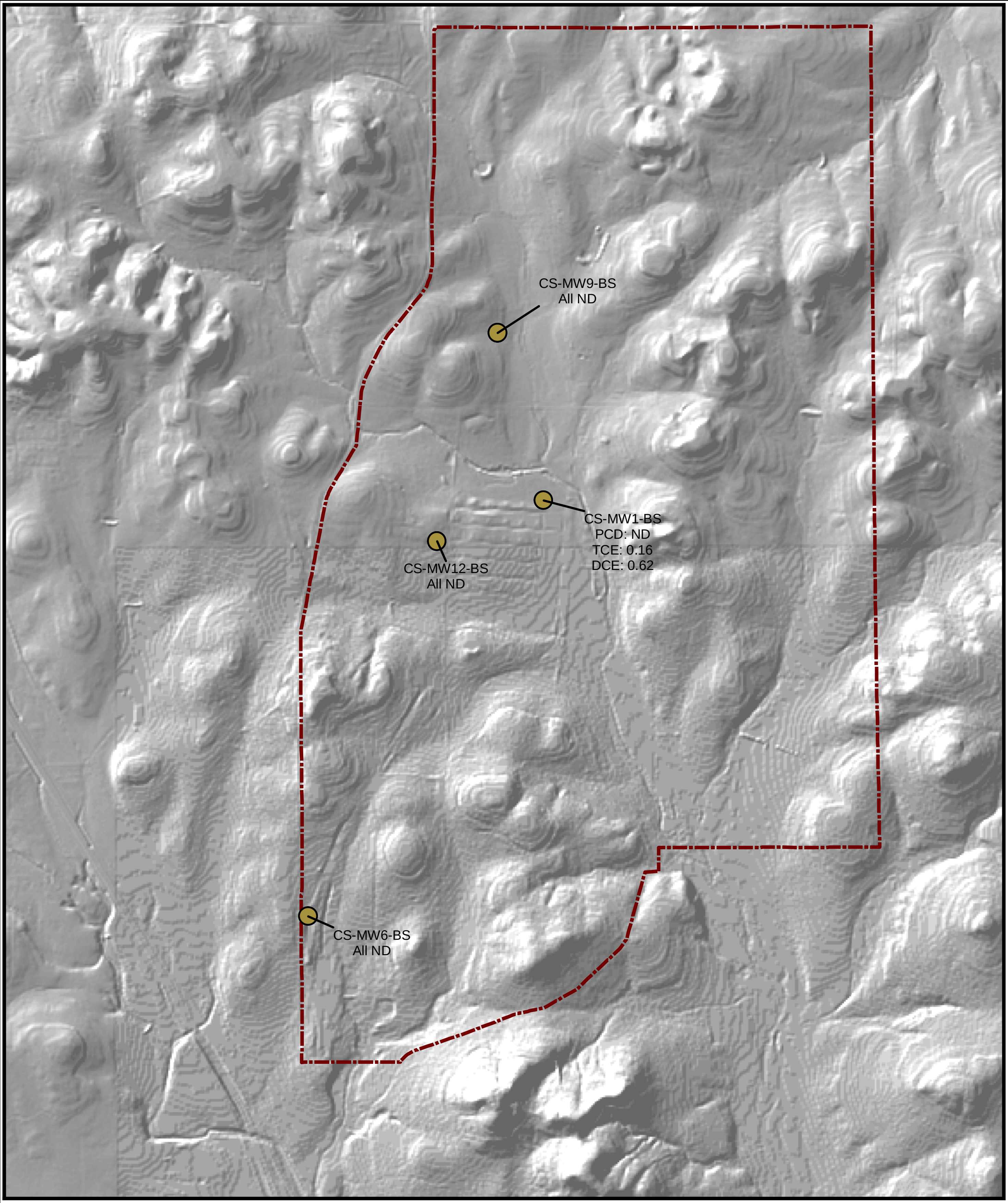
* Note: All results in ug/L
ND: COC not detected

Figure 3.3

Most Recent COC Concentrations
LGR Zone Wells

Camp Stanley Storage Activity

PARSONS



Most Recent Sampling Event

- 4Q 2009
- 2Q 2009
- 1Q 2009
- 1Q 2008

N
W E
S

2,500 1,250 0 2,500 Feet

* Note: All results in ug/L
ND: COC not detected

Figure 3.4

Most Recent COC Concentrations
BS Zone Wells

Camp Stanley Storage Activity

PARSONS

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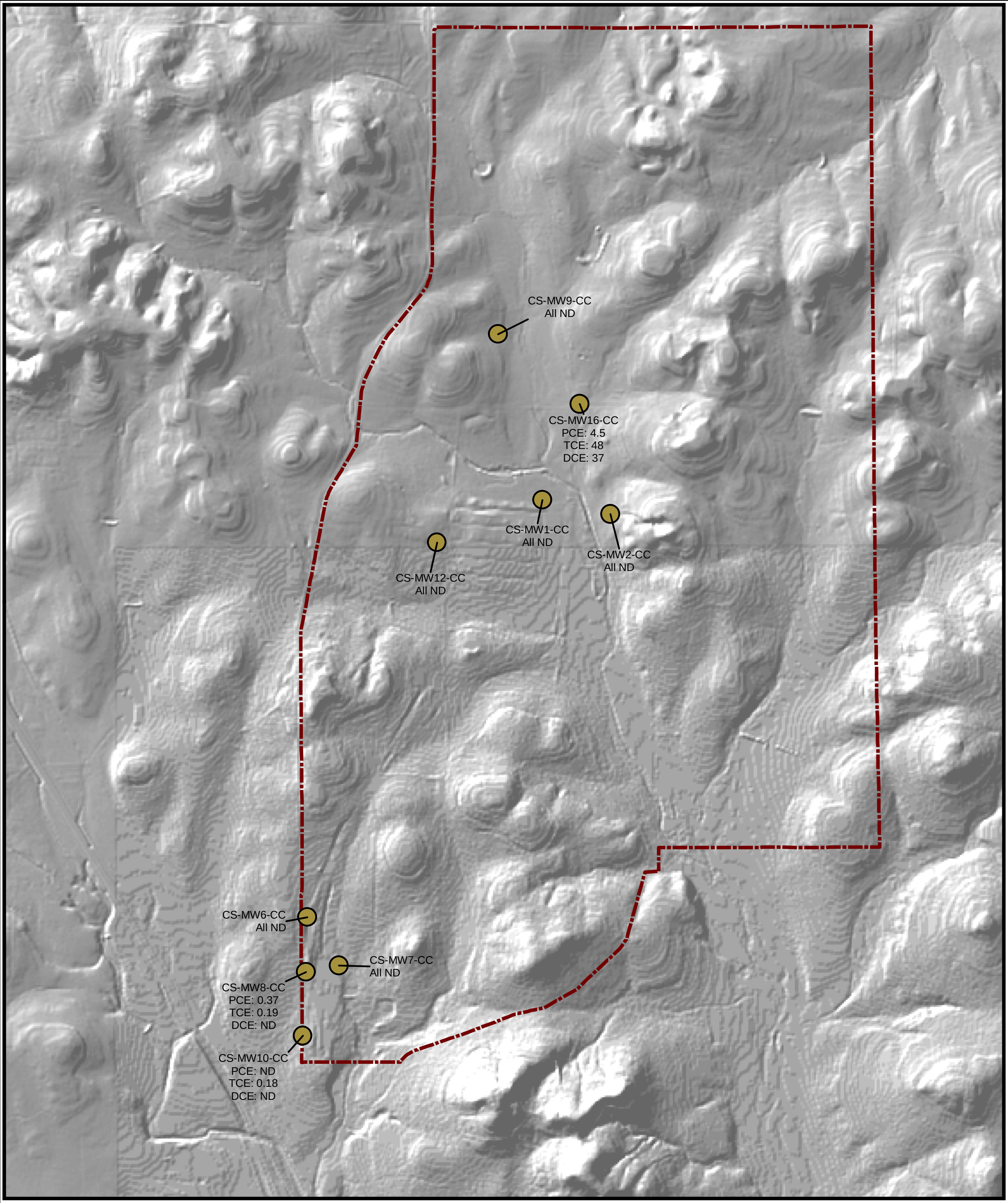

Most Recent Sampling Event

- 4Q 2009
- 2Q 2009
- 1Q 2009
- 1Q 2008

* Note: All results in ug/L
ND: COC not detected

Figure 3.5

Most Recent COC Concentrations
CC Zone Wells

Camp Stanley Storage Activity

PARSONS

J:\746\746545_746546\01000 GW Mon\LTMO Update\GIS\mxds\Figure_3-5_CC.mxd - 7/13/2010 @ 2:06:48 PM

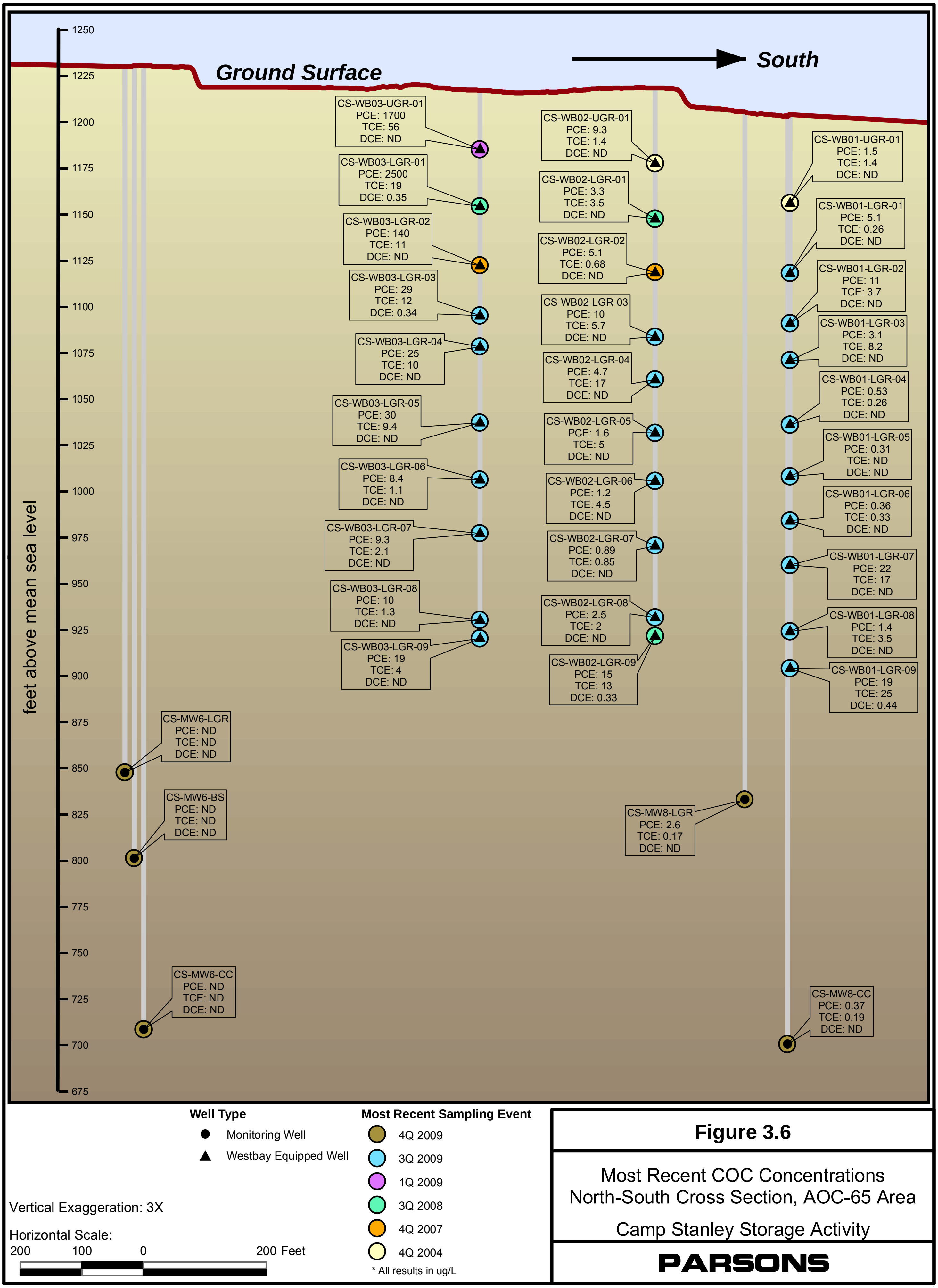

Figure 3.6

Most Recent COC Concentrations
North-South Cross Section, AOC-65 Area

Camp Stanley Storage Activity

J:\746\746545_746546\01000 GW Mon\LTMO Update\GIS\mxds\Figure_3-6_NS_x-section.mxd

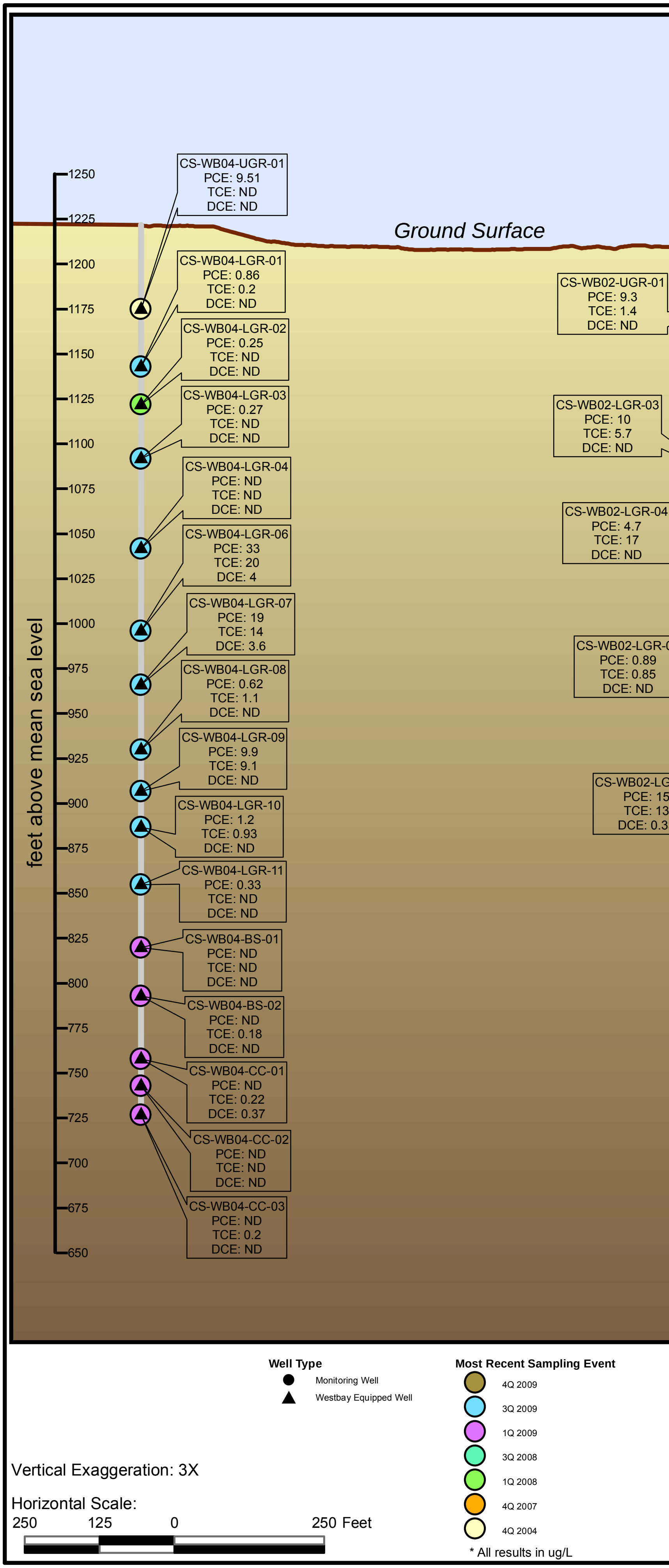

Figure 3.7

Most Recent COC Concentrations
West-East Cross Section, AOC-65 Area

Camp Stanley Storage Activity

PARSONS

J:\746\746545_746546\01000 GW Mon\LTMO Update\GIS\mxds\Figure_3-7_EW_x-section.mxd

TABLE 3.2
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	3,387	0 - 30,000	54%	21%	5	153	115	50
Trichloroethene	TCE	3,382	0 - 500	46%	16%	5	153	94	37
Lead	PB	637	0 - 250	56%	6%	15	53	50	13
Dichloroethene, cis-1,2-	DCE12C	3,335	0 - 290	14%	2%	70	153	52	3
Bromodichloromethane	BDCME	1,401	0 - 8.7	2%	2%	0	97	12	12
Mercury	HG	576	0 - 11	15%	1%	2	52	34	2
Nickel	NI	489	0 - 216	50%	1%	100	52	47	4
Bromoform	TBME	1,109	0 - 3.4	1%	0.6%	0	97	6	6
Methylene chloride	MTLNCL	1,389	0 - 19	20%	0.6%	5	97	84	7
Chromium	CR	577	0 - 240	33%	0.5%	100	52	47	2
Cadmium	CD	626	0 - 15	18%	0.5%	5	52	39	3
Alkalinity, Bicarbonate	ALKB	37	142,000 - 349,000	100%			36	36	
Alkalinity, Total (as CACO3)	ALK	105	211,000 - 380,000	100%			39	39	
Calcium	CA	60	1,620 - 120,000	100%			42	42	
Chloride	CL	65	7,300 - 32,300	100%			54	54	
Dichloroethene, 1,2- (total)	DCE12TO	1	43 - 43	100%			1	1	
Magnesium	MG	60	7.0 - 52,259	100%			42	42	
Methane	CH4	34	0.19 - 9.2	100%			33	33	
Potassium	K	62	750 - 360,000	100%			44	44	
Sodium	NA	60	6,070 - 97,150	100%			42	42	
Sulfate	SO4	39	8,780 - 134,000	100%			37	37	
Total Dissolved Solids	TDS	82	130,000 - 500,000	100%			21	21	
Barium	BA	446	0 - 300	97%		2,000	52	52	
Manganese	MN	64	0 - 81	97%			44	43	
Fluoride	F	39	0 - 2,300	95%			37	36	
Zinc	ZN	455	0 - 3,470,454	91%			52	52	
Nitrate	NO3N	37	0 - 6,330	73%			35	27	
Iron	FE	65	0 - 28,227	71%			42	37	
Arsenic	AS	451	0 - 30	67%		50	52	47	
Copper	CU	454	0 - 180	45%		1,300	52	42	

TABLE 3.2
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Bromide	BR	38	0 - 1,060	29%			37	11	
Selenium	SE	25	0 - 6.0	24%			15	4	
Isopropanol	ISOPROH	501	0 - 338	21%			48	41	
Acetone	ACE	1,017	0 - 3,610	15%			61	48	
Nitrite	NO2N	37	0 - 1,700	14%			35	5	
Chloroform	TCLME	1,418	0 - 65	13%		80	97	26	
Toluene	BZME	2,142	0 - 160	9%		1,000	145	56	
Phosphorus, Total Orthophosphate	PORTHO	25	0 - 790	8%			23	2	
Alkalinity, Carbonate	ALKC	38	0 - 69,000	8%			36	3	
Dichloroethane, 1,2-	DCA12	291	0 - 0.14	6%			80	16	
Benzene	BZ	345	0 - 2.3	5%			88	11	
Dichloroethene, trans-1,2-	DCE12T	3,368	0 - 34	5%		100	153	14	
Chloromethane	CLME	337	0 - 5.0	5%			82	7	
Trimethylbenzene, 1,2,4-	TMB124	264	0 - 0.35	3%			80	7	
Dichlorodifluoromethane	FC12	1,110	0 - 1.9	3%			97	2	
Naphthalene	NAPH	1,097	0 - 0.86	2%			97	12	
Dichloroethene, 1,1-	DCE11	2,258	0 - 1.0	2%		70	142	14	
Vinyl chloride	VC	2,238	0 - 1.3	1%		2	142	12	
Dibromochloromethane	DBCME	1,401	0 - 4.5	1%		60	97	10	
Trimethylbenzene, 1,3,5-	TMB135	263	0 - 0.14	1%			78	3	
Trichlorobenzene, 1,2,3-	TCB123	264	0 - 0.24	1%			78	3	
Styrene	STY	262	0 - 0.043	1%			80	2	
Isopropyltoluene, 4- (Cymene, p-)	CYMP	264	0 - 0.090	1%			78	2	
Trichlorobenzene, 1,2,4-	TCB124	265	0 - 0.20	1%			80	1	
Xylene, o-	XYLO	266	0 - 0.14	1%			80	2	
Ethylbenzene	EBZ	267	0 - 0.070	1%			80	2	
Xylene, m,p-	XYLMP	267	0 - 1.2	1%			80	2	
Bromochloromethane	BRCLME	263	0 - 0.14	0.4%			78	1	
Butylbenzene, N-	BTBZN	263	0 - 0.13	0.4%			78	1	
Butylbenzene, sec-	BTBZS	263	0 - 0.090	0.4%			78	1	

TABLE 3.2
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Butylbenzene, tert-	BTBZT	263	0 - 0.070	0.4%			78	1	
Chlorotoluene, 2-	CLBZME2	263	0 - 0.069	0.4%			78	1	
Chlorotoluene, 4-	CLBZME4	263	0 - 0.048	0.4%			78	1	
Dibromomethane	DBMA	263	0 - 0.19	0.4%			78	1	
Hexachlorobutadiene	HCBU	263	0 - 0.25	0.4%			78	1	
Dichloroethane, 1,1-	DCA11	335	0 - 0.14	0.3%			82	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 153 sampling points shown on Table 3.1

TABLE 3.3
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - LGR WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	467	0 - 41	49%	9.0%	5	23	16	2
Trichloroethene	TCE	467	0 - 40	28%	9.0%	5	23	16	2
Lead	PB	275	0 - 91	48%	3.6%	15	23	23	4
Nickel	NI	186	0 - 150	73%	2.2%	100	23	23	3
Chromium	CR	246	0 - 240	39%	1.2%	100	23	22	2
Bromoform	TBME	216	0 - 0.10	0.5%	0.5%	0	23	1	1
Mercury	HG	244	0 - 7.8	10%	0.4%	2	23	14	1
Cadmium	CD	274	0 - 7.0	20%	0.4%	5	23	19	1
Alkalinity, Bicarbonate	ALKB	19	142,000 - 349,000	100%			18	18	
Alkalinity, Total (as CACO3)	ALK	32	250,000 - 349,000	100%			16	16	
Calcium	CA	32	6,080 - 120,000	100%			22	22	
Chloride	CL	32	7,300 - 22,000	100%			22	22	
Magnesium	MG	32	7.0 - 47,000	100%			22	22	
Manganese	MN	35	0.80 - 67	100%			23	23	
Methane	CH4	14	0.21 - 9.2	100%			13	13	
Potassium	K	33	1,200 - 35,810	100%			23	23	
Sodium	NA	32	6,070 - 50,000	100%			22	22	
Sulfate	SO4	24	8,780 - 40,000	100%			22	22	
Total Dissolved Solids	TDS	15	310,000 - 460,000	100%			2	2	
Barium	BA	157	0 - 230	99%		2,000	23	23	
Zinc	ZN	161	0 - 8,000	93%			23	23	
Fluoride	F	24	0 - 2,300	92%			22	21	
Nitrate	NO3N	23	0 - 6,330	78%			21	18	
Arsenic	AS	160	0 - 5.8	78%		50	23	23	
Iron	FE	37	0 - 28,227	65%			22	19	
Selenium	SE	4	0 - 6.0	50%			2	1	
Acetone	ACE	7	0 - 3,610	43%			4	2	
Methylene chloride	MTLNCL	295	0 - 3.4	27%		5	23	19	
Toluene	BZME	224	0 - 40	27%		1,000	23	16	
Bromide	BR	23	0 - 240	26%			22	6	
Copper	CU	161	0 - 110	25%		1,300	23	17	
Dichloroethene, cis-1,2-	DCE12C	465	0 - 54	24%		70	23	6	

TABLE 3.3
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - LGR WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Nitrite	NO2N	23	0 - 1,700	22%			21	5	
Trimethylbenzene, 1,2,4-	TMB124	29	0 - 0.35	17%			22	5	
Dichloroethene, trans-1,2-	DCE12T	464	0 - 2.5	11%		100	23	4	
Chloroform	TCLME	293	0 - 0.13	8%		80	23	2	
Trimethylbenzene, 1,3,5-	TMB135	29	0 - 0.14	7%			22	2	
Xylene, o-	XYLO	29	0 - 0.14	7%			22	2	
Benzene	BZ	30	0 - 0.17	7%			22	2	
Phosphorus, Total Orthophosphate	PORTHO	17	0 - 790	6%			15	1	
Alkalinity, Carbonate	ALKC	20	0 - 69,000	5%			18	1	
Xylene, m,p-	XYLMP	29	0 - 0.35	3%			22	1	
Ethylbenzene	EBZ	30	0 - 0.070	3%			22	1	
Styrene	STY	30	0 - 0.043	3%			22	1	
Naphthalene	NAPH	212	0 - 0.86	2%			23	4	
Vinyl chloride	VC	457	0 - 0.053	1%		2	23	4	
Dichloroethene, 1,1-	DCE11	459	0 - 0.055	1%		70	23	4	
Dibromochloromethane	DBCME	293	0 - 0.030	0.3%		60	23	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 23 wells classified as "LGR" in Table 3.1.

