RCRA Facility Investigation Report for Camp Stanley Storage Activity

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents the results of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) performed at Camp Stanley Storage Activity (CSSA) located in Boerne, TX. This RFI was conducted in order to fulfill the requirements of the U.S. Environmental Protection Agency (USEPA) Administrative Order on Consent (the Order) issued to CSSA on May 5, 1999. The purpose of the RFI at CSSA was to characterize the environmental setting, source of contamination, degree and extent of contamination, and actual or potential receptors.

FACILITY BACKGROUND

CSSA is located in northwestern Bexar County, about 19 miles northwest of downtown San Antonio. The installation consists of 4,004 acres immediately east of Ralph Fair Road, and approximately 0.5 mile east of Interstate Highway 10. Camp Bullis borders CSSA completely on the east, and partially on the north and south.

The present mission of CSSA is the receipt, storage, issue, and maintenance of ordnance as well as quality assurance testing and maintenance of military weapons and ammunition. Because of its mission, CSSA has been designated a restricted access facility. No changes to the CSSA mission and/or military activities are expected in the future.

SUMMARY OF ENVIRONMENTAL HISTORY

During a routine screening site visit on August 9, 1991, the Texas Department of Health (TDH) sampled CSSA several on-post water supply wells. Analytical results revealed that one well exceeded the maximum contaminant limits (MCLs) for *cis*-1,2-dichloroethene (*cis*-1,2-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), trichloroethene (TCE), and tetrachloroethene (PCE). In 1992, CSSA initiated environmental investigations and USEPA issued the Order in 1999.

Following issuance of the Order, a total of 84 potential contamination sites, including 39 Solid Waste Management Units (SWMU), 41 Areas of Concern (AOC), and five Range Management Units (RMU), were identified ; and investigations and remedial actions necessary for closure in accordance with State of Texas requirements have been completed at 77 of the sites. In 2012, four SWMUs (B-2, B-8, B-20/21, and B-24) were combined with RMU-1 as they are part of the active firing range. This range will be closed in the future when it is no longer active. A brief summary of CSSA's 84 sites is provided in the table below.

Table ES-1
Brief Summary of CSSA's 84 Sites

Unit No.	*Description*	*Closure Approval Date or Current Status*	*Closure Type Received*
B-1	Powder and ammo burn area (1954).	November-02	RRS1
B-2	Small arms ammunition burning area (1954) - North Pasture	Part of Active Range	--
B-3	Landfill area (garbage disposal and burning trash); filled in 1990-91.	Treatability Study in Progress	--
B-4	Classified burn area (documents and trash).	February-13	TRRP
B-5	Possible fired small arms ammo brass area. Not located.	October-02	RRS1
B-6	Possible solid waste disposal area.	October-02	RRS1
B-7	Possible fired small arms ammunition brass disposal area	October-02	RRS1
B-8	Fired small arms ammo brass disposal area (piles of fire bricks, ammo shells) - North Pasture	Part of Active Range	--
B-9	Miscellaneous solid waste (metal and weapons) disposal area.	March-03	RRS1
B-10	Ammunition disposal area.	January-04	RRS1
B-11	Miscellaneous solid waste disposal (ammo, scrap metal, const. debris).	September-04	RRS1
B-12	Landfill, WPA trash when igloos were being built	July-05	RRS1
B-13	Trash dump area.	July-13	NFA
B-14	*Possible fired brass area - not located.*	February-08	Delisting
B-15/16	Landfill (target vehicles, weapons mounts)	September-11	NFA
B-19	Solid waste disposal area (metals and weapons).	September-02	RRS1
B-20/21	Former OB/OD area & ammunition disposal areas - North Pasture	Part of Active Range	--
B-22	Burn area (artillery shells).	December-02	RRS1
B-23	Disposal trenches (two green canisters)	July-05	RRS1

Table ES-1
Brief Summary of CSSA's 84 Sites (*continued*)

Unit No.	*Description*	*Closure Approval Date or Current Status*	*Closure Type Received*
B-23A	Disposal Trench (glass ampoules of liquid)	March-05	RRS1
B-24	Spent ammo/rockets area - North Pasture	Part of Active Range	--
B-25	Possible disposal trench	July-05	RRS1
B-26	Possible disposal trench	November-04	Delisting
B-27	Sanitary landfill, consisting of 5-6 trenches (6 ft deep, 3 ft wide).	December-11	NFA
B-28	Disposal trenches (molten metal, ammo, ammo parts)	November-11	NFA
B-29	Solid waste disposal area (in old quarry)	February-08	RRS1
B-30	Solid waste disposal area	February-05	RRS1
B-31	Lead shot/sand pipe bedding	November-02	RRS1
B-32	Lead shot/sand pipe bedding	November-03	RRS1
B-33	Lead shot/sand pipe bedding	November-04	RRS1
B-34	Maintenance pit floor drain and discharge point	April-14	NFA
B-71	Livestock area. Inner cantonment, SW of Well 16.	October 2011	TRRP
AOC-64	Area east of SWMU B-4; flares observed in the area	October 2011	TRRP
Bldg 40	less-than 90-day accumulation container storage area	January-04 and January-06	RRS1
Bldg 43	Inactive makeshift ammo demolition facility	August-05	RRS1
DD	Dud ammunition disposal area	April-05	RRS1
F-14	*Hazardous waste storage area (<90-day)*	November-95	RRS1
I-1	Inactive incinerator (built in 1943), currently used for transformer storage	November-08	NFA
O-1	Waste liquid/sludge oxidation pond (1975)	April-02	RRS1
Coal Bins	*Coal bins (no longer in use)*	February-08	Delisting

Table ES-1
Brief Summary of CSSA's 84 Sites (*continued*)

Unit No.	*Description*	*Closure Approval Date or Current Status*	*Closure Type Received*
AOC-35	Area immediately around Well 16. Northeast area of inner cantonment.	February-03	RRS1
AOC-36	Area between Well 16 and B-3. Possible waste verified not present by magnetometer survey.	August-02	RRS1
AOC-37	Livestock area. NW of Well 16 and N of Well D.	January-05	NFA
AOC-38	Livestock area. Inner cantonment, SW of Well 16.	February-05	RRS1
AOC-39	None. Area west of Well 16 between North Outer Rd and cantonment fence.	September-02	RRS1
AOC-40	None. Area east of Well 16 between North Outer Rd and cantonment fence.	August-02	RRS1
AOC-41	Gate area east of well 16. North Pasture, north of gate 6.	July-05	NFA
AOC-42	None. South of SWMUs B-28 and B-19, west of B-4.	December-11	NFA
AOC-43	Shallow trench without mounds. Metal, UXO. Located 50 ft south of B-7.	February-03	RRS1
AOC-44	Fox holes and trenches south of B-9 along west slope of hill. UXO includes Stokes mortars and 20-lb bombs.	July-05	Delisting
AOC-45	Flat area with spent and undamaged bullets. Located east of B-31, near bend in road.	October-11	NFA
AOC-46	Bermed area with stockpile of lead shot and sand. Located south of Engineering on east side of Thompkins Road.	July-05	RRS1
AOC-47	Area of trenches and mounds (similar to B-15/16). South of B-15/16, in SW area of East Pasture.	September-02	RRS1
AOC-48	Three N-S trending mounds and a construction debris pile. Located north of B-15/16.	November-04	Delisting

Table ES-1
Brief Summary of CSSA's 84 Sites (*continued*)

Unit No.	*Description*	*Closure Approval Date or Current Status*	*Closure Type Received*
AOC-49	Trench (4 x 7 ft) without surficial debris. Located SW of deer stand 41 in central East Pasture.	July-05	Delisting
AOC-50	Area with orange discolored material (most likely nickel penetrate) at ground surface. South of B-30 along gravel road.	April-05	RRS1
AOC-51	East pasture, east of active range, approximately 25 acres, area around B-9	October-12	NFA
AOC-52	Area west of B-4 towards Salado Creek near trees, two trenches	December-11	NFA
AOC-53	Building foundation near B-27 at Central Road and road to "D" Tank, batteries at rear of slab	July-05	RRS1
AOC-54	Area near gutting pit, east of Welding Shop Building, right side of road batteries were stored in the area	November-04	RRS1
AOC-55	Landfill, south of Tenberg Drive, east of Salado Creek	June-08	RRS1
AOC-56	Landfill, at intersection of Bernard Road and East Outer Road, surface depression on south side of intersection	September-04	RRS1
AOC-57	East of Building 98 and KOA Area, cleaning/maintenance activities performed at temporary structures	September-11	NFA
AOC-58	Suspected disposal trench within Inner Cantonment	December-11	NFA
AOC-59	Trench-type anomaly located west Test Pad in the East Pasture	October-11	NFA
AOC-60	Trench located west of tunnel and entrance roadway in the East Pasture.	July-05	Delisting
AOC-61	Suspected landfill	February-03	RRS1
AOC-62	Located west of monitoring well MW-2 and east of Salado Creek.	December-11	NFA