TABLE 3.4
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN
ON-POST OPEN BOREHOLE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	385	0 - 230	40%	20.8%	5	12	10	3
Trichloroethene	TCE	388	0 - 300	33%	20.6%	5	12	7	3
Dichloroethene, cis-1,2-	DCE12C	358	0 - 290	24%	15.6%	70	12	4	2
Lead	PB	246	0 - 250	72%	11.4%	15	12	12	8
Bromodichloromethane	BDCME	324	0 - 4.7	2.5%	2.5%	0	12	4	4
Mercury	HG	234	0 - 11	18%	2.1%	2	12	9	1
Methylene chloride	MTLNCL	326	0 - 9.6	20%	1.8%	5	12	11	5
Bromoform	TBME	153	0 - 3.4	1.3%	1.3%	0	12	2	2
Cadmium	CD	240	0 - 15	19%	0.8%	5	12	10	2
Nickel	NI	210	0 - 216	35%	0.5%	100	12	11	1
Alkalinity, Bicarbonate	ALKB	9	218,500 - 285,700	100%			9	9	
Alkalinity, Total (as CACO3)	ALK	60	230,000 - 380,000	100%			10	10	
Calcium	CA	12	69,000 - 96,960	100%			10	10	
Chloride	CL	10	11,000 - 26,000	100%			9	9	
Dichloroethene, 1,2- (total)	DCE12TO	1	43 - 43	100%			1	1	
Fluoride	F	4	310 - 650	100%			4	4	
Magnesium	MG	12	11,026 - 32,578	100%			10	10	
Methane	CH4	8	0.21 - 6.3	100%			8	8	
Nitrate	NO3N	3	970 - 4,750	100%			3	3	
Potassium	K	12	750 - 4,600	100%			10	10	
Sodium	NA	12	7,060 - 13,440	100%			10	10	
Sulfate	SO4	4	12,000 - 26,500	100%			4	4	
Total Dissolved Solids	TDS	54	130,000 - 500,000	100%			11	11	
Zinc	ZN	214	0 - 3,470,454	98%			12	12	
Barium	BA	211	0 - 300	95%		2,000	12	12	
Manganese	MN	12	0 - 81	92%			10	10	
Copper	CU	215	0 - 180	67%		1,300	12	12	
Iron	FE	12	0 - 6,219	67%			10	8	
Arsenic	AS	214	0 - 30	50%		50	12	11	

TABLE 3.4
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN
ON-POST OPEN BOREHOLE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Bromide	BR	4	0 - 200	50%			4	2	
Chromium	CR	231	0 - 39	32%		100	12	11	
Chloroform	TCLME	336	0 - 49	25%		80	12	9	
Selenium	SE	17	0 - 4.0	24%			9	3	
Dichloroethene, trans-1,2-	DCE12T	399	0 - 12	16%		100	12	4	
Toluene	BZME	181	0 - 23	14%		1,000	12	11	
Chloromethane	CLME	145	0 - 5.0	10%			12	5	
Dichloroethene, 1,1-	DCE11	387	0 - 1.0	4%		70	12	6	
Dibromochloromethane	DBCME	324	0 - 4.5	2%		60	12	3	
Trichlorobenzene, 1,2,3-	TCB123	75	0 - 0.24	1%			10	1	
Bromochloromethane	BRCLME	76	0 - 0.14	1%			10	1	
Chlorotoluene, 2-	CLBZME2	76	0 - 0.069	1%			10	1	
Chlorotoluene, 4-	CLBZME4	76	0 - 0.048	1%			10	1	
Dibromomethane	DBMA	76	0 - 0.19	1%			10	1	
Vinyl chloride	VC	347	0 - 0.062	1%		2	12	1	
Dichloroethane, 1,1-	DCA11	143	0 - 0.14	1%			12	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 12 wells classified as "OPBH" in Table 3.1.

TABLE 3.5
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - CC ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Trichloroethene	TCE	163	0 - 120	18%	15.3%	5	9	4	1
Tetrachloroethene	PCE	163	0 - 58	21%	12.9%	5	9	4	1
Dichloroethene, cis-1,2-	DCE12C	164	0 - 120	16%	11.0%	70	9	3	1
Methylene chloride	MTLNCL	129	0 - 8.3	29%	0.8%	5	9	9	1
Alkalinity, Bicarbonate	ALKB	7	269,000 - 284,000	100%			7	7	
Alkalinity, Total (as CACO3)	ALK	7	269,000 - 284,000	100%			7	7	
Barium	BA	51	8.8 - 97	100%		2,000	9	9	
Calcium	CA	11	1,620 - 74,200	100%			7	7	
Chloride	CL	8	12,000 - 32,300	100%			8	8	
Fluoride	F	8	610 - 1,800	100%			8	8	
Magnesium	MG	11	490 - 52,259	100%			7	7	
Potassium	K	12	3,100 - 360,000	100%			8	8	
Sodium	NA	11	9,800 - 93,000	100%			7	7	
Sulfate	SO4	8	37,000 - 134,000	100%			8	8	
Arsenic	AS	50	0 - 11	94%		50	9	9	
Manganese	MN	12	0 - 60	92%			8	7	
Iron	FE	11	0 - 520	91%			7	7	
Zinc	ZN	53	0 - 350	70%			9	9	
Nitrate	NO3N	8	0 - 480	50%			8	4	
Lead	PB	76	0 - 2.9	42%		15	9	9	
Nickel	NI	62	0 - 23	40%		100	9	8	
Toluene	BZME	109	0 - 160	39%		1,000	9	9	
Bromide	BR	8	0 - 1,060	38%			8	3	
Acetone	ACE	10	0 - 8.5	30%			2	2	
Phosphorus, Total Orthophosphate	PORTHO	4	0 - 220	25%			4	1	
Isopropanol	ISOPROH	9	0 - 15	22%			1	1	
Copper	CU	51	0 - 19	20%		1,300	9	6	
Mercury	HG	63	0 - 0.20	16%		2	9	7	
Chromium	CR	65	0 - 17	15%		100	9	7	
Dichloroethene, trans-1,2-	DCE12T	161	0 - 34	15%		100	9	1	

TABLE 3.5
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - CC ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Cadmium	CD	73	0 - 1.8	14%		5	9	7	
Styrene	STY	8	0 - 0.043	13%			8	1	
Trimethylbenzene, 1,2,4-	TMB124	8	0 - 0.063	13%			8	1	
Benzene	BZ	9	0 - 0.048	11%			8	1	
Dichloroethene, 1,1-	DCE11	153	0 - 0.68	10%		70	9	2	
Vinyl chloride	VC	153	0 - 1.3	7%		2	9	3	
Naphthalene	NAPH	99	0 - 0.34	3%			9	3	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 9 wells classified as "CC" in Table 3.1.

TABLE 3.6
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - BS ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Lead	PB	35	0 - 114.8	34%	5.7%	15	4	4	1
Alkalinity, Bicarbonate	ALKB	2	181000 - 220,000	100%			2	2	
Alkalinity, Carbonate	ALKC	2	3500 - 29,500	100%			2	2	
Alkalinity, Total (as CACO3)	ALK	2	211000 - 224,000	100%			2	2	
Barium	BA	23	7 - 79	100%		2000	4	4	
Calcium	CA	5	3,800 - 21,610	100%			3	3	
Chloride	CL	3	10,770.0 - 26,490	100%			3	3	
Fluoride	F	3	1,200 - 1,600	100%			3	3	
Magnesium	MG	5	19,006 - 30,606	100%			3	3	
Manganese	MN	5	1 - 12	100%			3	3	
Potassium	K	5	12,920 - 82,000	100%			3	3	
Sodium	NA	5	43,150 - 97,150	100%			3	3	
Sulfate	SO4	3	37,000 - 105,250	100%			3	3	
Arsenic	AS	23	0 - 6	96%		50	4	4	
Iron	FE	5	0 - 81	80%			3	3	
Nitrate	NO3N	3	0 - 460	67%			3	2	
Zinc	ZN	23	0 - 85	65%			4	4	
Toluene	BZME	47	0 - 26	60%		1000	4	4	
Nickel	NI	27	0 - 19	37%		100	4	4	
Methylene chloride	MTLNCL	59	0 - 0.82	29%		5	4	4	
Benzene	BZ	4	0 - 0.045	25%			4	1	
Ethylbenzene	EBZ	4	0 - 0.07	25%			4	1	
Trimethylbenzene, 1,2,4-	TMB124	4	0 - 0	25%			4	1	
Naphthalene	NAPH	45	0 - 0.36	24%			4	3	
Mercury	HG	31	0 - 0	23%		2	4	4	
Dichloroethene, cis-1,2-	DCE12C	71	0 - 1	20%		70	4	2	
Vinyl chloride	VC	71	0 - 0	20%		2	4	3	
Chromium	CR	31	0 - 12.00	19%		100	4	3	
Copper	CU	23	0 - 9	17%		1300	4	3	
Cadmium	CD	35	0 - 2.6	14%		5	4	3	

TABLE 3.6
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN - BS ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Trichloroethene	TCE	71	0 - 0.2	10%		5	4	1	
Dichloroethene, 1,1-	DCE11	71	0 - 0.032	1%		70	4	1	
Tetrachloroethene	PCE	71	0 - 0.19	1%		5	4	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 4 wells classified as "BS" in Table 3.1.

TABLE 3.7

SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN
OFF-BASE OPEN BOREHOLE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	997	0 - 30.09	50%	6.7%	5	51	31	7
Bromodichloromethane	BDCME	597	0 - 8.74	3%	2.7%	0	49	8	8
Trichloroethene	TCE	988	0 - 10.25	31%	2.4%	5	51	17	2
Bromoform	TBME	593	0 - 1.21	1%	0.7%	0	49	3	3
Methylene chloride	MTLNCL	580	0 - 19	13%	0.001724138	5	49	41	1
Alkalinity, Total (as CACO3)	ALK	4	270,000 - 350,000	100%			4	4	
Barium	BA	4	30.1 - 35.6	100%		2,000	4	4	
Chloride	CL	12	11,000 - 21,000	100%			12	12	
Chromium	CR	4	2 - 4	100%		100	4	4	
Copper	CU	4	4 - 13	100%		1300	4	4	
Methane	CH4	12	0 - 1	100%			12	12	
Total Dissolved Solids	TDS	13	320,000 - 480,000	100%			8	8	
Zinc	ZN	4	22 - 204	100%			4	4	
Lead	PB	5	0 - 4	40%		15	5	2	
Nickel	NI	4	0 - 2	25%		100	4	1	
Chloroform	TCLME	602	0 - 64.52	13%		80	49	15	
Dichloroethane, 1,2-	DCA12	175	0 - 0.14	10%			36	16	
Toluene	BZME	600	0 - 4.59	6%		1000	49	16	
Dichloroethene, cis-1,2-	DCE12C	972	0 - 3	5%		70	51	8	
Acetone	ACE	21	0 - 1.7	5%			8	1	
Dichlorodifluoromethane	FC12	595	0 - 1.89	5%			49	2	
Benzene	BZ	150	0 - 0.17	5%			36	5	
Dibromochloromethane	DBCME	597	0 - 3	2%		60	49	6	
Chloromethane	CLME	148	0 - 0.48	1%			36	2	
Trichlorobenzene, 1,2,4-	TCB124	149	0 - 0	1%			36	1	
Isopropyltoluene, 4- (Cymene, p-)	CYMP	150	0 - 0	1%			36	2	
Trichlorobenzene, 1,2,3-	TCB123	150	0 - 0	1%			36	2	

TABLE 3.7

SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN
OFF-BASE OPEN BOREHOLE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Butylbenzene, N-	BTBZN	149	0 - 0.13	1%			36	1	
Butylbenzene, sec-	BTBZS	149	0 - 0	1%			36	1	
Butylbenzene, tert-	BTBZT	149	0 - 0.07	1%			36	1	
Hexachlorobutadiene	HCBU	149	0 - 0.3	1%			36	1	
Trimethylbenzene, 1,3,5-	TMB135	149	0 - 0.07	1%			36	1	
Xylene, m,p-	XYLMP	151	0 - 1.2	1%			36	1	
Naphthalene	NAPH	591	0 - 0.43	0%			49	2	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 51 wells classified as "OffBH" in Table 3.1.

TABLE 3.8
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN
WESTBAY AND AREA AOC65 WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Sampling Locations with	Number of Sampling Locations with	Number of Sampling Locations with MCL
Tetrachloroethene	PCE	1304	0 - 30,000	70%	39.0%	5	54	53	37
Trichloroethene	TCE	1305	0 - 500	74%	28.0%	5	54	49	29
Isopropanol	ISOPROH	492	0 - 338	21%			47	40	
Dichloroethene, cis-1,2-	DCE12C	1305	0 - 51	15%		70	54	29	
Acetone	ACE	979	0 - 1,160	15%			47	43	
Benzene	BZ	77	0 - 2	8%			8	2	
Dichloroethene, trans-1,2-	DCE12T	1306	0.0 - 0.93	1%		100	54	5	
Dichloroethene, 1,1-	DCE11	247	0 - 0	0%		70	43	1	
Vinyl chloride	VC	247	0 - 0	0%		2	43	1	

[a/] Analytical data analyzed includes sampling results from AOC65 wells from July 2002, through June 2004, and WB wells from January 2004, through September 2009.

[b/] µg/L = micrograms per liter.

[c/] Data includes 54 wells classified as "AOC65/WB" in Table 3.1.

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SECTION 4
QUALITATIVE LTMO EVALUATION

An effective groundwater monitoring program will provide information regarding contaminant plume migration and changes in chemical concentrations through time at appropriate locations, enabling decision-makers to verify that contaminants are not endangering potential receptors, and that remediation is occurring at rates sufficient to achieve remedial action objectives (RAO) within a reasonable time frame. The design of the monitoring program should therefore include consideration of existing receptor exposure pathways, as well as exposure pathways arising from potential future use of the groundwater.

Performance monitoring wells located within and downgradient from a plume provide a means of evaluating the effectiveness of a groundwater remedy relative to performance criteria. Long-term monitoring (LTM) of these wells also provides information about migration of the plume and temporal trends in chemical concentrations. Groundwater monitoring wells located downgradient from the leading edge of a plume (*i.e.*, sentry wells) are used to evaluate possible changes in the extent of the plume and, if warranted, to trigger a contingency response action if contaminants are detected.

Primary factors to consider when developing a groundwater monitoring program include at a minimum:

- Aquifer heterogeneity;
- Types of contaminants;
- Distance to potential receptor exposure points;
- Groundwater seepage velocity and flow direction(s);
- Potential surface-water impacts; and
- The effects of the remediation system.

These factors will influence the locations and spacing of monitoring points and the sampling frequency. Typically, the greater the seepage velocity and the shorter the distance to receptor exposure points, the more frequently groundwater sampling should be conducted.

One of the most important purposes of LTM is to confirm that the contaminant plume is behaving as predicted. Graphical and statistical tests can be used to evaluate plume stability. If a groundwater remediation system or strategy is effective, then over the long term, groundwater-monitoring data should demonstrate a clear and meaningful decreasing trend in concentrations at appropriate monitoring points. The CSSA Groundwater Monitoring Program is conducted under the provisions of the Off-post Groundwater Monitoring Program Response Plan (CSSA, 2002b) and the Data Quality Objectives for the Groundwater Monitoring Program (Parsons, 2003). The current groundwater monitoring program at CSSA was evaluated to identify potential opportunities for streamlining monitoring activities while still maintaining an effective performance and compliance monitoring program.

4.1 METHODOLOGY FOR QUALITATIVE EVALUATION OF MONITORING NETWORK

The LTMO evaluation included 153 sampling locations located on and off CSSA. These wells, their associated hydrogeologic zones, and the 2009 monitoring frequencies are listed in **Table 3.1**, and their locations are depicted on **Figures 3.1** and **3.2**. As shown in the table, the LTMO evaluation included on-post, off-post, and WB wells.

Multiple factors were considered in developing recommendations for continuation or cessation of groundwater monitoring at each well. The CSSA monitoring network was evaluated to determine any data gaps where information was needed to further characterize the plumes. Recommendations of areas of greater spatial uncertainty were given as locations for future monitoring wells. In some cases, a recommendation was made to continue monitoring a particular well, but at a reduced frequency. A recommendation to discontinue monitoring at a particular well based on the information reviewed does not necessarily constitute a recommendation to physically abandon the well. A change in site conditions might warrant resumption of monitoring at some time in the future at wells not currently recommended for continued sampling. Typical factors considered in developing recommendations to retain a well in, or remove a well from, a LTM program are summarized in **Table 4.1**. Typical factors considered in developing recommendations for monitoring frequency are summarized in **Table 4.2**.

Table 4.1 Monitoring Network Optimization Decision Logic
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Reasons for Retaining or Adding a Well to the Monitoring Network	Reasons for Removing a Well From Monitoring Network
Well is needed to further characterize the site or monitor changes in contaminant concentrations through time	Well provides spatially redundant information with a neighboring well (*e.g.*, same constituents, and/or short distance between wells)
Well is important for defining the lateral or vertical extent of contaminants.	Well has been dry for more than 2 years[a/]
Well is needed to monitor water quality at compliance point or receptor exposure point (*e.g.*, water supply well)	Contaminant concentrations are consistently below laboratory detection limits or cleanup goals
Well is important for defining background water quality	Well is completed in same water-bearing zone as nearby well(s)

a/ Periodic water level monitoring should be performed in dry wells to confirm that the upper boundary of the saturated zone remains below the well screen. If the well becomes re-wetted, then its inclusion in the monitoring program should be evaluated.

Table 4.2 Monitoring Frequency Decision Logic
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Reasons for Increasing Sampling Frequency	Reasons for Decreasing Sampling Frequency
Groundwater velocity is high	Groundwater velocity is low
Change in contaminant concentration would significantly alter a decision or course of action	Change in contaminant concentration would not significantly alter a decision or course of action
Well is necessary to monitor source area or operating remedial system	Well is distal from source area and remedial system
Cannot predict if concentrations will change significantly over time	Concentrations are not expected to change significantly over time, or contaminant levels have been below groundwater cleanup objectives for some prescribed period of time

4.2 RESULTS OF QUALITATIVE LTMO EVALUATION

Results of the qualitative evaluation of wells at CSSA are described in this subsection. The evaluation included the 153 on-post, off-post and WB-equipped monitoring points listed in **Table 3.1**. The evaluation grouped the wells into these three classifications. The qualitative LTMO evaluation considered historical analytical results, whether the well was necessary for plume definition, and the primary use of the well (i.e. drinking water or monitoring). All COCs from historical monitoring were considered for the qualitative evaluation but special consideration was given to PCE, TCE and cis-1,2-DCE concentrations.

Another factor used during the qualitative analysis was to evaluate the overall complexity and implementation of a large monitoring program. After the initial success of the 2005 LTMO process, the program was modified in 2009 to include “snapshot” events when all wells (on- and off-post) were sampled simultaneously so status of the entire plume(s) could be ascertained. The “snapshot” events occur every 9 months to account for temporal/seasonal changes that are known to occur under varying environmental conditions. The inclusion of the 9-month snapshot has been a helpful addition for plume monitoring, but has made the 2005 LTMO sampling strategy a little inefficient. Other factors also considered were redundant sampling strategies. For instance, wells CS-MW16-LGR and –CC are sampled semi-annually under the current LTMO monitoring program. However, the same wells are sampled quarterly under the Bioreactor remediation system, resulting in the wells being sampled 6 times per year.

Table 4.3 includes recommendations for retaining or removing each well, the recommended sampling frequency, and the rationale for the recommendations. On and off-post LGR zone wells qualitative evaluation results are displayed in **Figure 4.1**. The overall recommendation for groundwater monitoring is to move as many wells as possible to a 9-month or 18-month sampling strategies to provide adequate areal coverage of the plume and still meet the LTMO goals of temporal and spatial consideration. Certain wells will require additional monitoring based upon their use (potable water supply), location relative to areas above the MCL, or continuing adherence to the Off-Post DQOs.

TABLE 4.3
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

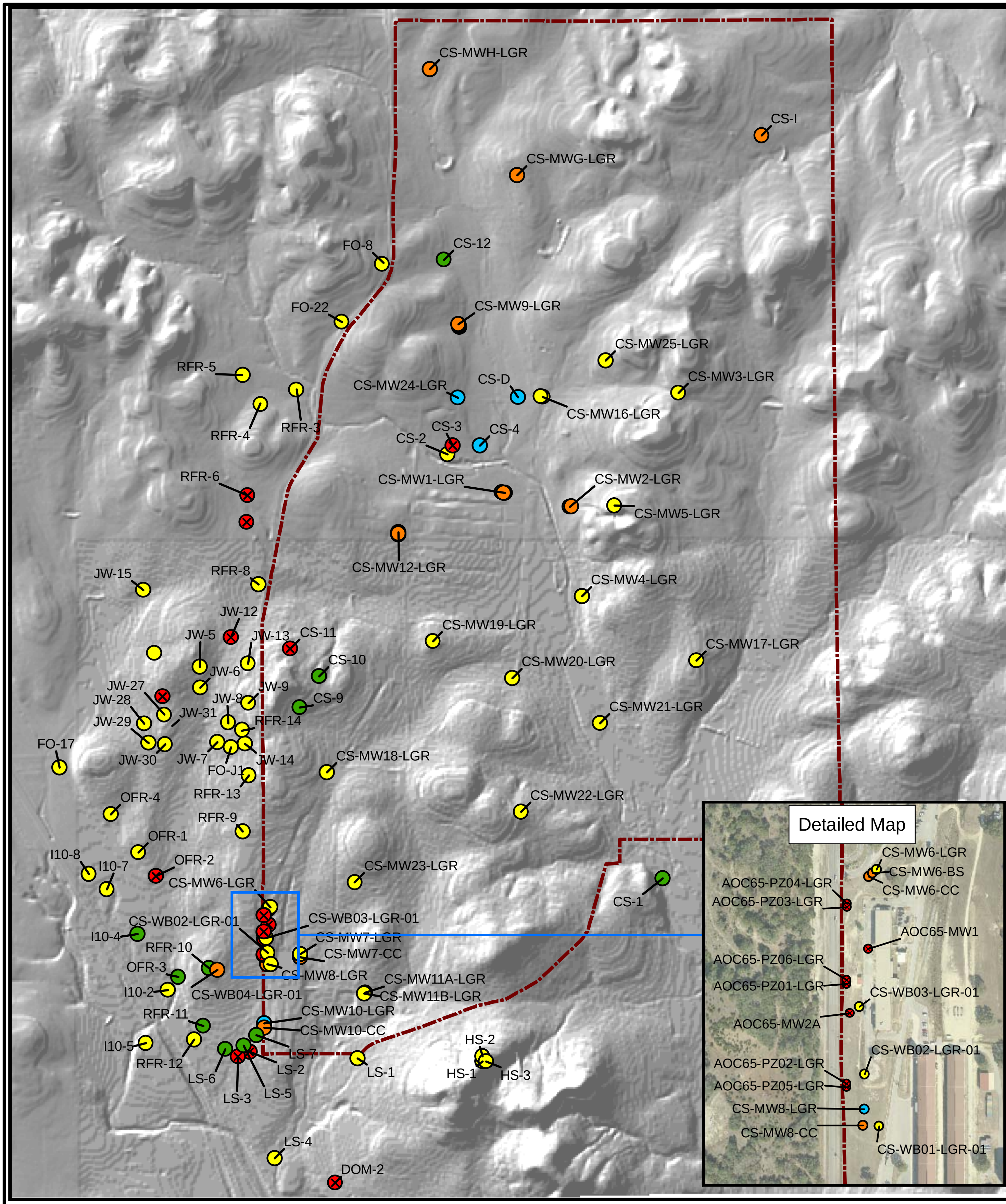
Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
On Post Monitoring Wells					
AOC65-MW1	Sample after major rain event	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-MW2A	Sample after major rain event	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ01-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ02-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ03-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ04-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ05-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ06-LGR	Exclude	✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
CS-1	Quarterly		✓	Quarterly	Active CSSA drinking water well with history of low-level detections.
CS-10	Quarterly		✓	Quarterly	Active CSSA drinking water well with history of low-level detections.
CS-11	Exclude (No pump)	✓		Exclude (No pump)	Inactive well no longer used for potable water supply
CS-12	Quarterly		✓	Quarterly	Future potable water supply well.
CS-2	Every 9 months		✓	Every 9 months	Already equipped with pump. Has slightly higher detections that CS-3. Western delineation well.
CS-3	Exclude	✓		Exclude	Well is essentially a duplicate location for CS-2. Similar results and well completion. Spatially redundant to CS-2.
CS-4	Semi-annually		✓	Semi-annual	Consistent detections below the MCL, except for recent large detections in December 2009.
CS-9	Quarterly		✓	Quarterly	Inactive well no longer used for potable water supply, but is still connected to the distribution system and can be utilized if needed.
CS-D	Semi-annually		✓	Semi-annual	Well is not fully penetrating into LGR. Concentrations have been increasing since 2002 above MCL. Indications that Plume 1 is moving westerly.
CS-I	Every 9 months		✓	Every 18 months	Upgradient NE pasture. Historically ND.
CS-MW10-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW10-LGR	Every 9 months		✓	Semi-annual	Plume 2 delineation Well
CS-MW11A-LGR	Semi-annually		✓	Semi-annual	Plume 2 delineation Well
CS-MW11B-LGR	Semi-annually		✓	Every 9 months	Plume 2 delineation Well for perched zone in large fracture system.
CS-MW12-BS	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW12-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW12-LGR	Every 9 months		✓	Every 9 months	Well is stable and typically non-detect.
CS-MW16-CC	Semi-annually		✓	Every 9 months	Plume 1 source area well with remediation system. Well already sampled quarterly as part of Bioreactor.
CS-MW16-LGR	Semi-annually		✓	Every 9 months	Plume 1 source area well with remediation system. Well already sampled quarterly as part of Bioreactor.
CS-MW17-LGR	Every 9 months		✓	Every 9 months	Consistent F-flagged hits of PCE. Concentrations are low and steady. Monitor annually for potential increase or change in plume margin.
CS-MW18-LGR	Semi-annually		✓	Every 9 months	Clean well between Plumes 1 and 2
CS-MW19-LGR	Semi-annually		✓	Every 9 months	Consistent F-flagged hits of PCE. Concentrations are low and steady. Monitor annually for potential increase or change in plume margin.
CS-MW1-BS	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW1-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW1-LGR	Semi-annually		✓	Semi-annual	Plume 1 delineation well downgradient of source. Typically above the MCL.
CS-MW20-LGR	Quarterly until new LTMO		✓	Every 9 months	Plume 1 delineation well for PCE.
CS-MW21-LGR	Quarterly until new LTMO		✓	Every 9 months	No VOCS, but has had metals issues.
CS-MW22-LGR	Quarterly until new LTMO		✓	Every 9 months	No VOCS, but has had metals issues.
CS-MW23-LGR	Quarterly until new LTMO		✓	Every 9 months	No VOCS, but has had metals issues.
CS-MW24-LGR	Quarterly until new LTMO		✓	Semi-annual	Plume 1 sentry well west of source. Historically non-detect, but plume may be moving that direction.
CS-MW25-LGR	Quarterly until new LTMO		✓	Every 9 months	No VOCS, but has had metals issues.
CS-MW2-CC	Biennially		✓	Every 18 months	Once every 18 to verify no change in conditions.
CS-MW2-LGR	Semi-annually		✓	Semi-annual	Plume 1 delineation well downgradient of source. Typically above the MCL.
CS-MW3-LGR	Semi-annually		✓	Every 9 months	No VOC hits to speak of. Well was primarily installed as a potentiometric control point between drainage basins
CS-MW4-LGR	Semi-annually		✓	Every 9 months	Plume 1 delineation well downgradient of source. Typically below the MCL.
CS-MW5-LGR	Semi-annually		✓	Every 9 months	Plume 1 delineation well downgradient of source. Typically below the MCL.
CS-MW6-BS	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW6-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW6-LGR	Semi-annually		✓	Every 9 months	Upgradient of Plume 2.
CS-MW7-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW7-LGR	Semi-annually		✓	Every 9 months	Plume 2 downgradient well.
CS-MW8-CC	Biennially		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MW8-LGR	Every 9 months		✓	Semi-annual	Plume 2 delineation well downgradient of source on fenceline.
CS-MW9-BS	Biennially		✓	Every 9 months	Upgradient of Plume 1. Well has had repeated hits of lead, sometimes above action limit. Sentry well for future CS-12 supply well.
CS-MW9-CC	Biennially		✓	Every 9 months	Upgradient of Plume 1. Well has had repeated hits of lead, sometimes above action limit. Sentry well for future CS-12 supply well.
CS-MW9-LGR	Semi-annually		✓	Every 18 months	Once every 18 months to verify no change in conditions.
CS-MWG-LGR	Every 9 months		✓	Every 18 months	Clean Upgradient Well
CS-MWH-LGR	Biennially		✓	Every 18 months	Clean Upgradient Well

TABLE 4.3
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
Off Post Monitoring Wells					
DOM-2	Exclude (No Power at Well)	✓		Exclude (No Power at Well)	Well was historically clean prior to becoming inoperable.
FO-17	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
FO-22	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
FO-8	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
FO-J1	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
HS-1	Quarterly		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
HS-2	Qtrly, 1 year thru June 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
HS-3	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
I10-2	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
I10-4	Quarterly		✓	Quarterly	Westernmost Plume 2 point above MCL. Quarterly to keep tabs on plume migration.
I10-5	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
I10-7	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
I10-8	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-12	Access agreement expired	✓		Access agreement expired	Consider 9-month events if access is regained.
JW-13	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-14	Qtrly, due to location		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-15	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-26	Declined Access	✓		Declined Access	Consider 9-month events if access is regained.
JW-27	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-28	Qtrly, due to location		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-29	Qtrly, due to location		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-30	Qtrly, due to location		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-31	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	New well on DQO schedule. Move to 9-month when well meets DQO criteria.
JW-5	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-6	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
JW-7	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
JW-8	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
JW-9	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
LS-1	Quarterly		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event. No longer PWS.
LS-2	Well is offline, to be plugged soon	✓		Well is offline, to be plugged	Abandoned when SAWS took over water supply to Leon Springs Villa water distribution.
LS-3	Well is offline, to be plugged soon	✓		Well is offline, to be plugged	Abandoned when SAWS took over water supply to Leon Springs Villa water distribution.
LS-4	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event. No longer PWS.
LS-5	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Likely to be treated with a Granular Activated Carbon (GAC) system in the future.
LS-6	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Well currently treated with Granular Activated Carbon (GAC) system.
LS-7	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Well currently treated with Granular Activated Carbon (GAC) system.
OFR-1	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
OFR-2	Exclude (Plugged.)	✓		Exclude (Plugged.)	Well no longer exists.
OFR-3	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Well currently treated with Granular Activated Carbon (GAC) system.
OFR-4	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-10	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Well currently treated with Granular Activated Carbon (GAC) system.
RFR-11	Qtrly, 1 year thru Dec. 10		✓	Quarterly	Well currently treated with Granular Activated Carbon (GAC) system.
RFR-12	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-13	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-14	Qtrly, 1 year thru Sept. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.
RFR-3	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-4	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-5	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-6	Exclude (Plugged.)	✓		Exclude (Plugged.)	Well no longer exists.
RFR-7	Exclude (Plugged.)	✓		Exclude (Plugged.)	Well no longer exists.
RFR-8	Annually		✓	Every 9 months	Move to 9-month schedule to be consistent with on-post "snapshot" event.
RFR-9	Qtrly, 1 year thru Sept. 10		✓	Every 9 months	Currently under quarterly event because of Off-Post DQO action, move to 9-months if meets DQO criteria.

TABLE 4.3
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
WestBay Wells					
CS-WB01-LGR-01	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-02	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-03	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-04	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-05	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-06	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-07	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-08	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB01-LGR-09	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB01-UGR-01	Semi-annually		✓	Every 9 months/Major Precip.	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-01	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-02	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-03	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-04	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-05	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-06	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-07	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-08	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB02-LGR-09	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB02-UGR-01	Semi-annually		✓	Every 9 months/Major Precip.	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-01	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-02	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-03	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-04	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-05	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-06	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-07	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-08	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB03-LGR-09	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB03-UGR-01	Semi-annually		✓	Every 9 months/Major Precip.	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-BS-01	Biennially		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-BS-02	Biennially		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-CC-01	Biennially		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-CC-02	Biennially		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-CC-03	Biennially		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-01	Semi-annually		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-02	Semi-annually		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-03	Semi-annually		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-04	Semi-annually		✓	Every 18 months	Move to 18-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-06	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB04-LGR-07	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB04-LGR-08	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.
CS-WB04-LGR-09	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB04-LGR-10	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB04-LGR-11	Semi-annually		✓	Every 9 months	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.+ 9-month snapshot samples for basewide LGR plume maps
CS-WB04-UGR-01	Semi-annually		✓	Every 9 months/Major Precip.	Move to 9-month schedule which doesn't coincide with basewide snapshot for labor reasoning.



N
W E
S

2,500 1,250 0 2,500 Feet

LGR Zone Wells

Recommended Sampling Frequency

- Quarterly
- Semi-annualy
- Every 9 months
- Every 18 months
- Exclude

Figure 4.1

Qualitative Evaluation Recommended Sampling Frequencies, LGR Zone Wells

Camp Stanley Storage Activity

PARSONS

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The qualitative analysis recommends moving all off-post wells and on-post LGR wells to a common 9-month schedule. Most on-post BS and CC wells (currently biennial) would move to an 18-month schedule. LGR wells close the plume centers would also incorporate a semi-annual schedule since those wells are subject to higher variability in concentrations. All on-post potable water supply wells and off-post wells undergoing GAC treatment would continue to be monitored on a quarterly basis. Finally, even though all off-post wells are recommended for a 9-month schedule, the current DQOs would pre-empt trump the LTMO schedule. For instance, if an off-post well is currently sampled quarterly because of the DQO "rules", than that well would continue to be sampled quarterly.

4.2.1 On-post Wells

A total of 56 on-post monitoring wells were considered during the LTMO process for CSSA. Recommendations for on-post wells included 14 wells recommended for 18-month sampling, 20 recommendations for 9-month sampling, 8 recommendations for semi-annual sampling (twice per year), 4 recommendations for quarterly (potable wells), and 9 wells recommended for removal. The recommendations and accompanying rationale for on-post wells are summarized in the following paragraphs.

Four on-post drinking water wells were recommended to be retained on a quarterly sampling frequency. Historical detections have been below the reporting limit or non-detect and quarterly sampling will ensure that on-post drinking water will continue to meet drinking water standards in the future. This recommendation applied to wells CS-1, CS-9, CS-10, and CS-12.

Eight wells were recommended for sampling on a semi-annual basis. This is big reduction from the 20 wells that were recommended for semi-annual monitoring in 2005, with the remainder being recommended for a 9-month frequency. The wells recommended for semi-annual monitoring are mostly around those portions of the plumes that are at, or above the MCLs. These include: CS-4, CS-D, CS-MW1-LGR, CS-MW2-LGR, CS-MW8-LGR, CS-MW10-LGR, CS-MW11A-LGR, and CS-MW24-LGR. Well CS-MW24-LGR is being included with the semi-annual because recent events have indicated significant contamination at the western edge of the plume (CS-4).

Fourteen wells were recommended to be sampled every 18 months. This group includes 11 wells completed in the BS and CC formations. Groundwater monitoring at CSSA has consistently demonstrated that the BS and CC formations are not impacted by COCs. Well CS-MW16-CC is located near the source area and is the one exception. Detections of PCE, TCE and *cis*-1,2-DCE in CS-MW16-CC are the only detections in a CC well above the reporting limit. The remaining wells recommended for the 18-month interval include clean upgradient wells in the North Pasture (CS-G, CS-MWH-LGR, and CS-I). These wells exhibit no contamination and are expected to continue to do so.

Ten wells were recommended to be excluded from the basewide groundwater monitoring program. Well CS-3 is spatially redundant to CS-2 (less than 200 apart) and well CS-11 which is spatially redundant to CS-9 and CS-10 and no longer has a pump. The eight remaining wells are located at AOC-65. These wells are shallow and typically dry throughout most of the year. These wells are generally utilized for supporting activities associated with AOC-65 remedial activities. Therefore, it is recommended that these wells be removed from the basewide monitoring program and utilized strictly as part of AOC-65 activities.

The remaining 20 on-post wells are recommended for a 9-month sampling frequency. Most of the wells recommended for this schedule are currently on a semi-annual schedule, but are stable in terms of concentration and variability is low.

4.2.2 Off-post Monitoring Wells

A total of 51 off-post drinking water wells were considered during the LTMO evaluation for CSSA. Of the 51 evaluated wells, 7 are recommended to be retained on a quarterly sampling schedule and 36 are recommended to be sampled at a reduced frequency of every 9 months. The remaining 8 wells will be excluded either because they have been plugged or CSSA no longer has access rights to the well. Under the DQOs currently in effect for the CSSA Groundwater Monitoring Program, the sampling frequency can be reduced as needed at selected wells based on cumulative analytical results.

Six of the off-post drinking water wells to be retained on a quarterly sampling frequency have had concentrations exceeding the MCL for PCE and have been equipped with GAC water treatment systems to ensure drinking water for residents meets EPA and TCEQ drinking water standards. These wells will be retained on a quarterly schedule to continue plume characterization and include LS-5, LS-6, LS-7, OFR-3, RFR-10, and RFR-11. Inactive well I10-4 has also been included in the quarterly schedule because of its importance as a sentry well. The well is located at the western margin of Plume 2, and has a history of exceeding the MCLs.

The remaining 36 off-post drinking water wells have been sampled either quarterly or annually in the past. The qualitative analysis suggests changing the sampling frequency of wells that are currently on an annual sampling frequency to a 9-month schedule that would coincide with the on-post sampling regimen. This would allow for a seasonal snapshot of the aquifer condition across the affected plume areas, both on- and off-post. It is worthwhile to mention that the off-post DQOs would still be in effect, and that any well that made a notable change in concentration could be sampled on a quarterly frequency if the condition arises.

4.2.3 Westbay-equipped Monitoring Wells

A total of 46 zones from four WB-equipped monitoring wells were considered during the LTMO process for CSSA. There are three WB wells installed on-post and one installed off-post. WB01, WB02 and WB03 are installed on-post near Building 90 and are completed in zones UGR-01 and LGR zones 01 through 09. WB04 is installed off-post near drinking water well RFR-10 and is complete in zones UGR-01, LGR zones 01 through 11, BS-01, BS-02, CC-01, CC-02 and CC-03. These wells are equipped with the Westbay MP38 system which allows hydraulic pressure data collection and groundwater sampling of each zone using the Westbay MOSDAX sampling probe.

Until the original LTMO recommendations for the Westbay wells started in March 2006, all WB zones which contained water were sampled almost monthly between September 2003 and August 2005. Certain zones (CS-WB04-LGR-01, CS-WB04-LGR-03, and CS-WB02-LGR-02) have occasionally been dry and could not be sampled. Other zones are always dry and have been sampled less than four times since September 2003 (CS-WB01-UGR-01, CS-WB02-UGR-01, and, CS-WB04-UGR-01). These zones only contain water following rainfall of more than 1 inch in duration.

Due to the historical sampling results collected monthly since September 2003, concentrations in the LGR zones are well documented. As a result of the qualitative evaluation, the sampling frequency for all LGR zones was recommended to be reduced from semi-annually to a 9-month frequency. For the BS and CC zones of the WB wells the recommended sampling frequency can also be changed from a biennial (every 2 years) to every 18 months.

4.2.4 Laboratory Analytical Program

For on-post and off-post wells in the CSSA monitoring program, groundwater samples currently are analyzed for VOCs using method SW8260B for the full list and method SW8260B for the short list of VOCs. On-post drinking water wells are analyzed for the full list of VOCs. The majority of historical sampling events for on-post monitoring wells have been analyzed for the short list of VOCs which includes 1,1-DCE, *cis*-1,2-DCE, methylene chloride, PCE, TCE, *trans*-1,2-DCE, and VC. Prior to 2007, the VOC list also routinely included bromodichloromethane, bromoform, chloroform, dibromochloromethane, dichlorodifluoromethane, naphthalene, and toluene from the on-post wells. Metals are sampled once annually in the on-post monitoring wells and quarterly in the on-post drinking water wells. Metals are analyzed using methods SW6010B (chromium), SW6020 (cadmium and lead), and SW7470A (mercury). Prior to a 2008 DQO revision, the metals analysis also routinely included barium, copper, nickel, zinc (method SW6010B), and arsenic (method SW6020). All on-post and off-post drinking water and monitoring wells sampled receive data validation and verification in accordance with the AFCEE QAPP and the CSSA QAPP. Data packages are submitted to AFCEE chemists for review and approval.

For the WB-equipped wells groundwater samples are analyzed for the VOCs PCE, TCE, *cis*-1,2-DCE, *trans*-1,2-DCE and 1,1-DCE using method SW8260B. In 2006, 2-butanone, isopropanol, acetone and toluene were removed from the sampling list after a revision to the project DQOs. Laboratory data packages from the Westbay samples receive an internal data validation and review but are not subject to review and approval by the USACE.

4.2.5 LTM Program Flexibility

The LTM program recommendations summarized in **Table 4.3** are based on available data regarding current (and expected future) site conditions. Changing site conditions (*e.g.*, periods of drought or excessive rainfall) could affect plume behavior. Therefore, the LTM program should be reviewed if hydraulic conditions change significantly, and revised as necessary to adequately track changes in plume magnitude and extent over time.

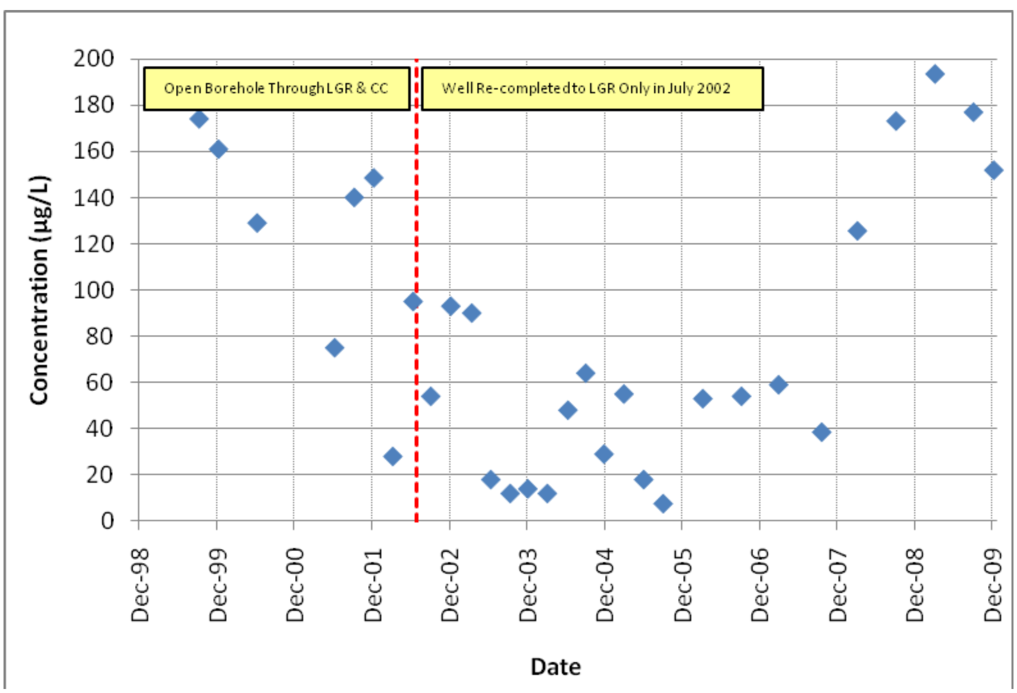
SECTION 5
TEMPORAL STATISTICAL EVALUATION

Chemical concentrations measured at different points in time (temporal data) can be examined graphically or using statistical tests, to evaluate dissolved-contaminant plume stability. If removal of chemical mass is occurring in the subsurface as a consequence of attenuation processes or operation of a remediation system, mass removal will be apparent as a decrease in chemical concentrations through time at a particular sampling location, as a decrease in chemical concentrations with increasing distance from chemical source areas, and/or as a change in the suite of chemicals detected through time or with increasing migration distance.

5.1 METHODOLOGY FOR TEMPORAL TREND ANALYSIS OF CONTAMINANT CONCENTRATIONS

Temporal chemical-concentration data can be evaluated for trends by plotting contaminant concentrations through time for individual monitoring wells (**Figure 5.1**), or by plotting contaminant concentrations versus downgradient distance from the contaminant source for several wells along the groundwater flowpath, over several monitoring events. Plotting temporal concentration data is recommended for any analysis of plume stability (Wiedemeier and Haas, 2000); however, visual identification of trends in plotted data may be a subjective process, particularly if (as is likely) the concentration data do not exhibit a uniform trend, but are variable through time (**Figure 5.2**).

Figure 5.1 PCE Concentrations through Time at Well CS-16-LGR
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS



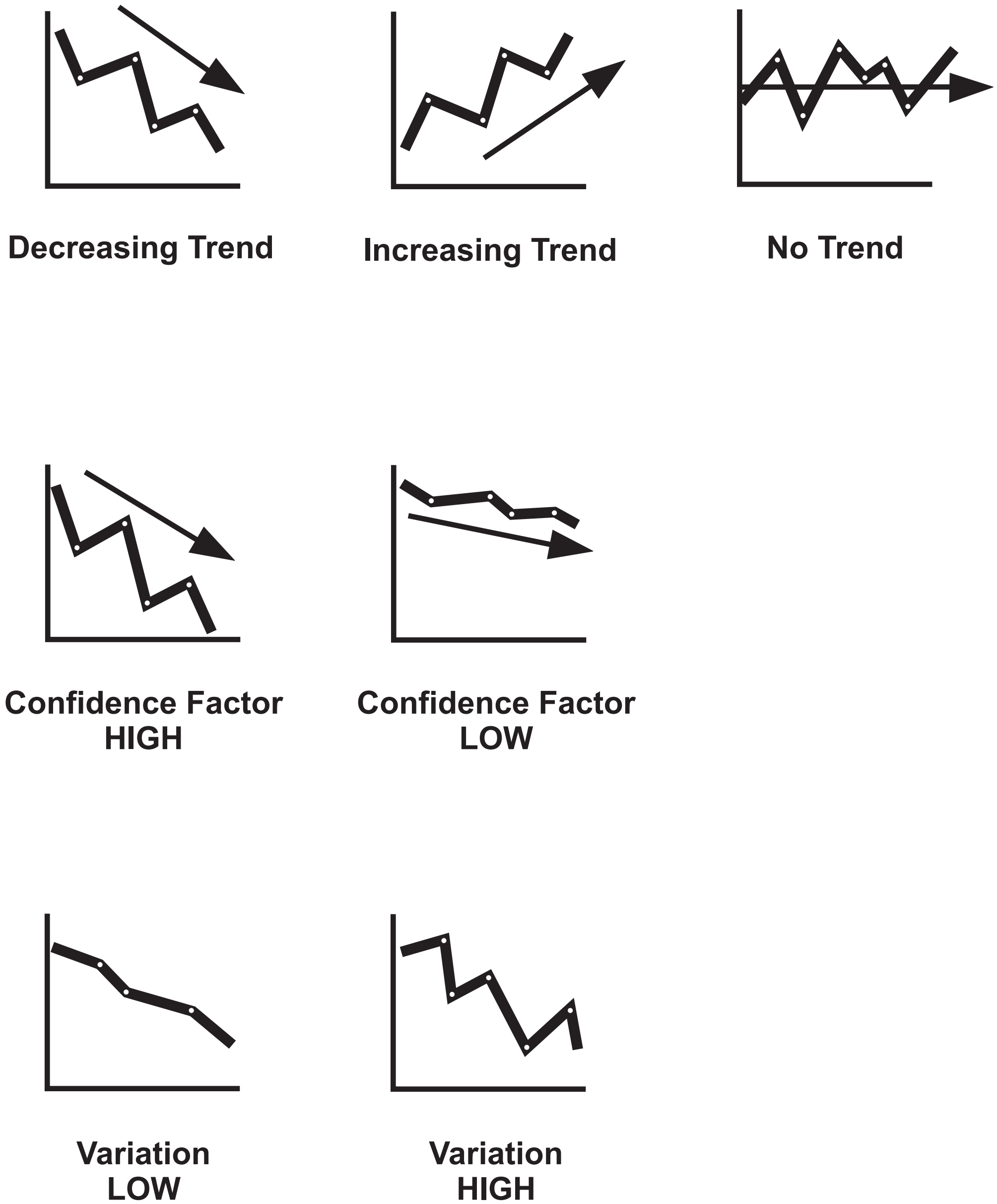


FIGURE 5.2

CONCEPTUAL REPRESENTATION OF TEMPORAL TRENDS AND TEMPORAL VARIATIONS IN CONCENTRATIONS

Long Term Monitoring Optimization
Camp Stanley, Texas

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The possibility of arriving at incorrect conclusions regarding plume stability on the basis of visual examination of temporal concentration data can be reduced by examining temporal trends in chemical concentrations using various statistical procedures, including regression analyses and the Mann-Kendall test for trends. The Mann-Kendall nonparametric test (Gibbons, 1994) is well-suited for evaluation of environmental data because the sample size can be small (as few as four data points), no assumptions are made regarding the underlying statistical distribution of the data, and the test can be adapted to account for seasonal variations in the data. The Mann-Kendall test statistic can be calculated at a specified level of confidence to evaluate whether a statistically significant temporal trend is exhibited by contaminant concentrations detected through time in samples from an individual well. A negative slope (indicating decreasing contaminant concentrations through time) or a positive slope (increasing concentrations through time) provides statistical confirmation of temporal trends that may have been identified visually from plotted data (**Figure 5.2**). In this analysis, a 90 percent confidence level is used to define a statistically significant trend.

The relative value of information obtained from periodic monitoring at a particular monitoring well can be evaluated by considering the location of the well with respect to the dissolved contaminant plume, potential receptor exposure points, and the presence or absence of temporal trends in contaminant concentrations in samples collected from the well. The degree to which the amount and quality of information that can be obtained at a particular monitoring point serve the two primary (*i.e.*, temporal and spatial) objectives of monitoring that must be considered in this evaluation. For example, the continued non-detection of a target contaminant in groundwater at a particular monitoring location provides no information about temporal trends in contaminant concentrations at that location, or information about the extent to which contaminant migration is occurring, unless the monitoring location lies along a groundwater flowpath between a contaminant source and a potential receptor exposure point (*e.g.*, downgradient of a known contaminant plume). Therefore, a monitoring well having a history of contaminant concentrations below detection limits may be providing little or no useful information, depending on its location.

A trend of increasing contaminant concentrations in groundwater at a location between a contaminant source and a potential receptor exposure point may represent information critical in evaluating whether contaminants are migrating to the exposure point, thereby completing an exposure pathway. Identification of a trend of decreasing contaminant concentrations at the same location may be useful in evaluating decreases in the areal extent of dissolved contaminants, but does not represent information critical to the protection of a potential receptor. Similarly, a trend of decreasing contaminant concentrations in groundwater near a contaminant source may represent important information regarding the progress of remediation near, and downgradient from the source. By contrast, the absence of a statistically significant (as defined by the Mann-Kendall test with a 90 percent confidence level) temporal trend in contaminant concentrations at a particular location within or downgradient from a plume indicates that virtually no additional information can be obtained by frequent monitoring of groundwater at that location, in that the results of continued monitoring through time are likely to fall within the historic range of concentrations that have already been detected (**Figure 5.3**). Continued monitoring at locations where no temporal trend in contaminant concentrations is present serves merely to confirm the results of previous monitoring activities at that location.

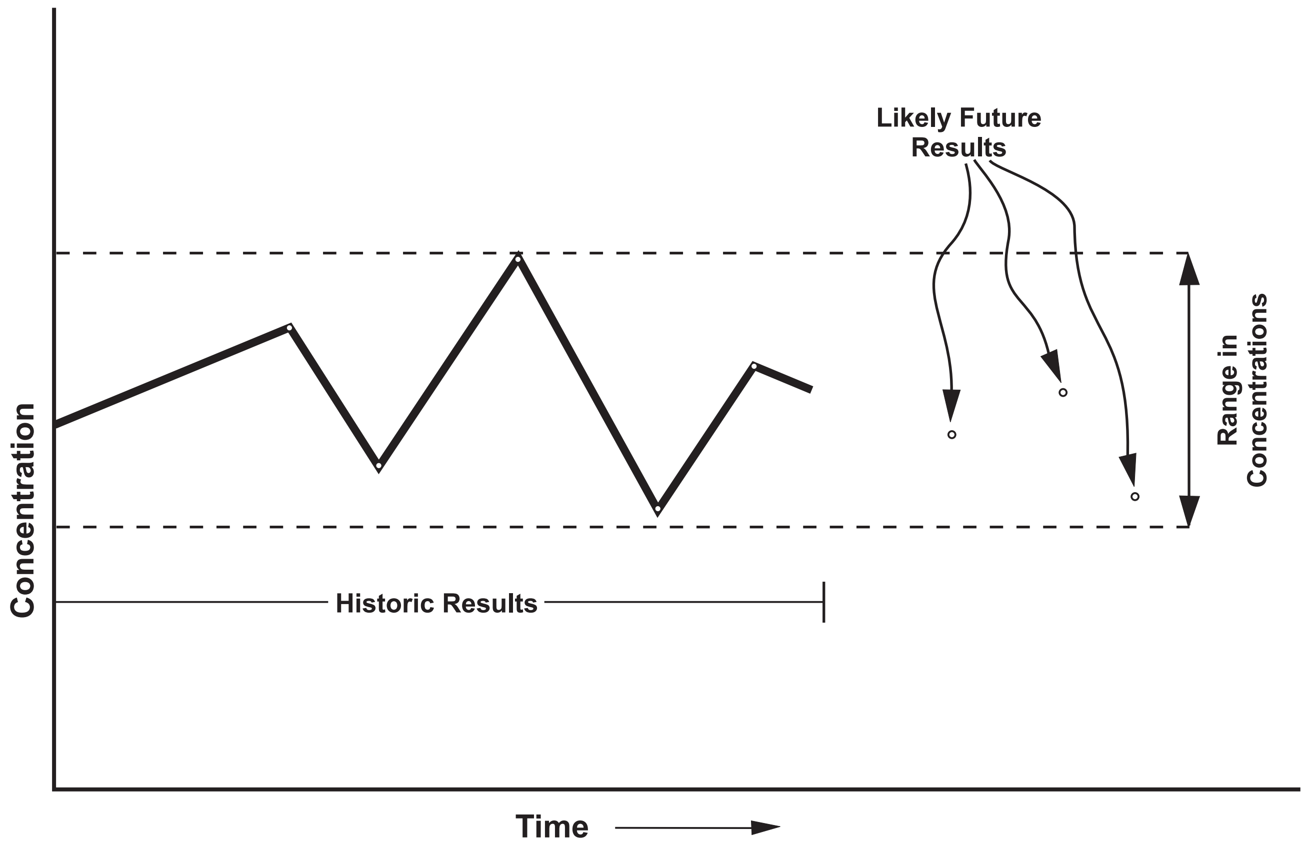

FIGURE 5.3

CONCEPTUAL REPRESENTATION OF CONTINUED MONITORING AT LOCATION WHERE NO TEMPORAL TREND IN CONCENTRATIONS IS PRESENT

Long Term Monitoring Optimization
Camp Stanley, Texas

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The temporal trends and relative location of wells can be weighed to determine if a well should be retained, excluded, or continue in the program with reduced sampling. **Figure 5.4** presents a flowchart demonstrating the methodology for utilizing trend results to draw these conclusions.