Table ES-1
Brief Summary of CSSA's 84 Sites (*continued*)

Unit No.	*Description*	*Closure Approval Date or Current Status*	*Closure Type Received*
AOC-63	Area consisting of 3 barrels containing rocks, south of deer stand 41 in the East Pasture.	July-09	TRRP
AOC-65	A concrete pit area that housed a metal vat that contained TCE and PCE.	Treatability Study in Progress	--
AOC-66	Area north of Well 16 in the outer cantonment.	February-05	NFA
AOC-67	Concrete pad near Building 90 housed a vat containing cleaning solvents.	September-10	NFA
AOC-68	Area includes metal slag/debris storage area from Wheelabrator operations next to Building 90-2.	September-10	NFA
AOC-69	Located on west side of CSSA.	October-09	NFA
AOC-70	Building used to mix pesticides. Near Building 1.	September-11	NFA
AOC-72	Area containing concrete, possible asbestos. Located east of Building 94, in SW CSSA.	May-12	NFA
AOC-73	Ranch landfill with overgrown trenches. Near Well I1, in northwest corner of CSSA.	January-09	NFA
AOC-74	Area with scattered building debris near Building 605 in the inner cantonment.	May-12	NFA
AOC-75	Area with high levels of mercury and barium.	November-13	NFA
RMU-1	Active firing range in the East Pasture	Part of Active Range	--
RMU-2	Rifle range located in the inner cantonment.	February-12	NFA
RMU-3	Firing range berm.	May-13	NFA
RMU-4	Former rifle range in East Pasture.	February-14	NFA
RMU-5	Former rocket range in North Pasture.	September-12	NFA

Contamination from past disposal activities resulted in multiple groundwater units, referred to as Plume 1 (SWMUs B-3 and O-1) and Plume 2 (AOC-65). Plume 1 has advectively migrated southward towards Camp Bullis, and west-southwest toward CSSA well fields and several off-

post public and private wells. VOC concentrations over 400 µg/L are present in Middle Trinity aquifer wells near the source area. However, contaminant concentrations are below 1 µg/L over most of the Plume 1 area. In contrast, little to no contamination within the Bexar Shale and CC Limestone has been consistently identified within Plume 1 except in association with former open borehole completions.

Contamination at Plume 2 originated at AOC-65, and spread southward and westward from the post. The greatest concentrations of solvents are reported at the near subsurface adjacent to the source area. Deeper in the subsurface, concentrations in excess of 100 µg/L have been reported in perched intervals above the main aquifer body in the LGR. However, multi-port well sampling has shown that once the main aquifer body is penetrated, the concentrations are diluted to trace levels. Off-post, concentrations in excess of MCLs have been detected in private and public wells with open borehole completions. Only sporadic, trace concentrations of solvents have been detected in Bexar Shale and CC Limestone wells within Plume 2. The soil at 0.34-acre SWMU O-1 was closed per TCEQ's requirements and a cap was placed on top of the former oxidation pond. Due to its proximity to SWMU B-3, groundwater at SWMU O-1 was evaluated as part of the SWMU B-3 investigation.

In general, due to the depth of groundwater (greater than 100 feet), the faulted karst nature of the aquifer, the existence of plumes associated with two areas (SWMUs B-3/O-1 and AOC-65), and CSSA's ongoing groundwater monitoring program, investigation of groundwater was conducted on a sitewide scale rather than during the investigation and closure of each individual SWMU, AOC, or RMU. CSSA is actively implementing remediation options for groundwater contamination associated with SWMU B-3/O-1 (Plume 1) and AOC-65 (Plume 2).

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
AL	Action Level
AOC	Area of concern
AR	Army Regulation
BFZ	Balcones fault zone
bgs	Below ground surface
BS	Bexar Shale
BCVI	black-capped vireos
CC	Cow Creek
CO_2	Carbon dioxide
COPC	Contaminant of potential concern
CSSA	Camp Stanley Storage Activity
CY	Cubic Yards
DCE	*cis*-1,2-dichloroethene
DNAPL	dense, non-aqueous phase liquid
EAA	Edwards Aquifer Authority
EM	Electromagnetic
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
GAC	granular activated carbon
GBRA	Guadalupe Blanco River Authority
GCWA	golden-cheeked warbler
gpm	Gallons per minute
GPR	Ground Penetrating Radar
HCSM	Hydrogeologic conceptual site model
HHRA	human health risk assessment
HS	Hammett Shale
IH	Interstate Highway
INRMP	Integrated Natural Resource Management Plan
ISCO	in situ chemical oxidation
LGR	Lower Glen Rose
LTMO	Long-Term Monitoring Optimization
MCL	Maximum contaminant level
NPS	National Park Service
NRHP	National Register of Historic Places
NW	Northwest
OB/OD	open burn/open detonation
Order	Administrative Order on Consent
OW	Oaks Water Supply Corporation
PCE	Tetrachloroethene
ppb	Parts per billion
PZ	Piezometer
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation

ACRONYMS AND ABBREVIATIONS (*continued*)

RL	Reporting limit
RMU	Range Management Unit
RRS1	Risk reduction standard 1
SAWS	San Antonio Water System
SE	Southeast
SVE	Soil vapor extraction
SW	Southwest
SWMU	Solid Waste Management Unit
TCE	Trichloroethene
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
TRRP	Texas Risk Reduction Program
UGR	Upper Glen Rose
USGS	U.S. Geological Survey
UU/UE	unrestricted use/unrestricted exposure
VC	Vinyl Chloride
VEW	Vapor extraction well
VOC	Volatile organic compound

SECTION 1
INTRODUCTION

Camp Stanley Storage Activity (CSSA) is located in northwestern Bexar County, Texas about 19 miles northwest (NW) of downtown San Antonio and 11 miles southeast (SE) of Boerne (**Figure 1.1**). On November 19, 1980, CSSA submitted a hazardous waste permit application which identified that, at that time, it treated, stored, or disposed of hazardous wastes at a surface impoundment and a tank. However, an open burn/open detonation (OB/OD) area in CSSA's North Pasture (SWMU B-20) was not included as a hazardous waste management area in the Part A permit application, or in subsequent hazardous waste activity notifications. CSSA had ceased operations at the B-20 site at the time of the Part A application but had resumed demolition activities in 1984 without modifying their permit. From the 1950s or 1960s until 1987 (with a hiatus in activities between 1980-1984 as stated above), CSSA used the B-20 site to treat and dispose of reactive explosives which are classified as hazardous wastes for reactivity (United States Environmental Protection Agency [USEPA] waste number D003). During an inspection in January 1993, USEPA determined that the SWMU B-20 site was a hazardous waste thermal treatment unit and did not have interim status since it was not included in the Part A permit application. The following paragraphs, as well as **Table 1.1**, summarize the chronology of remedial activities that followed at CSSA.

In 1991, two years prior to USEPA's determination on the SWMU B-20 site, routine water well testing by the Texas Department of Health detected the presence of dissolved tetrachloroethene (PCE), trichloroethene (TCE), and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) in a CSSA water supply well (Well 16) above maximum contaminant levels (MCLs) and the well was taken out of service. Subsequent sampling showed volatile organic compound (VOC) contamination levels above MCLs in several other wells. The potential sources of the waste constituents were believed to be the former oxidation pond (SWMU O-1) and Burn Area 3 (later renamed SWMU B-3). Later AOC-65 was also identified as another source of groundwater contamination.

As a result of the groundwater contamination and the findings on the SWMU B-20 site, USEPA issued CSSA an Administrative Order on Consent (the Order) under Section 3008(h) of RCRA on May 5, 1999 (USEPA 1999). The Order requires CSSA to identify, investigate, and prevent the further spread of releases of hazardous wastes and/or hazardous constituents to the environment at and/or from CSSA, and to ensure that corrective action activities are implemented to protect human health and the environment.

CSSA engaged in a series of environmental investigations during the ensuing 23 years to aid in the horizontal and vertical delineation of solvent contamination source areas within the aquifer. In addition, USEPA has a goal of having a "remedy-in-place" for all sites by 2020, though this is not specified in the Order. With the Order, USEPA is the lead agency for investigation and remediation of groundwater. The Texas Commission on Environmental Quality (TCEQ) is the lead agency for investigation and closure of waste disposal sites, though USEPA provides input.