5.2 TEMPORAL EVALUATION RESULTS

The analytical data for groundwater samples collected from the 153 sample points in the CSSA LTM program from September 1991 through December 2009 were examined for temporal trends using the Mann-Kendall test. The objective of the evaluation was to identify those wells having increasing or decreasing concentration trends for each COC, and to consider the quality of information represented by the existence or absence of concentration trends in terms of the location of each monitoring point. Increasing or decreasing trends are those identified as with positive or negative slopes, respectively, by the Mann-Kendall trend analysis with a confidence level of 90 percent.

Summary results of Mann-Kendall temporal trend analyses for COCs in groundwater samples from CSSA are presented in **Table 5.1**. Differences between the 2004 LTMO and 2010 LTMO update are highlighted in **Table 5.2**. Trends for eight potential COCs (PCE, TCE, DCE, PB, TMBE, BDCME, BZME, and VC) were evaluated to assess the value of temporal information for each well. As implemented, the algorithm used to evaluate concentration trends assigned a value of "ND" (not detected) to those wells with sampling results that were consistently below analytical detection limits through time, rather than assigning a surrogate value corresponding to the detection limit – a procedure that could generate potentially misleading and anomalous "trends" in concentrations. In addition, a value of "<PQL" was assigned to those constituents for which no values were measured above the practical quantitative limit (PQL), *i.e.*, all sample results were either ND or trace. For example, PCE results for groundwater samples from well CS-11 include four trace detections of 0.41 µg/L, 0.41 µg/L, 0.16 µg/L, and 0.062 µg/L on 6/14/00, 9/13/00, 3/19/01, and 3/14/02, respectively, and 32 measurements in which PCE was not detected. In the absence of the "<PQL" classification category, results of trend analysis would indicate a "no trend" result for PCE in those samples, which is primarily an artifact of the analytical procedures, and could generate false conclusions regarding concentration trends. The color-coding of the **Table 5.1** entries denotes the presence/absence of temporal trends, and allows those monitoring points having nondetectable concentrations, decreasing or increasing concentrations, or no discernible trend in concentrations to be readily identified. The 6 sample points that had fewer than four analytical results for each of the COCs could not be analyzed using the Mann-Kendall trend analysis, and have a "<4Meas" and/or "No Data" designation. **Figure 5.5** displays the Mann-Kendall results for PCE thematically by well for LGR zone wells, along with each well's relative plume location designation (*e.g.*, downgradient, upgradient).

The basis for the decision to exclude, reduce sampling or retain a well in the monitoring program based on the value of its temporal information is described in the "Rationale" column of **Table 5.1**, and a flow chart of the decision logic applied to the temporal trend analysis results is presented in **Figure 5.4**. Trend results from PCE, TCE, DCE and Pb were given more weight than those from the other potential COCs given their relatively higher impact.

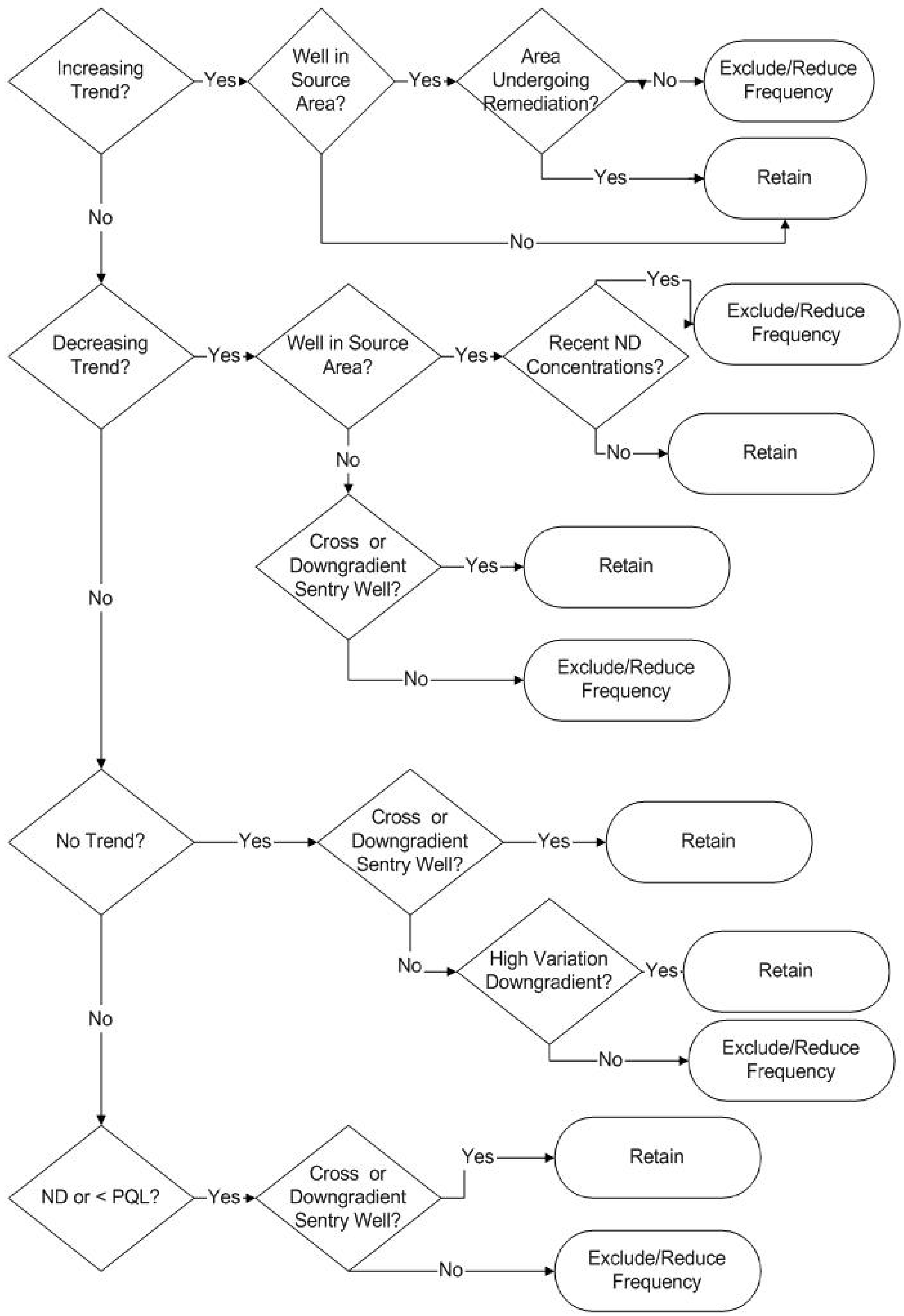


Figure 5.4

TEMPORAL TREND DECISION RATIONALE FLOWCHART

Long Term Monitoring Optimization
Camp Stanley Storage Area, Texas

PARSONS

TABLE 5.1
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
On Post Monitoring Wells											
AOC65-MW1	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time. Last measured in 2004.
AOC65-MW2A	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	COC concentrations highly variable in source area; PCE>MCL. Last measured in 2004.
AOC65-PZ01-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE and TCE > MCL. Last measured in 2004.
AOC65-PZ02-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE and TCE > MCL. Last measured in 2004.
AOC65-PZ03-LGR	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends upgradient; PCE and TCE near or below MCL. Last measured in 2004.
AOC65-PZ04-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing PCE trends upgradient consistently below MCL. Last measured in 2004.
AOC65-PZ05-LGR	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing PCE trends downgradient; PCE>MCL; stable TCE. Last measured in 2004.
AOC65-PZ06-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE > MCL. Last measured in 2004.
CS-1	PQL	No Trend	ND	Decreasing	No Trend	Decreasing	ND	No Trend		✓	Downgradient sentry well; decreasing lead below MCL since 2000; one low detection of TCE in 2000.
CS-10	PQL	ND	ND	No Trend	PQL	Increasing	ND	No Trend	✓		Downgradient; No PCE since 2004; lead below 6 ug/L since 1996; one low detection of BDCME in 2006; two low BZME detections
CS-11	PQL	PQL	PQL	Increasing	ND	Decreasing	ND	No Trend		✓	Downgradient; increasing lead above the MCL.
CS-12	<4Meas	<4Meas	<4Meas	<4Meas	<4Meas	<4Meas	<4Meas	<4Meas		✓	Continue sampling until sufficient data for trend statistics.
CS-2	No Trend	PQL	ND	No Trend	ND	ND	ND	No Trend	✓		Downgradient; only trace PCE since 1999; low lead concentrations; one low BZME detection in 2003.
CS-3	No Trend	ND	ND	No Trend	<4Meas	ND	ND	<4Meas	✓		Downgradient; well not measured since 1999 (trace PCE concentrations.)
CS-4	No Trend	Increasing	Increasing	PQL	ND	ND	ND	PQL		✓	Downgradient; increasing DCE and TCE; PCE>MCL and TCE>MCL in 2009.
CS-9	PQL	ND	ND	Increasing	ND	ND	ND	Increasing	✓		Downgradient: lead increasing; since 2006, six lead measurements > MCL. One BZME detection in 2003, trace through 2006..
CS-D	Increasing	Increasing	No Trend	No Trend	ND	ND	PQL	No Trend		✓	Increasing concentrations within source area undergoing remediation.
CS-I	PQL	PQL	ND	No Trend	ND	Decreasing	ND	No Trend		✓	Upgradient well; BZME ND since 2004; BDCME ND since 1994; highly variable lead concentrations > MCL.
CS-MW10-CC	PQL	PQL	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; one low detection of BZME in 2003.
CS-MW10-LGR	Decreasing	PQL	ND	PQL	ND	ND	ND	No Trend		✓	Slightly decreasing to stable PCE trend downgradient. All PCE concentrations < MCL.
CS-MW11A-LGR	Increasing	PQL	ND	PQL	ND	ND	ND	PQL		✓	Downgradient well; increasing PCE; three low PCE detections < MCL since 2008; trace since 2003.
CS-MW11B-LGR	Increasing	ND	ND	PQL	ND	ND	ND	PQL		✓	Downgradient well; increasing PCE; two low PCE detections < MCL since 2005; trace since 2003.
CS-MW12-BS	ND	ND	ND	PQL	ND	ND	PQL	Decreasing	✓		Downgradient (lower aquifer) well; trace BZME < MCL.
CS-MW12-CC	ND	ND	ND	PQL	ND	ND	PQL	Decreasing	✓		Downgradient (lower aquifer) well; three low BZME detections < MCL prior to 2005.
CS-MW12-LGR	ND	ND	ND	PQL	ND	ND	ND	No Trend		✓	Downgradient sentry well; most COCs historically ND; trace lead since 2004; one BZME detection < MCL in 2003.
CS-MW16-CC	Decreasing	Decreasing	Decreasing	PQL	ND	ND	PQL	No Trend		✓	Decreasing PCE, TCE, and DCE > MCL downgradient (below) source area.
CS-MW16-LGR	No Trend	No Trend	Decreasing	PQL	ND	ND	ND	No Trend		✓	Variable PCE and TCE > MCL and slightly decreasing DCE > MCL in source area.
CS-MW17-LGR	PQL	PQL	ND	PQL	ND	ND	ND	Decreasing	✓		Downgradient; COCs primarily ND or PQL; one BZME detection < 4 ug/L in 2003.
CS-MW18-LGR	PQL	PQL	ND	PQL	ND	ND	ND	Decreasing		✓	Downgradient sentry well; most COCs historically ND or PQL; two low BZME detections < MCL in 2003.
CS-MW19-LGR	PQL	ND	ND	PQL	ND	ND	PQL	Decreasing	✓		Downgradient; most COCs consistently ND or PQL; one BZME detection < 5 ug/L in 2003.
CS-MW1-BS	PQL	PQL	No Trend	PQL	ND	ND	PQL	Decreasing	✓		Downgradient (lower aquifer) well; variable DCE < 1.3 ug/L; decreasing BZME <10 ug/L.
CS-MW1-CC	ND	ND	ND	PQL	ND	ND	PQL	PQL	✓		Downgradient (lower aquifer) well; all COCs ND or PQL.
CS-MW1-LGR	No Trend	Increasing	No Trend	Increasing	ND	ND	PQL	Decreasing		✓	Variable PCE > MCL, increasing TCE> MCL, variable DCE < MCL, and increasing lead < MCL downgradient from source.
CS-MW20-LGR	Increasing	PQL	ND	PQL	<4Meas	<4Meas	ND	<4Meas		✓	Increasing PCE < MCL; trace lead.
CS-MW21-LGR	ND	PQL	ND	Decreasing	<4Meas	<4Meas	ND	<4Meas	✓		Lead detections < 3.5 ug/L; all other COCs ND or PQL.
CS-MW22-LGR	ND	PQL	ND	Decreasing	<4Meas	<4Meas	ND	<4Meas	✓		Four lead detections > MCL since 2007; trace since 2008; all other COCs ND or PQL.
CS-MW23-LGR	ND	ND	ND	Decreasing	<4Meas	<4Meas	ND	<4Meas	✓		Lead detections < 8 ug/L; all other COCs ND or PQL.
CS-MW24-LGR	ND	ND	ND	PQL	<4Meas	<4Meas	ND	<4Meas		✓	All COCs ND or PQL; lead < 3.5 ug/L.
CS-MW25-LGR	ND	ND	ND	Decreasing	<4Meas	<4Meas	ND	<4Meas	✓		Four lead detections > MCL since 2007; trace since 2008; all other COCs ND or PQL.
CS-MW2-CC	ND	ND	ND	No Trend	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; one lead detection < 2.5 ug/L; increasing BZME < MCL.
CS-MW2-LGR	Decreasing	Decreasing	Decreasing	Increasing	ND	ND	PQL	Increasing	✓		Downgradient; decreasing PCE, DCE, TCE < MCL; increasing lead <4 ug/L; increasing BZME < MCL.
CS-MW3-LGR	PQL	PQL	ND	Decreasing	ND	ND	ND	ND	✓		Crossgradient well; lead detection > MCL in 2001; trace lead < 2.5 ug/L since; most COCs ND or PQL.
CS-MW4-LGR	PQL	PQL	PQL	PQL	ND	ND	PQL	No Trend	✓		Downgradient; most COCs ND or PQL.
CS-MW5-LGR	Decreasing	Decreasing	Decreasing	PQL	ND	ND	ND	PQL	✓		Downgradient; slightly decreasing to stable PCE, TCE, DCE concentrations < MCL.
CS-MW6-BS	ND	ND	PQL	PQL	ND	ND	ND	Decreasing	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; decreasing BZME < MCL.
CS-MW6-CC	ND	PQL	PQL	PQL	ND	ND	ND	Decreasing	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; decreasing BZME < MCL.
CS-MW6-LGR	PQL	PQL	PQL	PQL	ND	ND	ND	No Trend	✓		Upgradient well: COCs historically PQL or ND.
CS-MW7-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; COCs historically PQL or ND.
CS-MW7-LGR	PQL	PQL	ND	PQL	ND	ND	ND	Decreasing		✓	Downgradient sentry well; most COCs ND or PQL; decreasing BZME < MCL.
CS-MW8-CC	PQL	PQL	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; COCs historically PQL or ND.
CS-MW8-LGR	Increasing	PQL	PQL	PQL	ND	ND	ND	No Trend		✓	Downgradient; increasing PCE detections < MCL; most other COCs ND or PQL.
CS-MW9-BS	ND	ND	ND	Increasing	ND	ND	PQL	PQL		✓	Downgradient (lower aquifer) well; increasing lead detections > MCL; most other COCs ND or PQL.
CS-MW9-CC	ND	ND	PQL	PQL	ND	ND	ND	PQL	✓		Downgradient (lower aquifer) well; COCs historically PQL or ND.
CS-MW9-LGR	PQL	PQL	ND	PQL	ND	ND	ND	PQL	✓		Upgradient; COCs historically PQL or ND.
CS-MWG-LGR	ND	ND	ND	No Trend	ND	ND	ND	PQL	✓		Upgradient well; lead < MCL since 2001; most other COCs ND or PQL.
CS-MWH-LGR	ND	ND	ND	Decreasing	PQL	ND	ND	Decreasing	✓		Upgradient well; lead decreasing and < MCL since 2001; decreasing BZME last detected in 2003; most other COCs ND or PQL.
Off Post Monitoring Wells											
DOM-2	ND	ND	ND	No Data	ND	ND	ND	PQL	✓		Historically ND or PQL downgradient.
FO-17	ND	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically PQL or ND.
FO-22	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND crossgradient sentry well.
FO-8	ND	ND	ND	No Data	ND	ND	ND	PQL	✓		Crossgradient well; all COCs PQL or ND.
FO-J1	PQL	PQL	PQL	No Data	ND	ND	ND	PQL	✓		Historically ND or PQL downgradient.

TABLE 5.1
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
HS-1	PQL	ND	ND	No Data	No Data	No Data	ND	No Data		✓	All COCs PQL or ND.
HS-2	PQL	ND	ND	No Data	ND	ND	ND	PQL		✓	Downgradient sentry well; all COCs PQL or ND.
HS-3	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Historically ND downgradient sentry well.
I10-2	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well.
I10-4	Increasing	Increasing	ND	No Data	ND	ND	ND	ND		✓	Downgradient well; increasing PCE > MCL; increasing TCE < MCL.
I10-5	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Downgradient sentry well; COCs historically ND.
I10-7	ND	PQL	ND	No Data	ND	ND	ND	PQL		✓	Downgradient sentry well; COCs historically PQL or ND.
I10-8	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas		✓	Downgradient sentry well; All COCs ND.
JW-12	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND or PQL downgradient well.
JW-13	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Downgradient sentry well; COCs historically ND.
JW-14	PQL	ND	ND	No Data	PQL	No Trend	ND	No Trend	✓		Downgradient; BDCME detection < 6 ug/L in 2003; BZME detection < 2.5 ug/L in 2003; all other COCs PQL or ND.
JW-15	ND	ND	ND	No Data	ND	ND	ND	ND	✓		All COCs ND.
JW-26	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Downgradient ell; all COCs PQL or ND. Last measured in 2006.
JW-27	PQL	PQL	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically PQL or ND.
JW-28	ND	ND	ND	No Data	ND	ND	ND	PQL		✓	Historically ND or PQL downgradient sentry well.
JW-29	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically PQL or ND.
JW-30	PQL	PQL	PQL	<4Meas	ND	ND	ND	ND	✓		Downgradient; all COCs PQL or ND.
JW-31	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	<4Meas	No Data		✓	Retain until statistical determination can be made.
JW-5	PQL	ND	ND	No Data	ND	ND	ND	ND		✓	All COCs PQL or ND.
JW-6	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Crossgradient sentry well; COCs historically PQL or ND.
JW-7	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically PQL or ND.
JW-8	PQL	PQL	PQL	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically PQL or ND.
JW-9	PQL	ND	PQL	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically PQL or ND.
LS-1	PQL	PQL	Increasing	No Data	PQL	PQL	ND	ND		✓	Downgradient: DCE detection of 2.5 ug/L in 2009.
LS-2	Decreasing	PQL	ND	No Data	ND	PQL	ND	ND	✓		Downgradient; decreasing PCE < MCL. Last measured in 2006.
LS-3	Decreasing	PQL	ND	No Data	ND	PQL	ND	No Trend	✓		Downgradient; decreasing PCE < MCL; last BZME detection < 5 ug/L in 2004. Last measured in 2007.
LS-4	PQL	ND	ND	No Data	ND	PQL	ND	ND		✓	Downgradient sentry well; COCs historically ND.
LS-5	PQL	No Trend	ND	No Data	ND	ND	ND	ND		✓	Downgradient; variable TCE detections < MCL.
LS-6	Decreasing	Increasing	ND	No Data	ND	PQL	ND	PQL		✓	Downgradient; decreasing PCE < MCL; increasing TCE < MCL.
LS-7	Decreasing	Increasing	ND	<4Meas	ND	PQL	ND	PQL		✓	Downgradient; decreasing PCE < MCL; increasing TCE < MCL.
OFR-1	PQL	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient well; all COCs PQL or ND.
OFR-2	PQL	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically PQL or ND. Last measured in 2006.
OFR-3	No Trend	No Trend	PQL	No Data	ND	ND	ND	ND		✓	Downgradient; variable PCE and TCE > MCL.
OFR-4	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well.
RFR-10	No Trend	No Trend	PQL	<4Meas	ND	ND	ND	PQL		✓	Downgradient; variable PCE and TCE > MCL.
RFR-11	Decreasing	Increasing	ND	No Data	ND	ND	ND	PQL		✓	Downgradient; decreasing PCE near MCL; increasing TCE < MCL.
RFR-12	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	Downgradient sentry well; all COCs PQL or ND.
RFR-13	ND	ND	ND	No Data	No Trend	Decreasing	ND	ND		✓	TBME detection of 1.2 ug/l in 2005; highest BDCME detection was 8.7 ug/L in 2005.
RFR-14	PQL	ND	PQL	No Data	<4Meas	<4Meas	ND	<4Meas	✓		All COCs PQL or ND.
RFR-3	PQL	ND	ND	<4Meas	ND	ND	ND	ND	✓		Crossgradient; COCs historically PQL or ND.
RFR-4	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas	✓		Crossgradient; COCs historically ND.
RFR-5	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas	✓		Crossgradient; COCs historically ND.
RFR-6	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Exclude; well plugged
RFR-7	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Exclude; well plugged
RFR-8	ND	ND	ND	<4Meas	ND	ND	ND	ND	✓		Crossgradient; COCs historically ND.
RFR-9	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Crossgradient; COCs historically PQL or ND.
WestBay Equipped Wells											
CS-WB01-LGR-01	No Trend	PQL	ND	No Data	No Data	No Data	ND	ND		✓	Variable PCE > MCL and TCE < MCL downgradient.
CS-WB01-LGR-02	Increasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Increasing PCE > MCL and TCE near MCL downgradient.
CS-WB01-LGR-03	No Trend	No Trend	PQL	No Data	No Data	No Data	ND	ND		✓	Variable PCE < MCL and TCE > MCL downgradient.
CS-WB01-LGR-04	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND	✓		Decreasing PCE; only trace TCE since 2003 downgradient.
CS-WB01-LGR-05	No Trend	Decreasing	ND	No Data	No Data	No Data	ND	ND	✓		Decreasing trace TCE downgradient.
CS-WB01-LGR-06	No Trend	Decreasing	ND	No Data	No Data	No Data	ND	ND	✓		Decreasing TCE < MCL downgradient.
CS-WB01-LGR-07	Increasing	Increasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	Increasing PCE and TCE > MCL downgradient.
CS-WB01-LGR-08	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	PQL	ND	✓		Decreasing PCE; trace PCE since 2004; decreasing TCE < MCL downgradient.
CS-WB01-LGR-09	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Increasing PCE and TCE > MCL; increasing DCE < MCL downgradient.
CS-WB01-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time. Last measured in 2004.
CS-WB02-LGR-01	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	Decreasing PCE > MCL; variable TCE near MCL downgradient.
CS-WB02-LGR-02	Increasing	Increasing	No Trend	No Data	No Data	No Data	<4Meas	ND		✓	Increasing PCE > MCL; increasing TCE < MCL; one DCE detection of 1.7 ug/L in 2005 downgradient. Last measured in 2007.
CS-WB02-LGR-03	No Trend	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	Variable PCE > MCL; decreasing TCE near MCL downgradient.
CS-WB02-LGR-04	Decreasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Decreasing PCE near MCL; increasing TCE > MCL downgradient.
CS-WB02-LGR-05	Decreasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Decreasing PCE near MCL; increasing TCE near MCL downgradient.
CS-WB02-LGR-06	Decreasing	Increasing	No Trend	No Data	No Data	No Data	ND	ND		✓	Decreasing PCE near MCL; increasing TCE near MCL; variable DCE < MCL downgradient.

TABLE 5.1
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
CS-WB02-LGR-07	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND	✓		Decreasing PCE and TCE < MCL downgradient.
CS-WB02-LGR-08	Decreasing	Decreasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Decreasing PCE and TCE near MCL; increasing DCE < MCL downgradient.
CS-WB02-LGR-09	No Trend	No Trend	No Trend	No Data	No Data	No Data	ND	ND		✓	Variable PCE and TCE > MCL; variable DCE < MCL downgradient.
CS-WB02-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time. Last measured in 2004.
CS-WB03-LGR-01	No Trend	No Trend	PQL	No Data	No Data	No Data	<4Meas	ND		✓	PCE and TCE highly variable in source area.
CS-WB03-LGR-02	Decreasing	No Trend	PQL	No Data	No Data	No Data	<4Meas	ND		✓	PCE decreasing in source area. Last measured in 2007.
CS-WB03-LGR-03	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	ND	ND		✓	PCE and TCE decreasing in source area.
CS-WB03-LGR-04	Decreasing	No Trend	PQL	No Data	No Data	No Data	ND	ND		✓	PCE decreasing in source area.
CS-WB03-LGR-05	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	PCE decreasing in source area.
CS-WB03-LGR-06	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	PCE, TCE, and DCE decreasing in source area.
CS-WB03-LGR-07	Decreasing	No Trend	Increasing	No Data	No Data	No Data	ND	ND		✓	PCE decreasing; DCE increasing in source area.
CS-WB03-LGR-08	Decreasing	Decreasing	PQL	No Data	No Data	No Data	ND	ND		✓	PCE and TCE decreasing in source area.
CS-WB03-LGR-09	Decreasing	No Trend	Decreasing	No Data	No Data	No Data	ND	ND		✓	PCE and DCE decreasing in source area.
CS-WB03-UGR-01	No Trend	Increasing	No Trend	No Data	No Data	No Data	ND	ND		✓	TCE increasing in source area.
CS-WB04-BS-01	PQL	Decreasing	ND	No Data	No Data	No Data	<4Meas	ND	✓		Historically ND or PQL downgradient. TCE was non-detect since 2003.
CS-WB04-BS-02	PQL	PQL	PQL	No Data	No Data	No Data	<4Meas	ND	✓		Historically ND or PQL downgradient.
CS-WB04-CC-01	ND	PQL	Increasing	No Data	No Data	No Data	<4Meas	ND	✓		Trace DCE consistently since 2004 downgradient.
CS-WB04-CC-02	PQL	PQL	ND	No Data	No Data	No Data	<4Meas	ND	✓		Historically ND or PQL downgradient.
CS-WB04-CC-03	PQL	PQL	ND	No Data	No Data	No Data	<4Meas	ND	✓		Historically ND or PQL downgradient.
CS-WB04-LGR-01	PQL	PQL	ND	No Data	No Data	No Data	ND	ND	✓		Historically ND or PQL downgradient.
CS-WB04-LGR-02	PQL	ND	ND	No Data	No Data	No Data	<4Meas	ND	✓		Historically ND or PQL downgradient.
CS-WB04-LGR-03	PQL	ND	ND	No Data	No Data	No Data	ND	ND	✓		Historically ND or PQL downgradient.
CS-WB04-LGR-04	PQL	PQL	ND	No Data	No Data	No Data	ND	ND	✓		Historically ND or PQL downgradient.
CS-WB04-LGR-06	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Increasing PCE and TCE > MCL; increasing DCE < MCL downgradient.
CS-WB04-LGR-07	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Increasing PCE and TCE > MCL; increasing DCE < MCL downgradient.
CS-WB04-LGR-08	No Trend	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND	✓		Decreasing TCE < MCL downgradient. DCE non-detect since 2003.
CS-WB04-LGR-09	Increasing	No Trend	No Trend	No Data	No Data	No Data	ND	ND		✓	Increasing PCE > MCL; variable TCE > MCL; variable DCE < MCL downgradient.
CS-WB04-LGR-10	PQL	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	Variable TCE < MCL downgradient.
CS-WB04-LGR-11	Increasing	Decreasing	ND	No Data	No Data	No Data	ND	ND		✓	Increasing PCE < MCL downgradient. TCE was non-detect since 2003.
CS-WB04-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time. Last measured in 2004.

TABLE 5.2
CHANGES IN TEMPORAL TREND ANALYSIS BETWEEN 2004 AND 2010 LTMO UPDATE
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Description of Change
On Post Monitoring Wells											
AOC65-MW1	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		
AOC65-MW2A	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	
AOC65-PZ01-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		
AOC65-PZ02-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		
AOC65-PZ03-LGR	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	No Data	✓		
AOC65-PZ04-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		
AOC65-PZ05-LGR	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	No Data	✓		
AOC65-PZ06-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		
CS-1	PQL	No Trend	ND	Decreasing	No Trend	**Decreasing**	ND	No Trend		✓	BDCM was previously "No Trend"
CS-10	PQL	ND	ND	No Trend	**PQL**	**Increasing**	ND	No Trend	✓		Bromoform and BDCM were both previously "ND"
CS-11	PQL	PQL	PQL	Increasing	ND	Decreasing	ND	No Trend		✓	
CS-12	**<4Meas**	**<4Meas**	**<4Meas**	**<4Meas**	**<4Meas**	**<4Meas**	**<4Meas**	**<4Meas**		✓	New Well since 2004 LTMO
CS-2	No Trend	PQL	ND	No Trend	ND	ND	ND	No Trend	✓		
CS-3	No Trend	ND	ND	No Trend	<4Meas	ND	ND	<4Meas	✓		
CS-4	No Trend	Increasing	Increasing	**PQL**	ND	ND	ND	PQL		✓	Previously Lead was "<4 Measurements"
CS-9	PQL	ND	ND	**Increasing**	ND	ND	ND	Increasing	✓		Previously Lead was "Decreasing"
CS-D	Increasing	Increasing	**No Trend**	No Trend	ND	ND	PQL	No Trend		✓	Previously cis-1,2-DCE was "Increasing"
CS-I	PQL	PQL	ND	No Trend	ND	Decreasing	ND	No Trend		✓	
CS-MW10-CC	PQL	**PQL**	ND	PQL	ND	ND	ND	No Trend	✓		Previously TCE was "ND"
CS-MW10-LGR	**Decreasing**	PQL	ND	PQL	ND	ND	ND	No Trend	✓		Previously PCE was "No Trend"
CS-MW11A-LGR	**Increasing**	**PQL**	ND	**PQL**	ND	ND	ND	PQL		✓	Previously PCE was "PQL", TCE was "ND", and Lead was "<4 Measurements"
CS-MW11B-LGR	**Increasing**	ND	ND	**PQL**	ND	ND	ND	PQL		✓	Previously PCE was "PQL" and Lead was "<4 Measurements"
CS-MW12-BS	ND	ND	ND	**PQL**	ND	ND	PQL	Decreasing	✓		Previously Lead was "<4 Measurements"
CS-MW12-CC	ND	ND	ND	**PQL**	ND	ND	PQL	**Decreasing**	✓		Previously Lead was "<4 Measurements" and Toluene was "No Trend"
CS-MW12-LGR	ND	ND	ND	**PQL**	ND	ND	ND	No Trend		✓	Previously Lead was "<4 Measurements"
CS-MW16-CC	**Decreasing**	**Decreasing**	**Decreasing**	**PQL**	ND	ND	PQL	**No Trend**		✓	Previously PCE, TCE, cis-1,2,-DCE were all "No Trend". Lead was "<4 Measurements". Toluene was "PQL"
	No Trend	**No Trend**	Decreasing	PQL	ND	ND	ND	No Trend		✓	Previously PCE and TCE were "Decreasing"
CS-MW17-LGR	PQL	PQL	ND	**PQL**	ND	ND	ND	Decreasing	✓		Previously Lead was "<4 Measurements"
CS-MW18-LGR	PQL	PQL	ND	**PQL**	ND	ND	ND	Decreasing		✓	Previously Lead was "<4 Measurements"
CS-MW19-LGR	PQL	ND	ND	**PQL**	ND	ND	PQL	**Decreasing**	✓		Previously Lead was "<4 Measurements" and Toluene was "No Trend"
CS-MW1-BS	PQL	PQL	**No Trend**	**PQL**	ND	ND	PQL	Decreasing	✓		Previously cis-1,2-DCE was "Decreasing" and Lead was "<4 Measurements"
CS-MW1-CC	ND	ND	ND	**PQL**	ND	ND	PQL	PQL	✓		Previously Lead was "<4 Measurements"
CS-MW1-LGR	No Trend	Increasing	No Trend	**Increasing**	ND	ND	PQL	Decreasing		✓	Previously Lead was "PQL"
CS-MW20-LGR	**Increasing**	**PQL**	**ND**	**PQL**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**		✓	New Well since 2004 LTMO
CS-MW21-LGR	**ND**	**PQL**	**ND**	**Decreasing**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**	✓		New Well since 2004 LTMO
CS-MW22-LGR	**ND**	**PQL**	**ND**	**Decreasing**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**	✓		New Well since 2004 LTMO
CS-MW23-LGR	**ND**	**ND**	**ND**	**Decreasing**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**	✓		New Well since 2004 LTMO
CS-MW24-LGR	**ND**	**ND**	**ND**	**PQL**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**		✓	New Well since 2004 LTMO
CS-MW25-LGR	**ND**	**ND**	**ND**	**Decreasing**	**<4Meas**	**<4Meas**	**ND**	**<4Meas**	✓		New Well since 2004 LTMO
CS-MW2-CC	ND	ND	ND	**No Trend**	ND	ND	ND	**No Trend**	✓		Previously Lead was "<4 Measurements" and Toluene was "PQL"
CS-MW2-LGR	Decreasing	Decreasing	Decreasing	**Increasing**	ND	ND	PQL	Increasing	✓		Previously Lead was "PQL"
CS-MW3-LGR	PQL	PQL	ND	Decreasing	ND	ND	ND	ND	✓		
CS-MW4-LGR	PQL	PQL	PQL	PQL	ND	ND	PQL	No Trend	✓		
CS-MW5-LGR	**Decreasing**	**Decreasing**	**Decreasing**	PQL	ND	ND	ND	PQL	✓		Previously PCE, TCE, cis-1,2,-DCE were all "No Trend"
CS-MW6-BS	ND	ND	PQL	**PQL**	ND	ND	ND	**Decreasing**	✓		Previously Lead was "ND" and Toluene was "No Trend"
CS-MW6-CC	ND	PQL	PQL	PQL	ND	ND	ND	**Decreasing**	✓		Previously Toluene was "No Trend"
CS-MW6-LGR	PQL	PQL	PQL	PQL	ND	ND	ND	No Trend	✓		
CS-MW7-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓		
CS-MW7-LGR	PQL	PQL	ND	PQL	ND	ND	ND	**Decreasing**		✓	Previously Toluene was "No Trend"
CS-MW8-CC	PQL	**PQL**	ND	PQL	ND	ND	ND	No Trend	✓		Previously TCE was "ND"
CS-MW8-LGR	**Increasing**	PQL	PQL	PQL	ND	ND	ND	No Trend		✓	Previously PCE was "PQL"
CS-MW9-BS	ND	ND	ND	**Increasing**	ND	ND	PQL	PQL		✓	Previously Lead was "PQL"
CS-MW9-CC	ND	ND	PQL	**PQL**	ND	ND	ND	PQL	✓		Previously Lead was "ND"
CS-MW9-LGR	PQL	PQL	ND	PQL	ND	ND	ND	PQL	✓		
CS-MWG-LGR	ND	ND	ND	No Trend	ND	ND	ND	PQL	✓		
CS-MWH-LGR	ND	ND	ND	Decreasing	PQL	ND	ND	**Decreasing**	✓		Previously Toluene was "No Trend"
Off Post Monitoring Wells											
DOM-2	ND	ND	ND	No Data	ND	ND	ND	**PQL**	✓		Previously Toluene was "ND"
FO-17	**ND**	**ND**	**ND**	No Data	**ND**	**ND**	**ND**	**PQL**	✓		Previously all analytes were "<4 Measurements"
FO-22	ND	ND	ND	No Data	ND	ND	ND	ND	✓		
FO-8	**ND**	**ND**	**ND**	No Data	**ND**	**ND**	**ND**	**PQL**	✓		Previously all analytes were "<4 Measurements"
FO-J1	PQL	PQL	PQL	No Data	ND	ND	ND	PQL	✓		

TABLE 5.2

CHANGES IN TEMPORAL TREND ANALYSIS BETWEEN 2004 AND 2010 LTMO UPDATE

LONG TERM MONITORING OPTIMIZATION

CAMP STANLEY STORAGE AREA, TEXAS

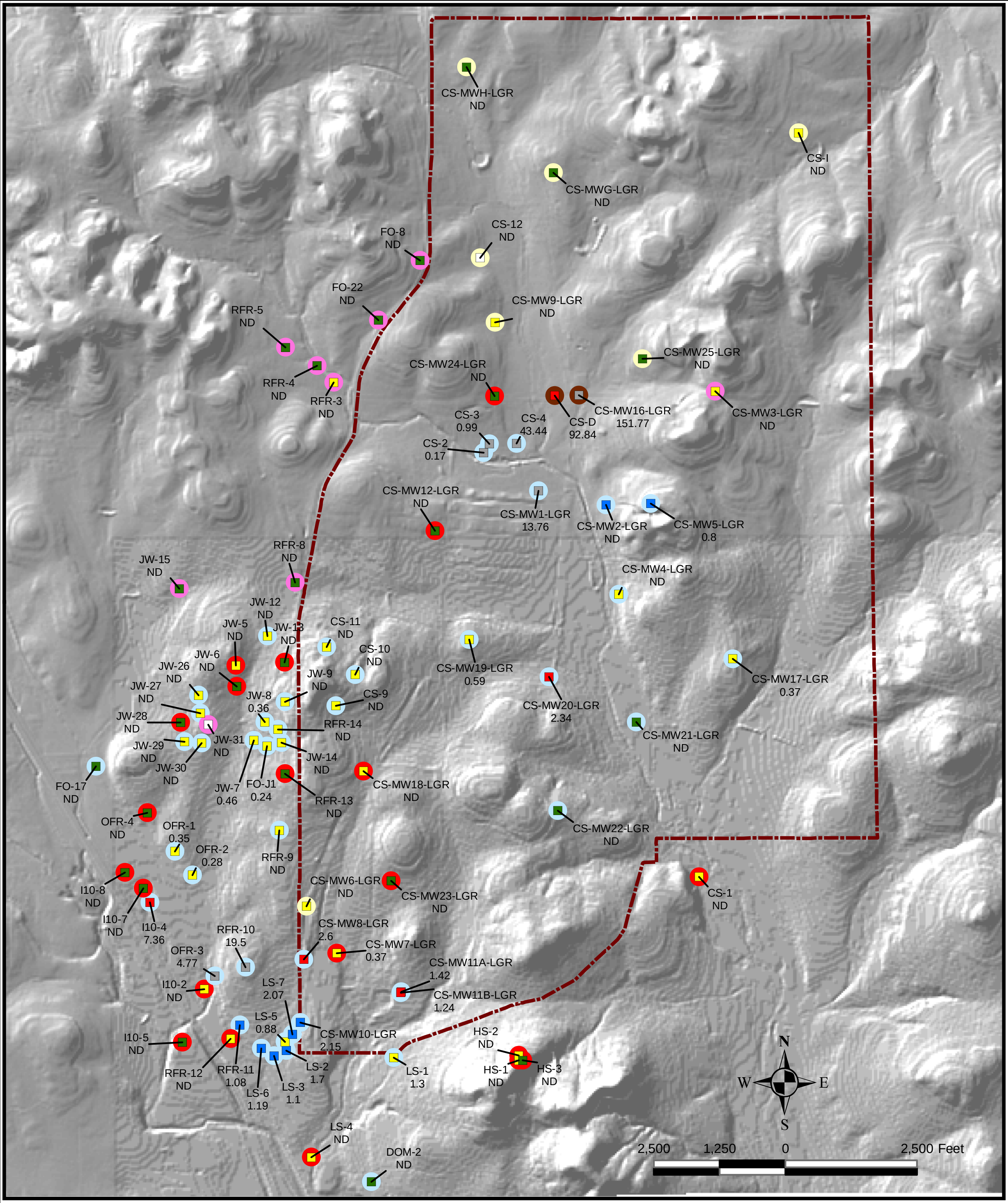
Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Description of Change
HS-1	PQL	ND	ND	No Data	No Data	No Data	ND	No Data		✓	Well was not sampled prior to 2004 LTMO
HS-2	PQL	ND	ND	No Data	ND	ND	ND	PQL		✓	
HS-3	ND	ND	ND	No Data	ND	ND	ND	ND		✓	
I10-2	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	
I10-4	Increasing	Increasing	ND	No Data	ND	ND	ND	ND		✓	Previously PCE was "No Trend" and TCE was "PQL"
I10-5	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Previously all analytes were "<4 Measurements"
I10-7	ND	PQL	ND	No Data	ND	ND	ND	PQL		✓	Previously TCE was "ND"
I10-8	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas		✓	Well was not sampled prior to 2004 LTMO
JW-12	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Previously all analytes were "<4 Measurements"
JW-13	ND	ND	ND	No Data	ND	ND	ND	ND		✓	
JW-14	PQL	ND	ND	No Data	PQL	No Trend	ND	No Trend	✓		
JW-15	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Well was not sampled prior to 2004 LTMO
JW-26	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		
JW-27	PQL	PQL	ND	No Data	ND	ND	ND	ND	✓		Previously all analytes were "<4 Measurements"
JW-28	ND	ND	ND	No Data	ND	ND	ND	PQL		✓	
JW-29	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		
JW-30	PQL	PQL	PQL	<4Meas	ND	ND	ND	ND	✓		
JW-31	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	<4Meas	No Data		✓	Well was not sampled prior to 2004 LTMO
JW-5	PQL	ND	ND	No Data	ND	ND	ND	ND		✓	Well was not sampled prior to 2004 LTMO
JW-6	ND	ND	ND	No Data	ND	ND	ND	ND		✓	
JW-7	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		
JW-8	PQL	PQL	PQL	No Data	ND	ND	ND	ND	✓		
JW-9	PQL	ND	PQL	No Data	ND	ND	ND	PQL	✓		
LS-1	PQL	PQL	Increasing	No Data	PQL	PQL	ND	ND		✓	Previously cis-1,2-DCE was "ND"
LS-2	Decreasing	PQL	ND	No Data	ND	PQL	ND	ND	✓		
LS-3	Decreasing	PQL	ND	No Data	ND	PQL	ND	No Trend	✓		Previously PCE was "No Trend" and TCE, BDCM was "ND", and Toluene was "Increasing"
LS-4	PQL	ND	ND	No Data	ND	PQL	ND	ND		✓	Previously BDCM ws "ND"
LS-5	PQL	No Trend	ND	No Data	ND	ND	ND	ND		✓	Previously TCE was "PQL"
LS-6	Decreasing	Increasing	ND	No Data	ND	PQL	ND	PQL		✓	Previously PCE was "No Trend" and TCE was "PQL"
LS-7	Decreasing	Increasing	ND	<4Meas	ND	PQL	ND	PQL		✓	Previously PCE and TCE was "No Trend"
OFR-1	PQL	ND	ND	No Data	ND	ND	ND	PQL	✓		
OFR-2	PQL	ND	ND	No Data	ND	ND	ND	PQL	✓		
OFR-3	No Trend	No Trend	PQL	No Data	ND	ND	ND	ND		✓	
OFR-4	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Previously all analytes were "<4 Measurements"
RFR-10	No Trend	No Trend	PQL	<4Meas	ND	ND	ND	PQL		✓	Previously PCE was "Increasing" and Toluene was "No Trend"
RFR-11	Decreasing	Increasing	ND	No Data	ND	ND	ND	PQL		✓	Previously PCE and TCE was "No Trend"
RFR-12	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	
RFR-13	ND	ND	ND	No Data	No Trend	Decreasing	ND	ND		✓	Well was not sampled prior to 2004 LTMO
RFR-14	PQL	ND	PQL	No Data	<4Meas	<4Meas	ND	<4Meas	✓		Well was not sampled prior to 2004 LTMO
RFR-3	PQL	ND	ND	<4Meas	ND	ND	ND	ND	✓		
RFR-4	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas	✓		Previously all analytes were "<4 Measurements"
RFR-5	ND	ND	ND	No Data	<4Meas	<4Meas	ND	<4Meas	✓		Previously all analytes were "<4 Measurements"
RFR-6	ND	ND	ND	No Data	ND	ND	ND	ND	✓		
RFR-7	ND	ND	ND	No Data	ND	ND	ND	ND	✓		
RFR-8	ND	ND	ND	<4Meas	ND	ND	ND	ND	✓		
RFR-9	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Previously PCE was "ND"
Westbay Wells											
CS-WB01-LGR-01	No Trend	PQL	ND	No Data	No Data	No Data	ND	ND		✓	Previously PCE was "Decreasing", TCE was "ND", and VC was "Not Analyzed"
CS-WB01-LGR-02	Increasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "No Trend", and VC was "Not Analyzed"
CS-WB01-LGR-03	No Trend	No Trend	PQL	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Increasing", cis-1,2-DCE was "Non Detect", and VC ws "Not Analyzed"
CS-WB01-LGR-04	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND	✓		Previously TCE was "ND" and VC was Not Analyzed"
CS-WB01-LGR-05	No Trend	Decreasing	ND	No Data	No Data	No Data	ND	ND	✓		Previously PCE was "ND", TCE was "PQL", and VC was "Not Analyzed"
CS-WB01-LGR-06	No Trend	Decreasing	ND	No Data	No Data	No Data	ND	ND	✓		Previously PCE was "ND", TCE was "PQL", and VC was "Not Analyzed"
CS-WB01-LGR-07	Increasing	Increasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE was "Decreasing", TCE was "No Trend", cis-1,2-DCE was "ND" and VC ws "Not Analyzed"
CS-WB01-LGR-08	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	PQL	ND	✓		Previously TCE was "No Trend", cis-1,2-DCE was "ND", and VC was "Not Analyzed"
CS-WB01-LGR-09	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "No Trend", cis-1,2-DCE was "Decreasing", and VC was "Not Analyzed"
CS-WB01-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		
CS-WB02-LGR-01	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	Previously PCE was "No Trend" and TCE was "Decreasing" and VC was "Not Analyzed"
CS-WB02-LGR-02	Increasing	Increasing	No Trend	No Data	No Data	No Data	<4Meas	ND		✓	Previously TCE was "No Trend", cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"
CS-WB02-LGR-03	No Trend	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE was "Decreasing" and VC was "Not Analyzed"
CS-WB02-LGR-04	Decreasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Decreasing" and VC was "Not Analyzed"
CS-WB02-LGR-05	Decreasing	Increasing	ND	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Decreasing" and VC was "Not Analyzed"
CS-WB02-LGR-06	Decreasing	Increasing	No Trend	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "No Trend", cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"

TABLE 5.2
CHANGES IN TEMPORAL TREND ANALYSIS BETWEEN 2004 AND 2010 LTMO UPDATE
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Description of Change
CS-WB02-LGR-07	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND	✓		Previously PCE and TCE were "No Trend", cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"
CS-WB02-LGR-08	Decreasing	Decreasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "No Trend", cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"
CS-WB02-LGR-09	No Trend	No Trend	No Trend	No Data	No Data	No Data	ND	ND		✓	Previously PCE, TCE, cis-1,2-DCE were "Decreasing" and VC was "Not Analyzed"
CS-WB02-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		
CS-WB03-LGR-01	No Trend	No Trend	PQL	No Data	No Data	No Data	<4Meas	ND		✓	Previously "<4 Measurements" for all data
CS-WB03-LGR-02	Decreasing	No Trend	PQL	No Data	No Data	No Data	<4Meas	ND		✓	Previously "<4 Measurements" for all data
CS-WB03-LGR-03	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "No Trend" and VC was "Not Analyzed"
CS-WB03-LGR-04	Decreasing	No Trend	PQL	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Decreasing", cis-1,2-DCE was "Non Detect", and VC was "Not Analyzed"
CS-WB03-LGR-05	Decreasing	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Decreasing" and VC was Not Analyzed"
CS-WB03-LGR-06	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND		✓	Previously VC was "Not Analyzed"
CS-WB03-LGR-07	Decreasing	No Trend	Increasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE and cis-1,2-DCE were "No Trend", TCE was "Increasing", and VC was "Not Analyzed"
CS-WB03-LGR-08	Decreasing	Decreasing	PQL	No Data	No Data	No Data	ND	ND		✓	Previously cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"
CS-WB03-LGR-09	Decreasing	No Trend	Decreasing	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Decreasing" and VC was "Not Analyzed"
CS-WB03-UGR-01	No Trend	Increasing	No Trend	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "No Trend" and VC was "Not Analyzed"
CS-WB04-BS-01	PQL	Decreasing	ND	No Data	No Data	No Data	<4Meas	ND	✓		Previously PCE and TCE were "Non Detect" and VC was Not Analyzed"
CS-WB04-BS-02	PQL	PQL	PQL	No Data	No Data	No Data	<4Meas	ND	✓		Previously PCE, TCE, and cis-1,2-DCE were "Non Detect" and VC was Not Analyzed"
CS-WB04-CC-01	ND	PQL	Increasing	No Data	No Data	No Data	<4Meas	ND	✓		Previously cis-1,2-DCE was "No Trend", and VC was "Not Analyzed"
CS-WB04-CC-02	PQL	PQL	ND	No Data	No Data	No Data	<4Meas	ND	✓		Previously PCE and TCE were "Non Detect" and VC was "Not Analyzed"
CS-WB04-CC-03	PQL	PQL	ND	No Data	No Data	No Data	<4Meas	ND	✓		Previously TCE was "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-01	PQL	PQL	ND	No Data	No Data	No Data	ND	ND	✓		Previously PCE and TCE were "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-02	PQL	ND	ND	No Data	No Data	No Data	<4Meas	ND	✓		Previously PCE was "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-03	PQL	ND	ND	No Data	No Data	No Data	ND	ND	✓		Previously PCE was "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-04	PQL	PQL	ND	No Data	No Data	No Data	ND	ND	✓		Previously PCE and TCE were "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-06	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE was "Non Detect", TCE and cis-1,2-DCE were "No Trend", and VC ws "Not Analyzed"
CS-WB04-LGR-07	Increasing	Increasing	Increasing	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "PQL", cis-1,2-DCE was "Decreasing" and VC was "Not Analyzed"
CS-WB04-LGR-08	No Trend	Decreasing	Decreasing	No Data	No Data	No Data	ND	ND	✓		Previously PCE and cis-1,2-CE were "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-09	Increasing	No Trend	No Trend	No Data	No Data	No Data	ND	ND		✓	Previously cis-1,2-DCE was "Non Detect" and VC was "Not Analyzed"
CS-WB04-LGR-10	PQL	No Trend	ND	No Data	No Data	No Data	ND	ND		✓	Previously TCE was "Increasing" and VC was "Not Analyzed"
CS-WB04-LGR-11	Increasing	Decreasing	ND	No Data	No Data	No Data	ND	ND		✓	Previously PCE and TCE were "Non Detect" and VC was Not Analyzed"
CS-WB04-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		

Notes:

- No Data — Analyte has never been tested
- <4Meas — Less than Four Measurements
- ND — Result Consistently below Analytical Detection Limits
- PQL — No samples were measured above the Practical Quantitation Limit
- No Trend — Mann-Kendall Statistical Determination of no discernable trend in results
- Decreasing — Mann-Kendall Statistical Determination of Decreasing Trend in Concentration
- Increasing — Mann-Kendall Statistical Determination of Increasing Trend in Concentration



PCE Mann-Kendall Trend Result

- ND
- <PQL
- Decreasing
- Increasing
- No Trend
- <4 Measurements

Well Location within Plume

- Downgradient
- Sentry
- Source
- Upgradient
- Crossgradient

Labels:
Well Id
Most Recent
PCE Concentration

All results in ug/L
ND: PCE not detected

Figure 5.5

Temporal Trend Results for PCE
LGR Zone Wells

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Monitoring wells not considered "sentry" wells at which concentrations of COCs consistently have been non-detected or <PQL through time (*e.g.*, CS-MW4-LGR, CS-MW10-CC, CS-MW11A-LGR, DOM-2, HS-3) represent points that do not generate useful temporal information, and typically can be recommended for exclusion or reduced monitoring. Additionally, wells located downgradient of the source area that have either decreasing concentrations or a recent history of concentrations below MCLs (*e.g.*, CS-MW2-LGR, AOC-65-PZ05, LS-2, and CS-WB01-LGR05) will provide limited valuable temporal information in the future and are recommended for exclusion or reduced sampling. Conversely, monitoring wells (*e.g.*, CS-16-LGR, CS-WB03-LGR04) that exhibit decreasing temporal trends in a source area with recent concentrations above MCLs are valuable and should be retained because they provide information on the effectiveness of the remediation system. Additionally, downgradient wells with increasing COC concentration trends (*e.g.*, wells CS-4, CS-11, CS-MW1-LGR) provide valuable information about potential migration of contaminants, and should be retained. Wells with stable and/or low "no trend" results were recommended for exclusion or monitoring reduction (*e.g.*, wells CS-MW10-LGR, CS-MW5-LGR) because continued frequent sampling would not likely yield new information, while wells with highly variable COC concentrations (*e.g.*, wells CS-MW1-LGR, LS-6) were recommended for retention. Recommendations in wells that had different Mann-Kendall trend results for different COCs were based on the most conservative analysis.

Table 5.1 summarizes recommendations to retain 44 and exclude or reduce 81 of the 125 wells analyzed in the temporal evaluation (not including the 14 wells with fewer than four measurements) analyzed to optimize the monitoring program for CSSA. The recommendations provided in **Table 5.1** are based on the evaluation of ***temporal statistical results only***, and must be used in conjunction with the results of the qualitative and spatial evaluations to generate final recommendations regarding retention of monitoring points in the LTM program, and the frequency of monitoring at particular locations at CSSA.

SECTION 6
SPATIAL STATISTICAL EVALUATION

Spatial statistical techniques also can be applied to the design and evaluation of groundwater monitoring programs to assess the quality of information generated during monitoring, and to evaluate monitoring networks. *Geostatistics*, or the Theory of Regionalized Variables (Clark, 1987; Rock, 1988; American Society of Civil Engineers Task Committee on Geostatistical Techniques in Hydrology, 1990a and 1990b), is concerned with variables having values dependent on location, and which are continuous in space, but which vary in a manner too complex for simple mathematical description. Geostatistics is based on the premise that the differences in values of a spatial variable depend only on the distances between sampling locations, and the relative orientations of sampling locations--that is, the values of a variable (*e.g*., chemical concentration) measured at two locations that are spatially "close together" will be more similar than values of that variable measured at two locations that are "far apart". This approach downplays some of the irregular flow patterns associated with Karst hydrology, but is still considered valid for influencing the evaluation process.

6.1 GEOSTATISTICAL METHODS FOR EVALUATING MONITORING NETWORKS

Ideally, application of geostatistical methods to the results of the groundwater monitoring program at CSSA could be used to estimate COC concentrations at every point within the dissolved contaminant plume, and also could be used to generate estimates of the “error,” or uncertainty, associated with each estimated concentration value. Thus, the monitoring program could be optimized by using available information to identify those areas having the greatest uncertainty associated with the estimated plume extent and configuration. Conversely, sampling points could be successively eliminated from simulations, and the resulting uncertainty examined, to evaluate whether significant loss of information (represented by increasing error or uncertainty in estimated chemical concentrations) occurs as the number of sampling locations is reduced. Repeated application of geostatistical estimating techniques, using tentatively identified sampling locations, could then be used to generate a sampling program that would provide an acceptable level of uncertainty regarding the distribution of COCs with the minimum possible number of samples collected. Furthermore, application of geostatistical methods can provide unbiased representations of the distribution of COCs at different locations in the subsurface, enabling the extent of COCs to be evaluated more precisely.

Fundamental to geostatistics is the concept of <u>semivariance</u> [$\gamma(h)$], which is a measure of the spatial dependence between sample variables (*e.g*., chemical concentrations) in a specified direction. Semivariance is defined for a constant spacing between samples (***h***) by:

$$\gamma(h) = \frac{1}{2n} \sum [g(x) - g(x + h)]^2 \qquad \textit{Equation 6-1}$$

Where:

$\gamma(h)$ = semivariance calculated for all samples at a distance ***h*** from each other;

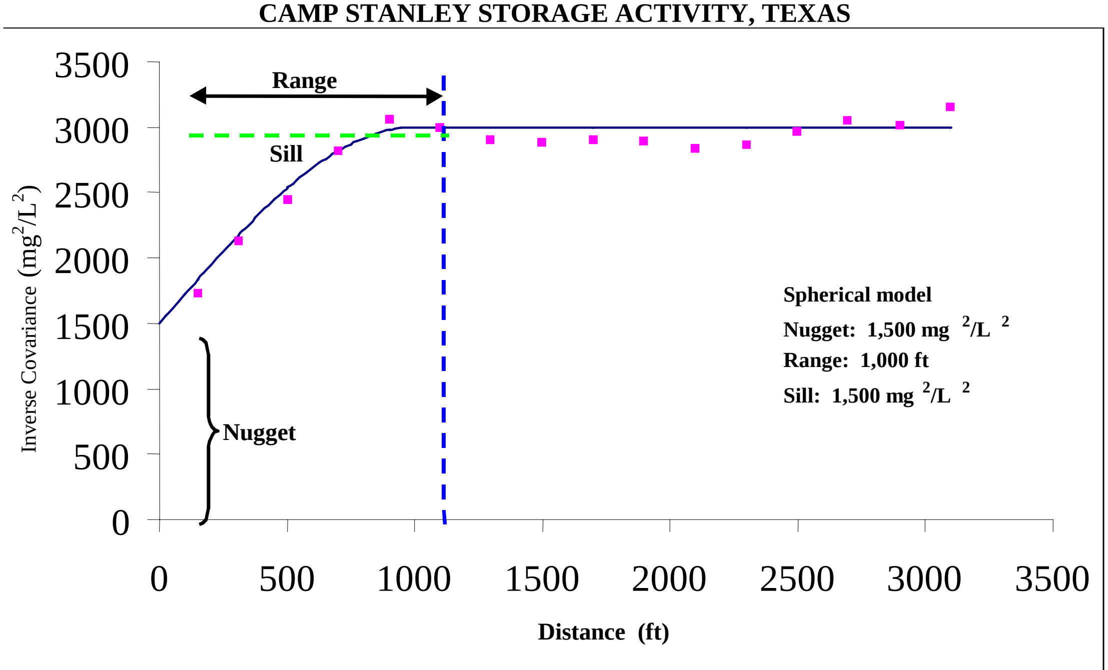
g(x) = value of the variable in sample at location ***x***;

g(x + h) = value of the variable in sample at a distance ***h*** from sample at location ***x***; and

n = number of samples in which the variable has been determined.

Semivariograms (plots of ***γ(h)*** versus ***h***) are a means of depicting graphically the range of distances over which, and the degree to which, sample values at a given point are related to sample values at adjacent, or nearby, points, and conversely, indicate how close together sample points must be for a value determined at one point to be useful in predicting unknown values at other points. For ***h*** = *0*, for example, a sample is being compared with itself, so normally *γ(0) = 0* (the semivariance at a spacing of zero, is zero), except where a so-called nugget effect is present (**Figure 6.1**), which implies that sample values are highly variable at distances less than the sampling interval. Analytical variability and sampling error can contribute to the nugget. As the distance between samples increases, sample values become less and less closely related, and the semivariance, therefore, increases, until a "sill" is eventually reached, where ***γ(h)*** equals the overall variance (*i.e.*, the variance around the average value). The sill is reached at a sample spacing called the "range of influence," beyond which sample values are not related. Only values between points at spacings less than the range of influence can be predicted; but within that distance, the semivariogram provides the proper weightings, which apply to sample values separated by different distances.

Figure 6.1 Idealized Semivariogram Model
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS



When a semivariogram is calculated for a variable over an area (*e.g.*, concentrations of PCE in the CSSA groundwater plume), an irregular spread of points across the semivariogram plot is the usual result (Rock, 1988). One of the most subjective tasks of geostatistical analysis is to identify a continuous, theoretical semivariogram model that most closely follows the real data. Fitting a theoretical model to calculated semivariance points is accomplished by trial-and-error, rather than by a formal statistical procedure (Davis, 1986; Clark, 1987; Rock, 1988). If a "good" model fit results, then $\gamma(h)$ (the semivariance) can be confidently estimated for any value of ***h***, and not only at the sampled points.

6.2 SPATIAL EVALUATION OF MONITORING NETWORK AT CSSA

The sum of PCE, TCE, and cis-1,2-DCE concentrations was used as the indicator chemical for the spatial evaluation of the groundwater monitoring network at CSSA. The sum of these COCs was selected because it encompasses the largest spatial distribution of contaminants that were detected in groundwater at CSSA. The kriging evaluation examines a two-dimensional spatial "snapshot" of the data. Therefore, the most recent (December 2009) validated analytical data available for this LTMO evaluation update were used in the kriging evaluation. Three separate kriging analyses were conducted for the LGR zone wells, and sampling locations in both the north to south (NS) and west to east (WE) vertical cross sections. The spatial evaluation has a lower limit of 11 wells; thus, the BS zone and CC zone well groups did not have adequate spatial coverage for analysis, and only those included in the cross sections were included in the spatial evaluation analyses.

Of the 86 LGR monitoring wells, off-post borehole, and on-post borehole wells grouped into the LGR zone, 78 were included in the kriging evaluation. In comparison to the 2004 LTMO, 14 new wells were added to the evaluation process. However, seven wells (DOM-2, JW-26, LS-2, LS-3, OFR-2, RFR-6, and RFR-7) previously used in the 2004 LTMO were excluded either because they had been plugged, loss of access agreement, or the well has become inoperable. The majority of wells were sampled during the 4^{th} quarter of 2009; a few of the wells (shown on **Figure 3.3**) were sampled during previous quarters of 2009. Although kriging considers a "spatial snapshot" of the wells during which sampling typically occurs at the same time, the wells sampled in previous quarters were included in the analysis because they all have trace or not detected COC results that have been stable over time.

A total of 35 sampling locations were used in the NS cross section kriging evaluation since none of the shallow wells and piezometers in the AOC-65 area have been sampled since 2004. Likewise, of the 30 sampling points in the WE cross section only 28 were included in the spatial evaluation because the two AOC-65 piezometers were excluded since they had not been recently sampled.

The commercially available geostatistical software package Geostatistical Analyst™ (an extension to the ArcView® geographic information system [GIS] software package) (Environmental Systems Research Institute, Inc. [ESRI], 2009) was used to develop a semivariogram model depicting the spatial variation in the sum of PCE, TCE and cis-1,2-DCE (Total COC) concentrations in groundwater for the selected wells in the LGR zone, NS and WE cross sections.

As semivariogram models were calculated for Total COCs (Equation 6-1), considerable scatter of the data was apparent during fitting of the models. Several data transformations (including a log transformation) were attempted to obtain a representative semivariogram model. Ultimately, the concentration data were transformed to "rank statistics," in which, for example, the 78 wells in the LGR zone were ranked from 1 to 78 according to their most recent Total COC concentration. Tie values were assigned the median rank of the set of ranked values; for example, if 5 wells had non-detected concentrations, they would each be ranked "3", the median of the set of ranks: [1,2,3,4,5]. Transformations of this type can be less sensitive to outliers, skewed distributions, or clustered data than semivariograms based on raw concentration values, and thus may enable recognition and description of the underlying spatial structure of the data in cases where ordinary data are too “noisy”.

The Total COC rank statistics were used to develop semivariograms that most accurately modeled the spatial distribution of the data in the LGR zone, NS and WE cross sections. Anisotropy was incorporated into the LGR zone model to adjust for the directional influence of groundwater flow to the south-southwest. The parameters for best-fit semivariograms for the three spatial evaluations are listed in **Table 6.1**.

Table 6.1 Best-Fit Semivariogram Model Parameters

LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Parameter	LGR Zone	NS Cross Section	WE Cross Section
Model	Spherical	Exponential	Spherical
Range (feet)	2500	300	410
Sill	275	155	55
Nugget	125	0	26
Minor Range (feet)	1500	NA	NA
Direction (°)	225	NA	NA

After the semivariogram models were developed, they were used in the kriging system implemented by the Geostatistical Analyst software package (ESRI, 2009) to develop 2-dimensional kriging realizations (estimates of the spatial distribution of Total COCs in groundwater at CSSA), and to calculate the associated kriging prediction standard errors. The median kriging standard deviation was obtained from the standard errors calculated using the entire monitoring network for each zone (*e.g.*, the 78 wells the LGR Zone). Next, each of the wells was sequentially removed from the network, and for each resulting well network configuration, a kriging realization was completed using the Total COC concentration rankings from the remaining wells. The “missing-well” monitoring network realizations were used to calculate prediction standard errors, and the median kriging standard deviations were obtained for each “missing-well” realization and compared with the median kriging standard deviation for the “base-case” realization (obtained using the complete monitoring network), as a means of evaluating the amount of information loss (as indicated by increases in kriging error) resulting from the use of fewer monitoring points.

Figure 6.2 illustrates and example of the spatial-evaluation procedure by showing kriging prediction standard-error maps for three kriging realizations for the LGR zone wells. Each map shows the predicted standard error associated with a given group of wells based on the semivariogram parameters discussed above. Lighter colors represent areas with lower spatial uncertainty, and darker colors represent areas with higher uncertainty; regions in the vicinity of wells (*i.e.*, data points) have the lowest associated uncertainty. Map A on **Figure 6.2** shows the predicted standard error map for the “base-case” realization in which all 78 wells are included.

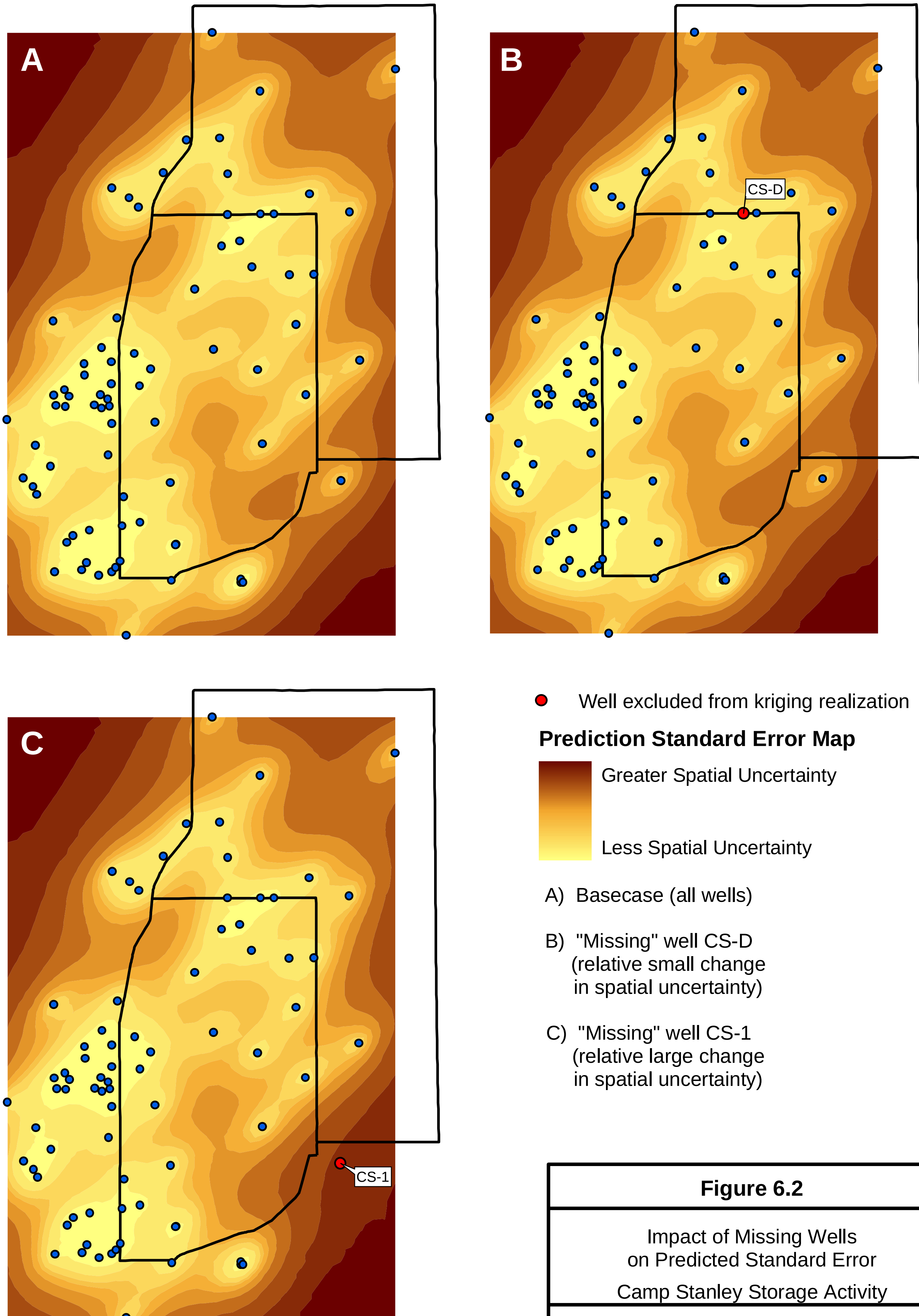


Figure 6.2

Impact of Missing Wells
on Predicted Standard Error

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Map B shows the realization in which well CS-D was removed from the monitoring network, and Map C shows the realization in which well CS-1 was removed. **Figure 6.2** shows that when a well is removed from the network, the predicted standard error in the vicinity of the missing well increases (as indicated by a darkening of the shading in the vicinity of that well). If a "removed" (missing) well is in an area with several other wells (*e.g.*, well CS-D; Map B on **Figure 6.2**), the predicted standard error may not increase as much as if a well (*e.g.*, CS-1; Map C) is removed from an area with fewer surrounding wells.

Based on the Kriging evaluation, each well received a relative value of spatial information "test statistic" calculated from the ratio of the median "missing well" error to median "base case" error. If removal of a particular well from the monitoring network caused very little change in the resulting median kriging standard deviation, the test statistic equals one, and that well was regarded as contributing only a limited amount of information to the LTM program. Likewise, if removal of a well from the monitoring network produced larger increases in the kriging standard deviation (more than 1 percent), this was regarded as an indication that the well contributes a relatively greater amount of information, and is relatively more important to the monitoring network. At the conclusion of the kriging realizations, each well was ranked from 1 (providing the least information) to the number of wells included in the zone analysis (providing the most information), based on the amount of information (as measured by changes in median kriging standard deviation) the well contributed toward describing the spatial distribution of Total COCs, as shown in **Tables 6.2** to **6.4**. Wells providing the least amount of information represent possible candidates for exclusion from the monitoring network at CSSA.

6.3 SPATIAL STATISTICAL EVALUATION RESULTS

6.3.1 Kriging Ranking Results

Figures 6.3 through **6.5** and **Tables 6.2** to **6.4** present the test statistics and associated rankings of the evaluated subset of monitoring locations in the LGR zones, NS and WE cross-sections, respectively, based on the relative value of recent Total COCs information provided by each well, as calculated based on the kriging realizations. Examination of these results indicate that monitoring wells in close proximity to several other monitoring wells (*e.g.*, red color coding on **Figures 6.2** to **6.4**) generally provide relatively lesser amounts of information than do wells at greater distances from other wells, or wells located in areas having limited numbers of monitoring points (*e.g.*, blue color coding on **Figures 6.2** to **6.4**). This is intuitively obvious, but the analysis allows the most valuable and least valuable wells to be identified quantitatively. For example, **Table 6.2** identifies the wells ranked at or below 26 that provide the relative least amount of information, and the wells ranked at or above 53 that provide the greatest amount of relative information regarding the occurrence and distribution of Total COCs in groundwater among those wells included in the kriging analysis. The lowest-ranked wells are potential candidates for exclusion from the CSSA groundwater monitoring program, and the highest-ranked wells are candidates for retention in the monitoring program, intermediate-ranked wells receive no recommendation for removal or retention in the monitoring program based on the spatial analysis.

TABLE 6.2
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a/]	Kriging Metric	Kriging Ranking [b/]	Exclude	Retain
CS-I	0.984192	1	✓	
CS-MWH-LGR	0.990456	2	✓	
LS-4	0.994171	3	✓	
FO-17	0.996506	4	✓	
CS-MW1-LGR	0.999956	5	✓	
JW-13	0.999981	6	✓	
CS-MW8-LGR	0.999984	7	✓	
JW-6	0.999991	8	✓	
RFR-13	0.999997	10.5	✓	
JW-9	0.999997	10.5	✓	
JW-31	0.999997	10.5	✓	
JW-14	0.999997	10.5	✓	
RFR-14	1.000000	15.5	✓	
JW-8	1.000000	15.5	✓	
JW-7	1.000000	15.5	✓	
JW-30	1.000000	15.5	✓	
FO-J1	1.000000	15.5	✓	
CS-4	1.000000	15.5	✓	
OFR-4	1.000009	20.5	✓	
OFR-1	1.000009	20.5	✓	
CS-MW10-LGR	1.000009	20.5	✓	
JW-29	1.000009	20.5	✓	
RFR-10	1.000016	23.5	✓	
CS-10	1.000016	23.5	✓	
JW-27	1.000022	25	✓	
CS-9	1.000028	26	✓	
RFR-9	1.000032	27	-- [d/]	--
RFR-11	1.000041	29	--	--
LS-7	1.000041	29	--	--
CS-11	1.000041	29	--	--
JW-5	1.000069	31	--	--
CS-MW6-LGR	1.000126	32.5	--	--
LS-5	1.000126	32.5	--	--
CS-MW2-LGR	1.000154	34	--	--
CS-MW7-LGR	1.000158	35	--	--
JW-28	1.000167	36	--	--
JW-12	1.000170	37	--	--
OFR-3	1.000176	38	--	--
I10-8	1.000183	39	--	--
I10-7	1.000224	40	--	--
RFR-12	1.000255	41	--	--
CS-D	1.000287	42	--	--
LS-6	1.000293	43	--	--
CS-16-LGR	1.000337	44	--	--
I10-2	1.000340	45	--	--
I10-4	1.000618	46	--	--
FO-22	1.000630	47	--	--

TABLE 6.2
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a/]	Kriging Metric	Kriging Ranking [b/]	Exclude	Retain
CS-2	1.000671	48	--	--
CS-MW11B-LGR	1.000885	49	--	--
CS-MW11A-LGR	1.000967	50	--	--
HS-1	1.001033	51	--	--
RFR-4	1.001056	52	--	--
HS-3	1.001125	53		✓
HS-2	1.001245	54		✓
CS-MW24-LGR	1.001264	55		✓
CS-12	1.001333	56		✓
I10-5	1.001377	57		✓
FO-8	1.002023	58		✓
CS-MW5-LGR	1.002051	59		✓
RFR-5	1.002518	60		✓
RFR-3	1.002524	61		✓
CS-MW9-LGR	1.002782	62		✓
LS-1	1.002817	63		✓
CS-1	1.002870	64		✓
CS-MW12-LGR	1.002889	65		✓
CS-MW25-LGR	1.002984	66		✓
RFR-8	1.003457	67		✓
CS-MW4-LGR	1.003633	68		✓
CS-MW18-LGR	1.003854	69		✓
CS-MW3-LGR	1.004383	70		✓
CS-G-LGR	1.004815	71		✓
CS-MW17-LGR	1.005108	72		✓
JW-15	1.005208	73		✓
CS-MW23-LGR	1.005435	74		✓
CS-MW19-LGR	1.006128	75		✓
CS-MW20-LGR	1.007008	76		✓
CS-MW21-LGR	1.008032	77		✓
CS-MW22-LGR	1.009468	78		✓

[a/] Includes On-Post and Off-Post Wells that are screened across the LGR.

[b/] 1= least relative amount of information; 78= most relative amount of information.

[c/] Tie values receive the median ranking of the set.

[d/] Well in the “intermediate” range; received no recommendation for removal/ exclusion or retention/addition

TABLE 6.3
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE IN THE NORTH TO SOUTH VERTICAL CROSS SECTION
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a/]	Kriging Metric	Kriging Ranking [b/]	Exclude	Retain
WB03-LGR-05	0.999482	1	✓	
WB03-LGR-06	0.999585	2	✓	
WB02-LGR-08	0.999713	3	✓	
WB03-LGR-08	0.999719	4	✓	
WB02-LGR-06	0.999738	5.5	✓	
WB02-LGR-05	0.999738	5.5	✓	
WB02-LGR-07	0.999750	7	✓	
WB03-LGR-03	0.999774	8	✓	
WB03-LGR-04	0.999841	9	✓	
WB03-LGR-07	0.999848	10	✓	
WB03-LGR-02	0.999957	12	✓	
WB01-LGR-08	0.999957	12	✓	
WB01-LGR-07	0.999957	12	✓	
WB01-LGR-09	0.999970	14	-- [d/]	--
WB02-UGR-01	1.000000	20.5	--	--
WB02-LGR-04	1.000000	20.5	--	--
WB02-LGR-03	1.000000	20.5	--	--
WB02-LGR-02	1.000000	20.5	--	--
WB02-LGR-01	1.000000	20.5	--	--
WB01-UGR-01	1.000000	20.5	--	--
WB01-LGR-06	1.000000	20.5	--	--
WB01-LGR-05	1.000000	20.5	--	--
WB01-LGR-04	1.000000	20.5	--	--
WB01-LGR-03	1.000000	20.5	--	--
WB01-LGR-02	1.000000	20.5	--	--
WB01-LGR-01	1.000000	20.5	--	--
WB03-LGR-01	1.000177	27		✓
CS-MW6-BS	1.002811	28		✓
WB03-UGR-01	1.003079	29		✓
WB02-LGR-09	1.004025	30		✓
WB03-LGR-09	1.006756	31		✓
CS-MW6-LGR	1.011793	32		✓
CS-MW8-LGR	1.012507	33		✓
CS-MW8-CC	1.013824	34		✓
CS-MW6-CC	1.015842	35		✓

[a/] Data used for statistics includes October 2009 for the WB wells and December 2009 for MW wells.

[b/] 1= least relative amount of information; 35= most relative amount of information.

[c/] Tie values receive the median ranking of the set.

[d/] Well in the “intermediate” range; received no recommendation for removal/ exclusion or retention/addition

TABLE 6.4

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR- ZONE IN THE WEST TO EAST VERTICAL CROSS SECTION

THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a]	Kriging Metric	Kriging Ranking [b]	Exclude	Retain
WB02-LGR-05	0.999662	1	✓	
WB02-LGR-04	0.999803	2	✓	
WB02-LGR-03	0.999831	3	✓	
WB02-LGR-06	0.999859	4	✓	
WB04-LGR-09	0.999873	5	✓	
WB04-LGR-08	0.999887	6	✓	
WB04-LGR-10	0.999915	7.5	✓	
WB04-LGR-07	0.999915	7.5	✓	
WB04-LGR-06	0.999944	9	✓	
WB04-LGR-11	0.999958	10	--[d]	--
WB02-LGR-02	0.999986	11	--	--
WB04-BS-01	1.000000	12	--	--
WB04-LGR-04	1.000042	13.5	--	--
WB04-BS-02	1.000042	13.5	--	--
WB04-LGR-03	1.000071	15	--	--
WB04-LGR-02	1.000085	16	--	--
WB04-CC-01	1.000099	17	--	--
WB04-LGR-01	1.000134	18	--	--
WB04-CC-02	1.000141	19		✓
WB02-LGR-01	1.000176	20		✓
WB04-CC-03	1.000268	21		✓
WB04-UGR-01	1.000367	22.5		✓
WB02-UGR-01	1.000367	22.5		✓
WB02-LGR-07	1.000592	24		✓
WB02-LGR-08	1.002383	25		✓
WB02-LGR-09	1.003356	26		✓
CS-MW07-CC	1.017105	27		✓
CS-MW07-LGR	1.027215	28		✓

[a] Data used for statistics includes October 2009 for the WB wells and December 2009 for MW wells.

[b] 1= least relative amount of information; 35= most relative amount of information.

[c] Tie values receive the median ranking of the set.

[d] Well in the “intermediate” range; received no recommendation for removal/ exclusion or retention/addition

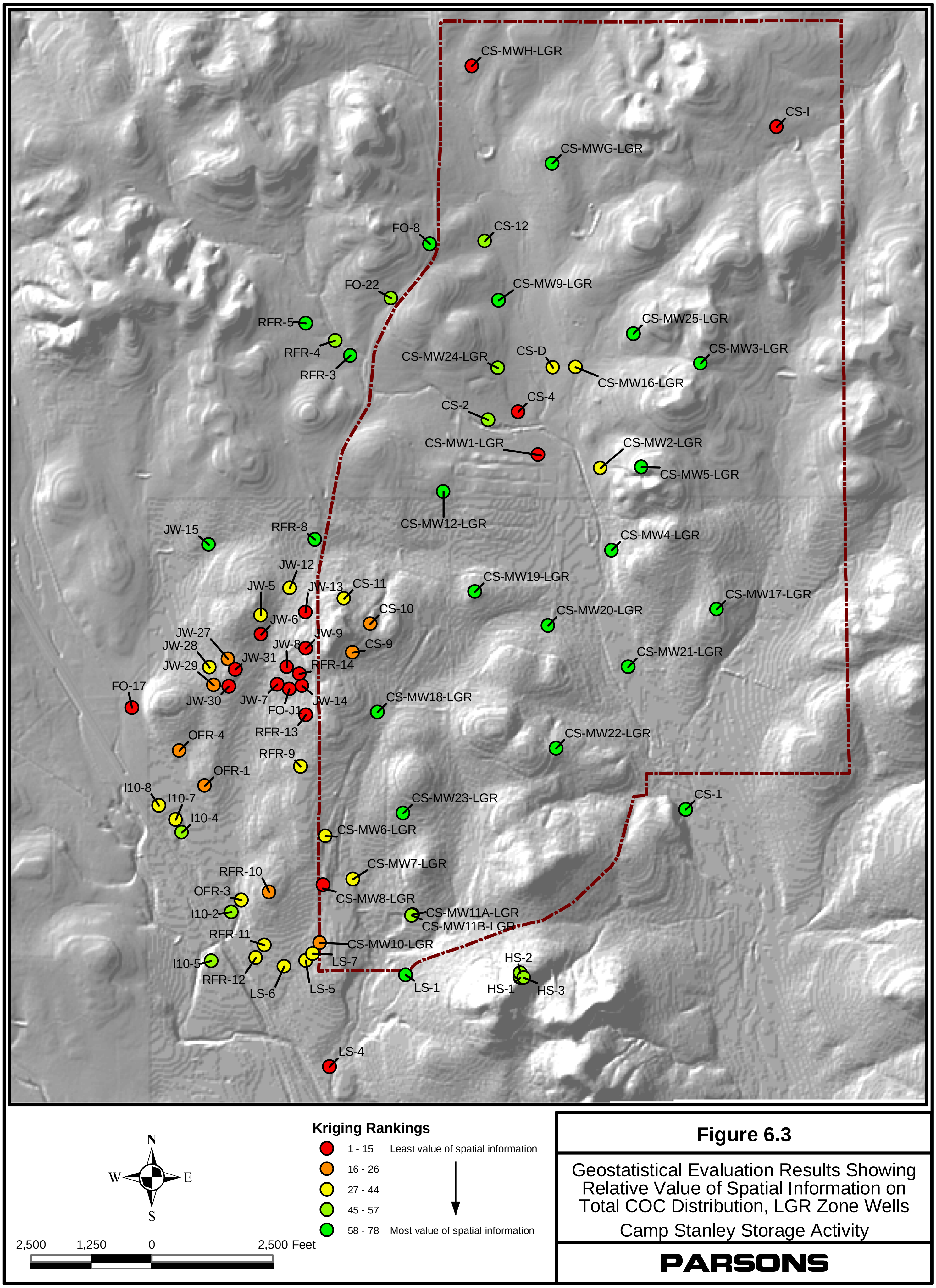

Figure 6.3

Geostatistical Evaluation Results Showing Relative Value of Spatial Information on Total COC Distribution, LGR Zone Wells

Camp Stanley Storage Activity

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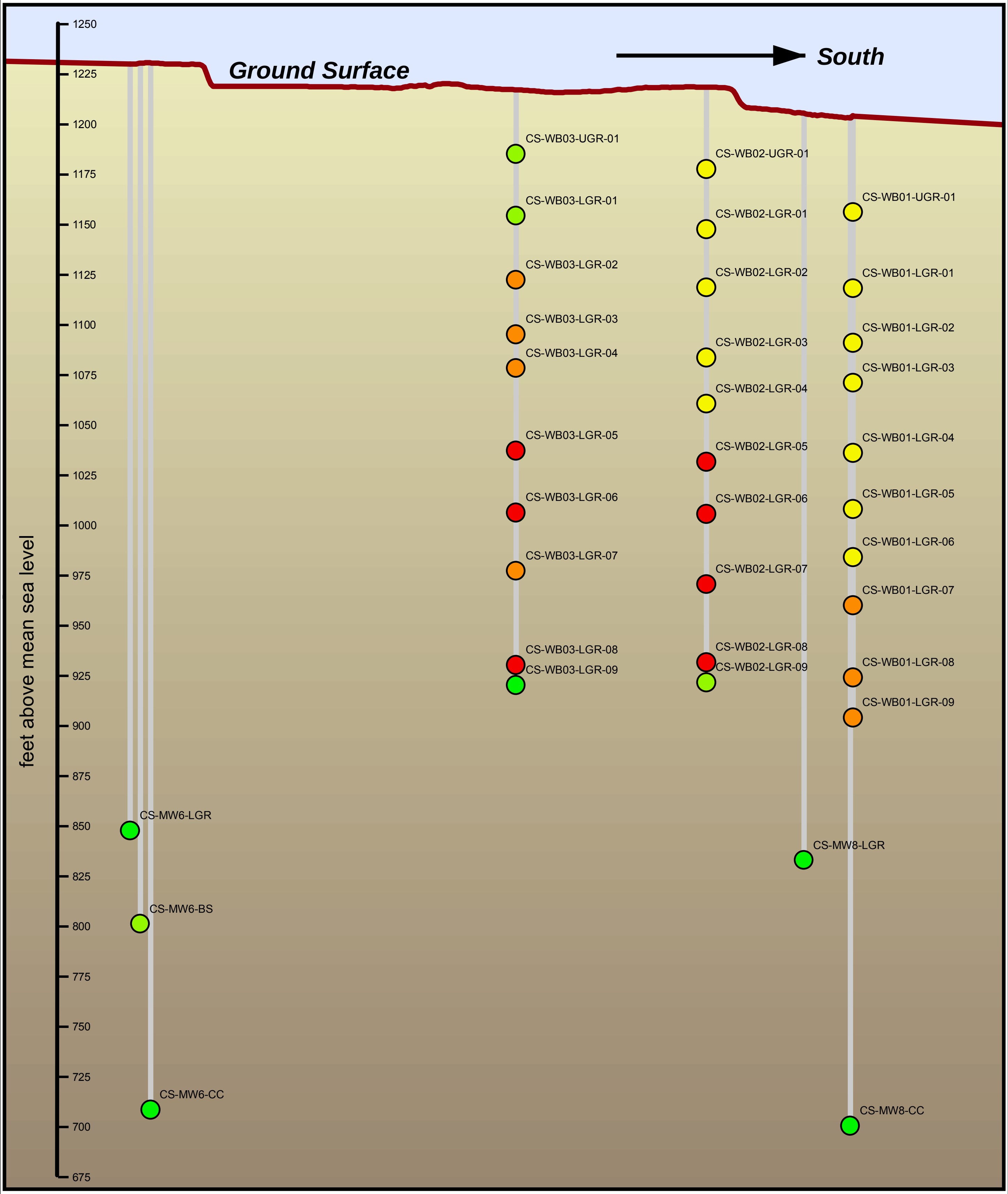

Kriging Rankings

- 1 - 7 Least value of spatial information
- 8 - 14
- 15 - 21
- 22 - 30
- 31 - 35 Most value of spatial information

Vertical Exaggeration: 3X

Horizontal Scale:
200 100 0 200 Feet

Figure 6.4

Geostatistical Evaluation Results Showing Relative Value of Spatial Information on Total COC Distribution, North-South Cross Section Camp Stanley Storage Activity

PARSONS

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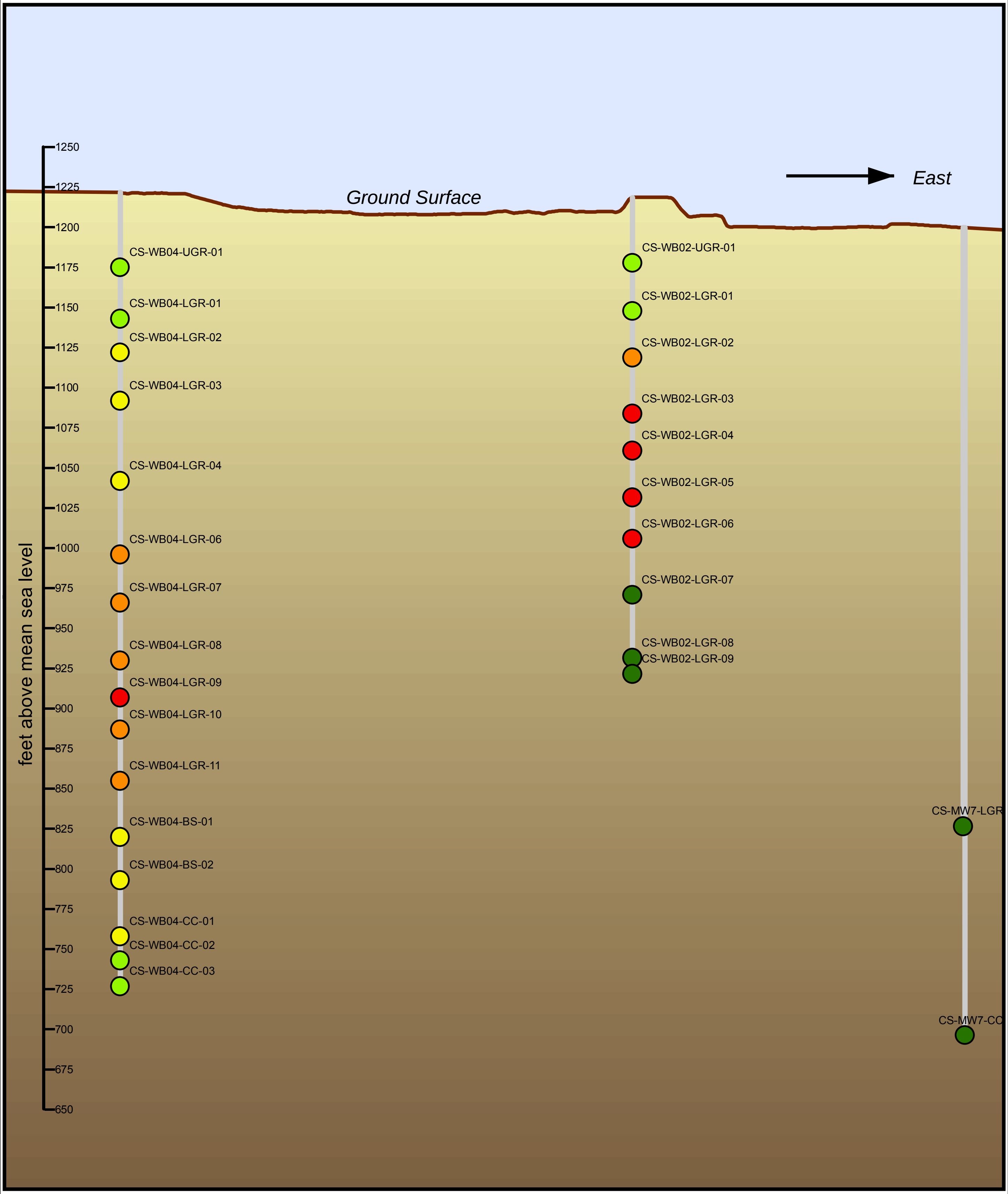

Vertical Exaggeration: 3X

Horizontal Scale:

250 125 0 250 Feet

Kriging Rankings

- 1 - 5 Least value of spatial information
- 6 - 11
- 12 - 17
- 18 - 23
- 23 - 28 Most value of spatial information

Figure 6.5

Geostatistical Evaluation Results Showing Relative Value of Spatial Information on Total COC Distribution, West-East Cross Section Camp Stanley Storage Activity

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SECTION 7
SUMMARY OF THREE-TIERED LONG-TERM MONITORING OPTIMIZATION EVALUATION

The 153 sampling points at CSSA were evaluated using qualitative hydrogeologic information, temporal statistical techniques, and spatial statistics. As each tier of the evaluation was performed, monitoring points that provide relatively greater amounts of information regarding the occurrence and distribution of COCs in groundwater were identified, and were distinguished from those monitoring points that provide relatively lesser amounts of information. In this section, the results of the evaluations are combined to generate a refined monitoring program that could potentially provide information sufficient to address the primary objectives of monitoring, at reduced cost. Monitoring wells not retained in the refined monitoring network could be removed from the monitoring program with relatively little loss of information. The results of the qualitative, temporal, and spatial evaluations are summarized in **Table 7.1**, along with the final recommendations for sampling point retention or exclusion and final sample frequency. **Figure 7.1** shows the final recommendations for the LGR zone wells. The results of the evaluations were combined and summarized in accordance with the following decision logic:

1. Each well retained in the monitoring network on the basis of the qualitative hydrogeologic evaluation is recommended to be retained in the refined monitoring program.
2. Those wells recommended for removal from the monitoring program on the basis of all three evaluations, or on the basis of the qualitative and temporal evaluations (with no recommendation resulting from the spatial evaluation) should be removed from the monitoring program.
3. If a well is recommended for removal based on the qualitative evaluation and recommended for retention based on the temporal or spatial evaluation, the final recommendation is based on a case-by-case review of well information.
4. If a well is recommended for retention based on the qualitative evaluation and recommended for removal based on the temporal and spatial evaluation, the recommended sampling frequency is based on a case-by-case review of well information.
5. Establish an overall programmatic monitoring frequency that was consistent, logical, and provided area wide snapshot events which spanned seasonal variations and hydrogeologic conditions.

It should be noted, as stated in number four above, the final recommended monitoring frequencies shown in **Table 7.1** are not, in all cases, the same as those recommended as a result of the qualitative evaluation (**Table 4.3**). In the CSSA qualitative evaluation, few wells were recommended for exclusion from the monitoring network, while many were recommended for reduced sampling frequency. Thus, the temporal and spatial statistical evaluation results were primarily used to confirm or adjust qualitative monitoring frequency recommendations. The justification for these modifications is provided in the "Rationale" column in **Table 7.1**, and fall into the following general categories:

TABLE 7.1

SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM

LONG TERM MONITORING OPTIMIZATION

CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			Rationale
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	
On Post Monitoring Wells												
AOC65-MW1	Sample after major rain event	✓		Exclude	Not Analyzed		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-MW2A	Sample after major rain event	✓		Exclude		✓	Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ01-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ02-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ03-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ04-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ05-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
AOC65-PZ06-LGR	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Well is part of AOC-65 program and only sampled on an as-needed basis.
CS-1	Quarterly		✓	Quarterly		✓		✓		✓	Quarterly	Temporal and Spatial analysis confirm qualitative evaluation
CS-10	Quarterly		✓	Quarterly	✓		✓			✓	Quarterly	Qualitative factor (drinking water well) overrides temporal recommendations
CS-11	Exclude (No pump)	✓		Exclude (No pump)		✓	--[a/]	--	✓		Exclude (No pump)	Exclude due to well being inactive (no pump)
CS-12	Quarterly		✓	Quarterly		✓		✓		✓	Quarterly	Temporal/Spatial analysis confirm qualitative evaluation. Quarterly based on drinking water well.
CS-2	Every 9 months		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative factor (delineation well) overrides temporal recommendations
CS-3	Exclude	✓		Exclude	✓		Not Included		✓		Exclude	Spatially redundant well to CS-2 with no pump.
CS-4	Semi-annually		✓	Semi-annual		✓	✓			✓	Semi-annual + 9-month snapshot event	Temporal analysis confirms qualitative evaluation. Frequency based upon importance to plume delineation.
CS-9	Quarterly		✓	Quarterly	✓		✓			✓	Quarterly	Qualitative factor (drinking water well) overrides temporal/spatial recommendations
CS-D	Semi-annually		✓	Semi-annual		✓	--	--		✓	Semi-annual + 9-month snapshot event	Temporal analysis confirms qualitative evaluation. Frequency based upon importance to plume delineation.
CS-I	Every 9 months		✓	Every 18 months		✓	✓			✓	Every 18 months	Temporal statistics confirm qualitative evaluation. Decrease sampling frequency.
CS-MW10-CC	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW10-LGR	Every 9 months		✓	Semi-annual		✓	✓			✓	Semi-annual + 9-month snapshot event	Qualitative and temporal evaluation override spatial evaluation. Increased sampling frequency.
CS-MW11A-LGR	Semi-annually		✓	Semi-annual		✓	--	--		✓	Semi-annual + 9-month snapshot event	Qualitative and temporal evaluation override spatial evaluation. Increased sampling frequency.
CS-MW11B-LGR	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluation override spatial evaluation.
CS-MW12-BS	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (BS confining unit).
CS-MW12-CC	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW12-LGR	Every 9 months		✓	Every 9 months		✓		✓		✓	Every 9 months	Temporal and Spatial analysis confirm qualitative evaluation
CS-MW16-CC	Semi-annually		✓	Every 9 months		✓	Not Included			✓	Every 9 months	Temporal evaluation confirms qualitative analysis, retain as remediation well.
CS-MW16-LGR	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Temporal evaluation confirms qualitative analysis, retain as remediation well.
CS-MW17-LGR	Every 9 months		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluations override temporal analysis.
CS-MW18-LGR	Semi-annually		✓	Every 9 months		✓		✓		✓	Every 9 months	Temporal and Spatial analysis confirm qualitative evaluation
CS-MW19-LGR	Semi-annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluations override temporal analysis.
CS-MW1-BS	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (BS confining unit).
CS-MW1-CC	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW1-LGR	Semi-annually		✓	Semi-annual		✓	✓			✓	Semi-annual + 9-month snapshot event	Qualitative and temporal evaluation override spatial evaluation. Increased sampling frequency.
CS-MW20-LGR	Quarterly until new LTMO		✓	Every 9 months		✓		✓		✓	Every 9 months	Temporal and Spatial analysis confirm qualitative evaluation
CS-MW21-LGR	Quarterly until new LTMO		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW22-LGR	Quarterly until new LTMO		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW23-LGR	Quarterly until new LTMO		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW24-LGR	Quarterly until new LTMO		✓	Semi-annual		✓		✓		✓	Semi-annual + 9-month snapshot event	Temporal and Spatial analysis confirm qualitative evaluation. Increased sampling frequency.
CS-MW25-LGR	Quarterly until new LTMO		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW2-CC	Biennially		✓	Every 18 months	✓		Not Included			✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW2-LGR	Semi-annually		✓	Semi-annual	✓		--	--		✓	Semi-annual + 9-month snapshot event	Qualitative factor overrides temporal recommendations. Increased sampling frequency.
CS-MW3-LGR	Semi-annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW4-LGR	Semi-annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW5-LGR	Semi-annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW6-BS	Biennially		✓	Every 18 months	✓			↓[b/]		✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (BS confining unit).
CS-MW6-CC	Biennially		✓	Every 18 months	✓			↓		✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW6-LGR	Semi-annually		✓	Every 9 months	✓		--	↓--		✓	Every 9 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MW7-CC	Biennially		✓	Every 18 months	✓		--	--→[c/]		✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW7-LGR	Semi-annually		✓	Every 9 months		✓	--	--→		✓	Every 9 months	Temporal and Spatial analysis confirm qualitative evaluation.
CS-MW8-CC	Biennially		✓	Every 18 months	✓			↓		✓	Every 18 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW8-LGR	Every 9 months		✓	Semi-annual		✓	✓	↓		✓	Semi-annual + 9-month snapshot event	Temporal and Spatial analysis confirm qualitative evaluation. Increased sampling frequency.
CS-MW9-BS	Biennially		✓	Every 9 months		✓	Not Included			✓	Every 9 months	Qualitative factor overrides temporal recommendations because of type of well (BS confining unit).
CS-MW9-CC	Biennially		✓	Every 9 months	✓		Not Included			✓	Every 9 months	Qualitative factor overrides temporal recommendations because of type of well (CC aquifer).
CS-MW9-LGR	Semi-annually		✓	Every 18 months	✓			✓		✓	Every 18 months	Qualitative and spatial evaluation override temporal evaluation.
CS-MWG-LGR	Every 9 months		✓	Every 18 months	✓			✓		✓	Every 18 months	Qualitative and spatial evaluation override temporal evaluation. Decrease sampling frequency.
CS-MWH-LGR	Biennially		✓	Every 18 months	✓		✓			✓	Every 18 months	Qualitative factor overrides temporal/spatial evaluations. Increase sampling frequency.

TABLE 7.1

SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM

LONG TERM MONITORING OPTIMIZATION

CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			Rationale
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	
Off Post Monitoring Wells												
DOM-2	Exclude (No Power at Well)	✓		Exclude (No Power at Well)	✓		Not Included		✓		Exclude (No Power at Well)	Exclude due to well being inactive (no power). Re-evaluate if conditions change.
FO-17	Annually		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative factors override temporal/spatial evaluation. Increase sampling frequency.
FO-22	Annually		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative/spatial factors override temporal evaluation. Increase sampling frequency.
FO-8	Annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative/spatial factors override temporal evaluation. Increase sampling frequency.
FO-J1	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	✓		✓			✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation. Re-evaluate frequency if DQO achieved.
HS-1	Quarterly		✓	Every 9 months		✓	--	--		✓	Every 9 months	All evaluations in agreement. Decrease sampling frequency due to statistics results
HS-2	Qtrly, 1 year thru June 10		✓	Every 9 months		✓		✓		✓	Every 9 months	All evaluations in agreement. Decrease sampling frequency due to statistics results
HS-3	Annually		✓	Every 9 months		✓		✓		✓	Every 9 months	Temporal statistics confirm qualitative evaluation. Increase sampling frequency.
I10-2	Annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Temporal statistics confirm qualitative evaluation. Increase sampling frequency.
I10-4	Quarterly		✓	Quarterly		✓	--	--		✓	Quarterly	Qualitative and temporal evaluations in agreement. Retain quarterly frequency as sentry well.
I10-5	Annually		✓	Every 9 months		✓		✓		✓	Every 9 months	All evaluations in agreement. Increase sampling frequency.
I10-7	Qtrly, 1 year thru Dec. 10		✓	Every 9 months		✓	--	--		✓	Quarterly/9-months	Temporal statistics confirm qualitative evaluation. Re-evaluate frequency if DQO achieved.
I10-8	Annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Temporal statistics confirm qualitative evaluation. Increase sampling frequency.
JW-12	Access agreement expired	✓		Access agreement expired	✓		--	--	✓		Access agreement expired	Exclude due to well being inaccessible. Re-evaluate if conditions change.
JW-13	Annually		✓	Every 9 months		✓	✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
JW-14	Qtrly, due to location		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
JW-15	Annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial analysis in agreement. Retain as delineation well and increase frequency.
JW-26	Declined Access	✓		Declined Access	✓		Not Included		✓		Declined Access	Exclude due to well being inaccessible. Re-evaluate if conditions change.
JW-27	Annually		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
JW-28	Qtrly, due to location		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Decrease sampling frequency.
JW-29	Qtrly, due to location		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Decrease sampling frequency.
JW-30	Qtrly, due to location		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Decrease sampling frequency.
JW-31	Qtrly, 1 year thru Dec. 10		✓	Every 9 months		✓	✓			✓	Quarterly/9-months	Temporal statistics confirm qualitative evaluation. Re-evaluate frequency if DQO achieved.
JW-5	Annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
JW-6	Annually		✓	Every 9 months		✓	✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
JW-7	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	✓		✓			✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation.. Re-evaluate frequency if DQO achieved.
JW-8	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	✓		✓			✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation.. Re-evaluate frequency if DQO achieved.
JW-9	Annually		✓	Every 9 months	✓		✓			✓	Every 9 months	Qualitative factors override temporal/spatial evaluation.. Increase sampling frequency.
LS-1	Quarterly		✓	Every 9 months		✓		✓		✓	Every 9 months	Temporal/Spatial analysis confirm qualitative evaluation. No longer water supply, decrease frequency.
LS-2	Well is offline, to be plugged soon	✓		Well is offline, to be plugged soon	✓		Not Included		✓		Well is offline, to be plugged soon	If well is not plugged, give consideration incorporating back into monitoring network.
LS-3	Well is offline, to be plugged soon	✓		Well is offline, to be plugged soon	✓		Not Included		✓		Well is offline, to be plugged soon	If well is not plugged, give consideration incorporating back into monitoring network.
LS-4	Annually		✓	Every 9 months		✓	✓			✓	Every 9 months	Temporal analysis confirm qualitative evaluation. No longer water supply, increase sampling frequency.
LS-5	Qtrly, 1 year thru Dec. 10		✓	Quarterly		✓	--	--		✓	Quarterly	Qualitative factor (GAC well)overrides spatial recommendations
LS-6	Qtrly, 1 year thru Dec. 10		✓	Quarterly		✓	--	--		✓	Quarterly	Qualitative factor (GAC well) overrides spatial recommendations
LS-7	Qtrly, 1 year thru Dec. 10		✓	Quarterly		✓	--	--		✓	Quarterly	Qualitative factor (GAC well) overrides spatial recommendations
OFR-1	Qtrly, 1 year thru Dec. 10		✓	Every 9 months	✓		✓			✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation.. Re-evaluate frequency if DQO achieved.
OFR-2	Exclude (Plugged.)	✓		Exclude (Plugged.)	✓		Not Included		✓		Exclude (Plugged.)	Excluded.
OFR-3	Qtrly, 1 year thru Dec. 10		✓	Every 9 months		✓	--	--		✓	Quarterly	Qualitative factor (GAC well) overrides spatial recommendations
OFR-4	Annually		✓	Every 9 months		✓	✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
RFR-10	Qtrly, 1 year thru Dec. 10		✓	Quarterly		✓	✓			✓	Quarterly	Qualitative factor (GAC well) overrides spatial recommendations
RFR-11	Qtrly, 1 year thru Dec. 10		✓	Quarterly		✓	--	--		✓	Quarterly	Qualitative factor (GAC well) overrides spatial recommendations
RFR-12	Annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
RFR-13	Annually		✓	Every 9 months		✓	✓			✓	Every 9 months	Qualitative and temporal evaluations override spatial evaluation. Increase sampling frequency.
RFR-14	Qtrly, 1 year thru Sept. 10		✓	Every 9 months	✓		✓			✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation.. Re-evaluate frequency if DQO achieved.
RFR-3	Annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluations override temporal evaluation. Increase sampling frequency.
RFR-4	Annually		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative evaluation overrides temporal/spatial evaluation. Increase sampling frequency.
RFR-5	Annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Qualitative and spatial evaluations override temporal evaluation. Increase sampling frequency.
RFR-6	Exclude (Plugged.)	✓		Exclude (Plugged.)	✓		Not Included		✓		Exclude (Plugged.)	Excluded.
RFR-7	Exclude (Plugged.)	✓		Exclude (Plugged.)	✓		Not Included		✓		Exclude (Plugged.)	Excluded.
RFR-8	Annually		✓	Every 9 months	✓			✓		✓	Every 9 months	Temporal/Spatial analysis confirm qualitative evaluation. Increase sampling frequency.
RFR-9	Qtrly, 1 year thru Sept. 1C		✓	Every 9 months	✓		--	--		✓	Quarterly/9-months	Qualitative factors override temporal/spatial evaluation.. Re-evaluate frequency if DQO achieved.

TABLE 7.1

SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM

LONG TERM MONITORING OPTIMIZATION

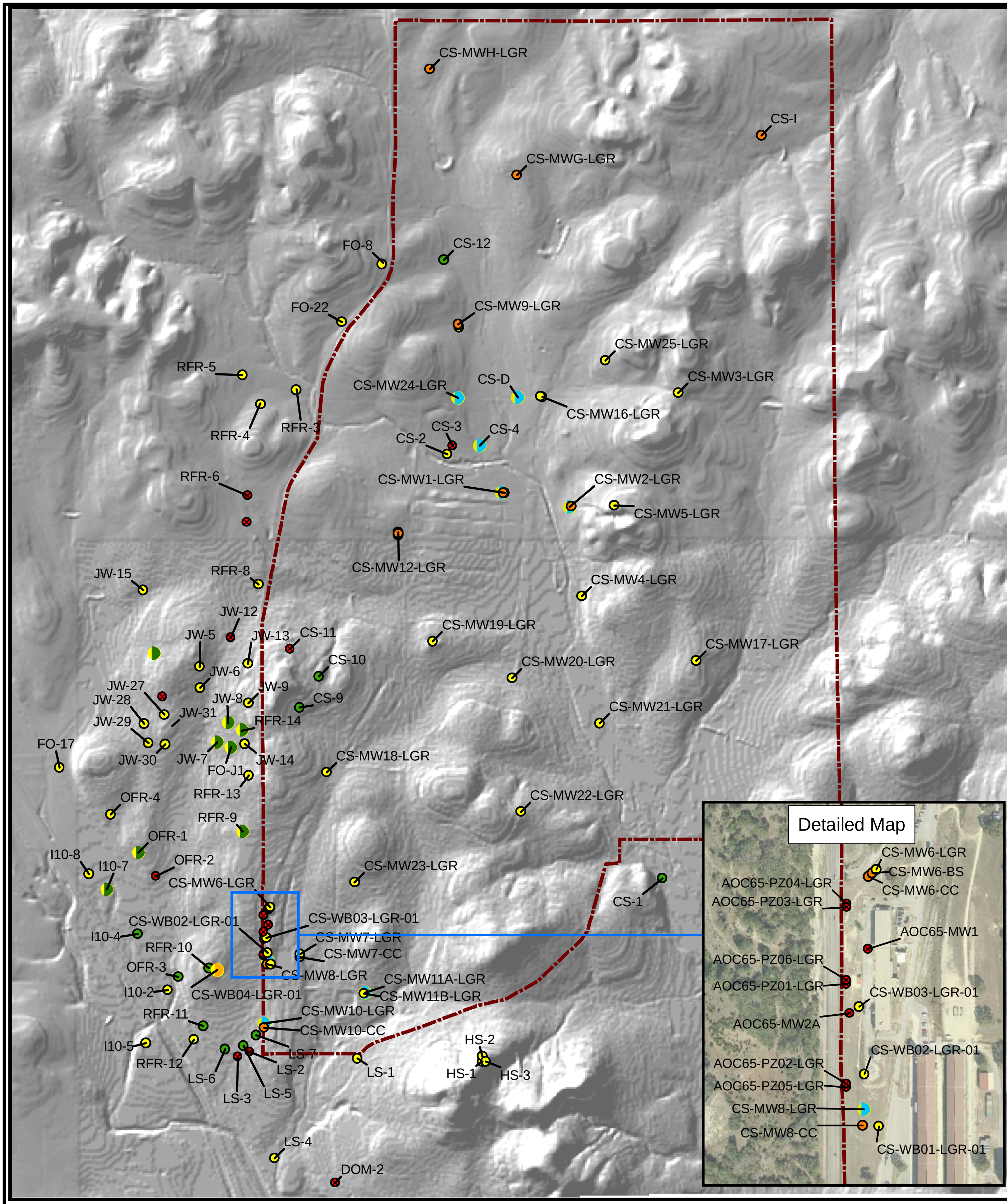
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	Rationale
WestBay Wells												
CS-WB01-LGR-01	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB01-LGR-02	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB01-LGR-03	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB01-LGR-04	Semi-annually		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB01-LGR-05	Semi-annually		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB01-LGR-06	Semi-annually		✓	Every 9 months	✓		--	--		✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB01-LGR-07	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB01-LGR-08	Semi-annually		✓	Every 9 months	✓		↓			✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB01-LGR-09	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB01-UGR-01	Semi-annually		✓	Every 9 months	Not Analyzed		--	--		✓	Every 9 months/Major Precip. Event	Typically dry. Decrease sampling frequency or after major rainfall events.
CS-WB02-LGR-01	Semi-annually		✓	Every 9 months		✓	--	→		✓	Every 9 months	Temporal/spatial evaluations confirm qualitative evaluation. Decrease sampling frequency.
CS-WB02-LGR-02	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB02-LGR-03	Semi-annually		✓	Every 9 months		✓	→	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial analysis. Decrease sampling frequency.
CS-WB02-LGR-04	Semi-annually		✓	Every 9 months		✓	→	--		✓	Every 9 months	Qualitative and temporal evaluations override spatial analysis. Decrease sampling frequency.
CS-WB02-LGR-05	Semi-annually		✓	Every 9 months		✓	↓→			✓	Every 9 months	Qualitative and temporal evaluations override spatial analysis. Decrease sampling frequency.
CS-WB02-LGR-06	Semi-annually		✓	Every 9 months		✓	↓→			✓	Every 9 months	Qualitative and temporal evaluations override spatial analysis. Decrease sampling frequency.
CS-WB02-LGR-07	Semi-annually		✓	Every 9 months	✓		↓	→		✓	Every 9 months	Qualitative and spatial evaluations override temporal analysis. Decrease sampling frequency.
CS-WB02-LGR-08	Semi-annually		✓	Every 9 months		✓	↓	→		✓	Every 9 months	Temporal/spatial evaluations confirm qualitative evaluation. Decrease sampling frequency.
CS-WB02-LGR-09	Semi-annually		✓	Every 9 months		✓		↓→		✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB02-UGR-01	Semi-annually		✓	Every 9 months	Not Analyzed		--	→		✓	Every 9 months/Major Precip. Event	Typically dry. Decrease sampling frequency or after major rainfall events.
CS-WB03-LGR-01	Semi-annually		✓	Every 9 months		✓		↓		✓	Every 9 months	Temporal/spatial evaluations confirm qualitative evaluation. Decrease sampling frequency.
CS-WB03-LGR-02	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-03	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-04	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-05	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-06	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-07	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-08	Semi-annually		✓	Every 9 months		✓	↓			✓	Every 9 months	Qualitative and temporal evaluations override spatial recommendations. Decrease sampling frequency.
CS-WB03-LGR-09	Semi-annually		✓	Every 9 months		✓		↓		✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB03-UGR-01	Semi-annually		✓	Every 9 months		✓		↓		✓	Every 9 months/Major Precip. Event	Temporal/spatial evaluations confirm qualitative evaluation. Decrease sampling frequency.
CS-WB04-BS-01	Biennially		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Increase sampling frequency.
CS-WB04-BS-02	Biennially		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Increase sampling frequency.
CS-WB04-CC-01	Biennially		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Increase sampling frequency.
CS-WB04-CC-02	Biennially		✓	Every 18 months	✓			→		✓	Every 18 months	Qualitative/spatial factors override spatial evaluations. Increase sampling frequency.
CS-WB04-CC-03	Biennially		✓	Every 18 months	✓			→		✓	Every 18 months	Qualitative/spatial factors override spatial evaluations. Increase sampling frequency.
CS-WB04-LGR-01	Semi-annually		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB04-LGR-02	Semi-annually		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB04-LGR-03	Semi-annually		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB04-LGR-04	Semi-annually		✓	Every 18 months	✓		--	--		✓	Every 18 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB04-LGR-06	Semi-annually		✓	Every 9 months		✓	→			✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB04-LGR-07	Semi-annually		✓	Every 9 months		✓	→			✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB04-LGR-08	Semi-annually		✓	Every 9 months	✓		→			✓	Every 9 months	Qualitative factors override temporal/spatial evaluations. Decrease sampling frequency.
CS-WB04-LGR-09	Semi-annually		✓	Every 9 months		✓	→			✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB04-LGR-10	Semi-annually		✓	Every 9 months		✓	→			✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB04-LGR-11	Semi-annually		✓	Every 9 months		✓	--	--		✓	Every 9 months+On-Post Sched.	Include this LGR zone with 9-month areawide "snapshot" events as well as Westbay schedule.
CS-WB04-UGR-01	Semi-annually		✓	Every 9 months	Not Analyzed			→		✓	Every 9 months/Major Precip. Even	Typically dry. Decrease sampling frequency or after major rainfall events.

[b/] Spatial recommendation result from North to South vertical cross section analysis that do not impact LGR zone well summary evaluation results.

[a/] Well in the "intermediate" range; received no recommendation for removal/exclusion or retention/addition in spatial evaluation

[c/] Spatial recommendation result from West to East vertical cross section analysis that do not impact LGR zone well summary evaluation results.



N
W E
S

2,500 1,250 0 2,500 Feet

LGR Zone Wells

Recommended Sampling Frequency

- Quarterly
- Semi-annualy
- Every 9 months
- Every 18 months
- Exclude

Figure 7.1

Combined Evaluation Recommended Sampling Frequencies, LGR Zone Wells

Camp Stanley Storage Activity

PARSONS

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- *Temporal and/or spatial statistical results confirm the sampling frequency recommendations from the qualitative evaluation.* For example, well CS-MW12-LGR is recommended for retention by both the temporal and spatial statistical results; thus, the statistics confirm the 9-month sampling frequency (currently 9-month). Likewise, well CS-MWH-LGR is recommended for exclusion from the network by both the temporal and spatial statistical results; thus, the statistics confirm the low 18-month sampling frequency (currently biennially).
- *Decrease sampling frequency due to statistics results.* For example, well CS-MW6-LGR (currently semi-annual) is recommended for 9-month sampling in the qualitative evaluation; however, the well was recommended for exclusion/reduction in the temporal evaluation because it has had only trace PCE/TCE since June 2001 and was determined to be of relatively little importance in the spatial evaluation. Therefore, the 9-month sampling is recommended in the summary evaluation.
- *Qualitative factor overrides statistics recommendations.* Well CS-10 is similar to CS-MW6-LGR, in that the statistical evaluations showed it to be contributing limited temporal and spatial information to the monitoring network. However, the qualitative quarterly sampling recommendation was due to the fact that the well is a drinking water supply well, which was not considered by the statistics, so the summary recommendation remains at a quarterly frequency. Similarly, analysis of several WB sampling points resulted in statistics that would support less frequent monitoring (*e.g.*, CS-WB01-LGR-04, CS-WB01-LGR-05, etc.), yet it was determined to begin 9-month sampling at all of the WB wells due to qualitative considerations and to continue plume characterization in the immediate area of Building 90.
- *Increase or retain sampling frequency due to statistical recommendations. In general the combined LTMO is recommending a 9-month sampling frequency for most on- and off-post wells open to the LGR portion of the aquifer. However, some wells are recommended for an increase of sampling in which the statistics have shown increasing trends or define the portion of the plume above the MCL.* For example, well CS-4 (currently semi-annual) was recommended for semi-annual sampling in the qualitative evaluation; but the combined evaluation recommends the semi-annual schedule plus an additional sample to be collected on the 9-month snapshot event. In most years, three samples will be collected from that well, except the semi-annual event coincides with a 9–month event. The basal LGR zones in the Westbay wells (CS-WB01-LGR09, CS-WB02-LGR09, etc.) are also recommended to have additional samples collected with the 9-month snapshot event. A total of 7 on-post wells and 8 Westbay zones are proposed to have the additional 9-month snapshot sampling activity in addition to their regular sampling.

In addition to the above situations, it should be noted that spatial statistical results obtained during the two vertical cross section analyses (shown with a ➔ [north-south cross-section] or 🡅 [east-west cross-section] in **Table 7.1**) were only applicable to the Westbay wells, and did not influence the summary result of the BS and CC wells included in the analysis.

In the 2005 LTMO, the results of the qualitative hydrogeologic and spatial analyses were also used to suggest locations for possible future monitoring wells. Based on the evaluations made during that study, eleven possible locations are shown on the left half of **Figure 7.2**. As a result of this analysis, six new wells (CS-MW20-LGR through CS-MW25-LGR) were drilled in 2007. The right half of **Figure 7.2** shows the impact the new well locations made to the current spatial analysis. As shown in that figure, the placement of the new wells significantly reduced the amount of spatial uncertainty in the CSSA monitoring well network.

At this time, no new wells are recommended based upon the spatial analysis. However, CSSA should consider identifying additional monitoring points to the west and southwest of the post, in the vicinity of private well I10-4 to better assess the contamination fronts associated with both Plumes 1 and 2.

Based upon the results of the combined evaluation, a total of seven monitoring frequencies are being recommended for the CSSA monitoring program (**Table 7.2**). Each frequency type is briefly discussed below:

Table 7.2 Combined Evaluation Recommended Monitoring Frequencies

LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

	18-month	9-month	Semi-Annual + 9-month	Quarterly	DQO Quarterly	Westbay 18-month Schedule[1]	Westbay 9-month Schedule[1]	Total
On-Post	14	20	8	4	-	-	-	46
Off-Post	-	28	-	7	8	-	-	43
Westbay		8*	-	0	-	9	37	46
	14	48	8	11	8	9	37	135

Notes: [1] *The Westbay schedule will follow 1 quarter behind the On-Off-Post Schedule*
**8 LGR Westbay Zones will also be sampled on the On/Off-Post Schedule for Mapping Purposes*

- ***18-Month Schedule:*** Fourteen wells are recommended for an 18-month sampling schedule. These generally include the on-post BS and CC wells in addition to the upgradient wells in the North Pasture.
- ***9-Month Schedule:*** The 9-month schedule is the recommended frequency for most on- and off-post wells that are open to the LGR portion of the aquifer to create a "snapshot" monitoring event that monitors the status of the entire plume(s). This snapshot event includes 20 on-post and 28 off-post wells. An additional 8 LGR zones from the Westbay wells will also be sampled during the event to characterize the condition near the AOC-65 source area.

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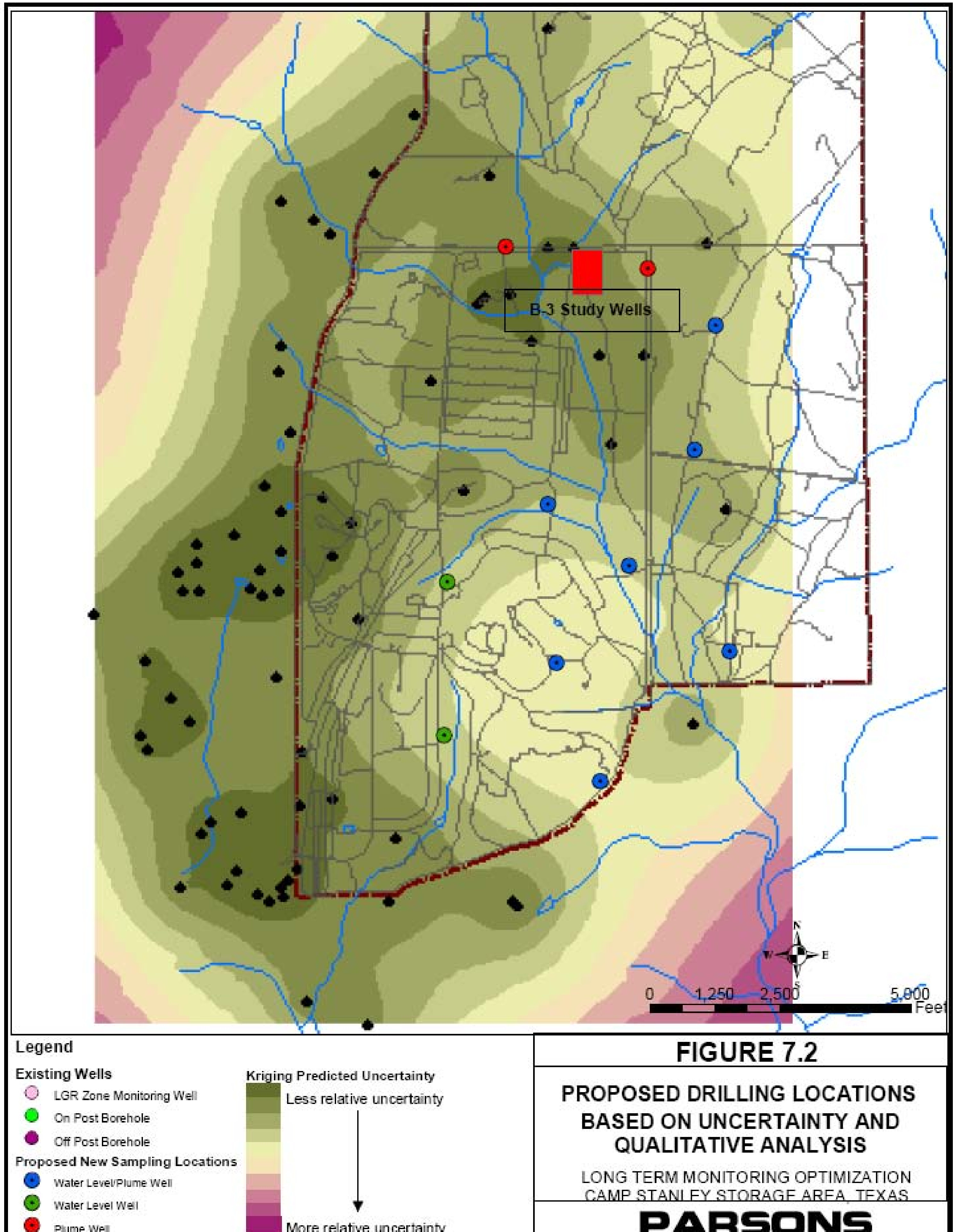
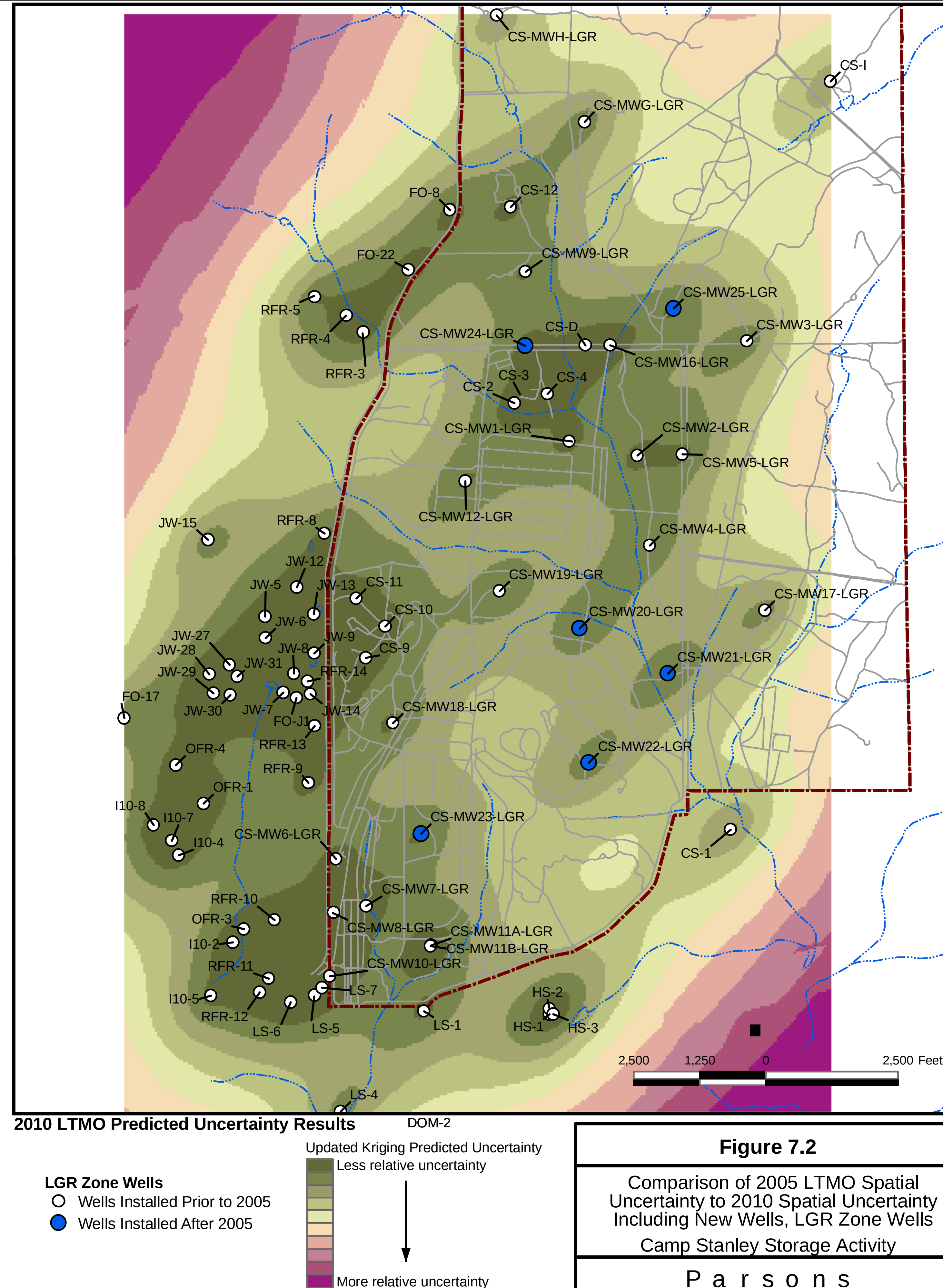


Figure from April 2005 LTMO Report Showing Proposed New Drilling Locations



2010 LTMO Predicted Uncertainty Results

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- ***Semi-annual + 9-Month Schedule:*** Eight on-post wells that are considered as important plume delineation or sentry wells will remain on a semi-annual schedule. Additional samples will also be collected from these well to coincide with area-wide snapshot monitoring event.
- ***Quarterly Schedule:*** Four on-post and seven off-post wells will remain on a quarterly sampling frequency. These include 4 on-post potable water supply wells, 6 offsite wells treated by GAC units, and I10-4 which is a critical sentry well for Plume 2 migration to the west.
- **Off-Post DQO Quarterly Schedule*:*** The current DQOs dictate off-post wells with VOC concentrations greater than the MDL and less than 80 percent of the applicable MCL should be sampled on a quarterly basis to develop trends for a minimum of one year (4 quarters). After a year the well can be moved to the 9-month schedule if the concentrations stabilize or decrease below the MDL. Each well will be reviewed by CSSA on a case-by-case basis to determine the frequency.
- ***Westbay 18-Month Schedule:*** At total of 9 LGR, BS, and CC Westbay zones at CS-WB04 are recommended to be sampled on an 18-month schedule.
- ***Westbay 9-Month Schedule:*** The remaining 37 UGR/LGR Westbay zones are recommended to be sampled at 9-month frequency.

A comparison of the current and recommended sampling frequencies is shown in **Table 7.3** for the on-post, off-post, and WB wells. Because their frequency patterns are not on an annual basis, the two sampling schedules are compared for a 5-year time frame to average out the differences.

For the 46 on-post and the 43 off-post wells, the LTMO results indicate that a refined monitoring program sampled less frequently would be adequate to address the two primary objectives of monitoring listed in Section 1. This refined on and off-post monitoring network would result in an average of 154.4 well-sampling events per year (76 on-post and 78.4 off-post), compared to 209 well-sampling events per year (100 on-post and 109 off-post) under the current (2005 LTMO) monitoring program. Reducing Westbay sampling from semi-annually every 9-months would reduce the number of sampling events from an average 294 events per year to 223.6 events per year.

Implementing these recommendations would reduce on- and off-post sampling events by 24 percent and 28 percent, respectively. Likewise the reduction of Westbay sampling would result in a 19 percent decrease in sampling events. Overall, the recommendations of the 2010 LTMO update will reduce the CSSA groundwater monitoring frequency by 24 percent.

TABLE 7.3

COMPARISON OF CURRENT AND RECOMMENDED LTMO PROGRAMS
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5						
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Total**	**Reduction**	**Avg. Samples per Year**
Current On-Post Samples	46	10	26	34	26	10	34	10	38	34	26	10	34	10	26	34	38	10	34	10	500		100
Proposed On-Post Samples	46	4	12	32	12	4	46	4	12	32	12	4	46	4	12	32	12	4	46	4	380		76
	0	6	14	2	14	6	-12	6	26	2	14	6	-12	6	14	2	26	6	-12	6	120	24%	
Current Off-Post Samples	43	22	22	22	43	22	22	22	43	22	22	22	43	22	22	22	43	22	22	22	545		109
Proposed Off-Post Samples	43	7	7	43	7	7	43	7	7	43	7	7	43	7	7	43	7	7	43	7	392		78.4
	0	15	15	-21	36	15	-21	15	36	-21	15	15	0	15	15	-21	36	15	-21	15	153	28%	
Current Westbay Samples	46	0	41	0	41	0	41	0	46	0	41	0	41	0	41	0	46	0	41	0	425		85
Proposed Westbay Samples	6	46	0	6	37	9	6	37	0	15	37	0	6	46	0	6	37	9	6	37	346		69.2
	40	-46	41	-6	4	-9	35	-37	46	-15	4	0	35	-46	41	-6	9	-9	35	-37	79	19%	
Total Current Sampling Per Quarter	135	32	89	56	110	32	97	32	127	56	89	32	118	32	89	56	127	32	97	32	1470		294
Total Proposed Sampling Per Quarter	95	57	19	81	56	20	95	48	19	90	56	11	95	57	19	81	56	20	95	48	1118		223.6
																					352	24%	

SECTION 8
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