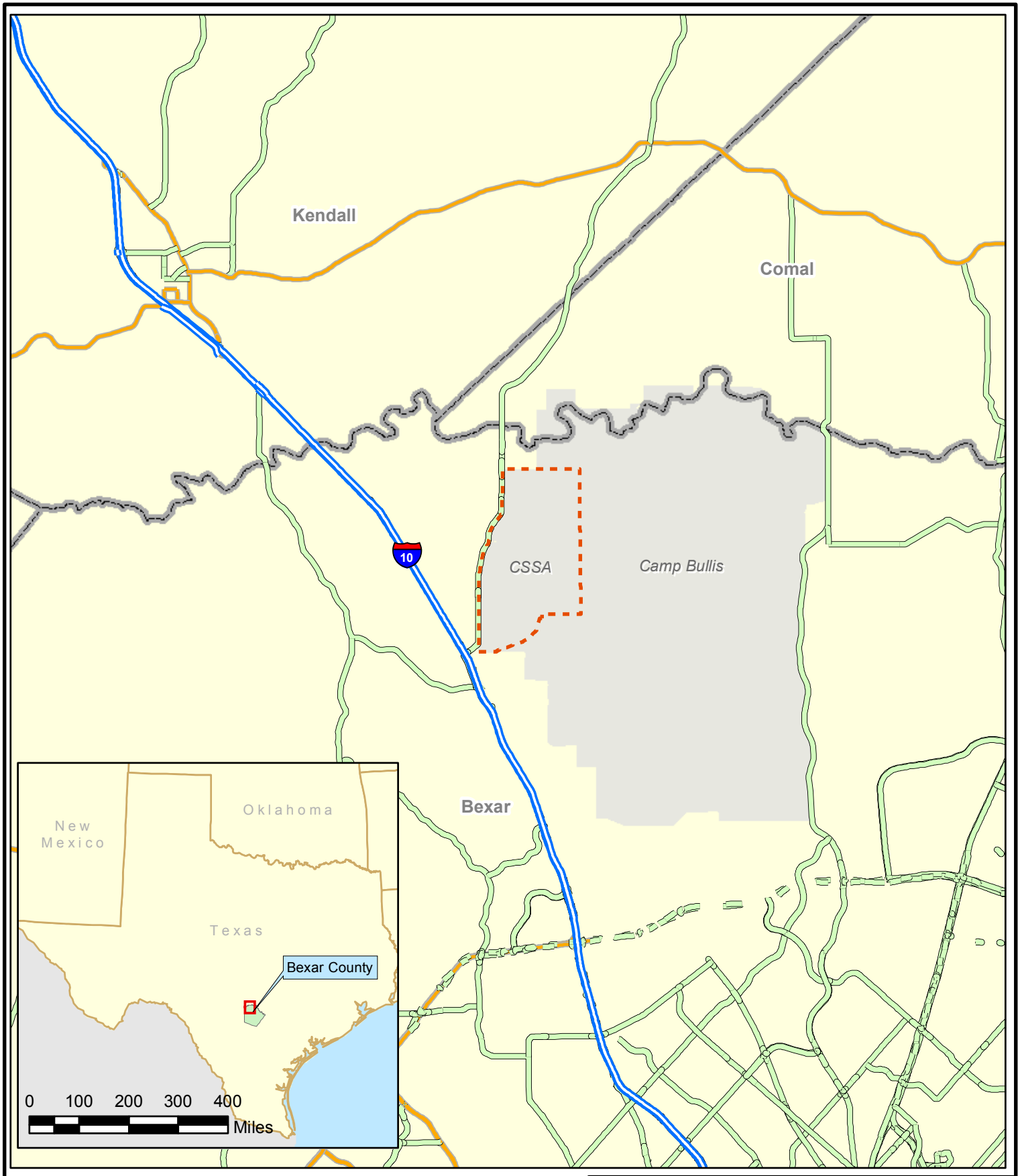

Figure 1.1

CSSA Location Map
Camp Stanley Storage Activity

PARSONS

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Table 1.1
Chronology of Remedial Activities at CSSA

	1980	1981-1983	1984	1985-1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
General	Hazardous waste permit submitted by CSSA.					Environmental Assessment (EA) site inspections begin.	EA completed; draft Administrative Order issued by USEPA.						USEPA issues Administrative Order on Consent to CSSA.	
Ground water					Routine water testing detects presence of VOCs in a CSSA water supply well.	Investigation of groundwater contamination begins at CSSA.		On-post groundwater monitoring initiated in 1994 and continued on a quarterly basis.		Installation of monitoring wells to delineate plumes			Groundwater contamination found in off-post private well in 1999; off-site monitoring program initiated and continued quarterly.	
SWMU B-3					Landfill area used for burning trash. Filled in circa 1991.				Geophysical survey, soil gas survey, soil and groundwater sampling.	SVE treatability studies conducted.				
AOC-65														Investigations initiated.
B-20 OB/OD Area			CSSA resumes OB/OD activities at SWMU B-20 without permit.	OB/OD activities continue through 1987.			USEPA determines SWMU B-20 is an unpermitted hazardous waste unit.	Environmental investigations, soil sifting, and treatability studies.					Interim removal actions.	
Other SWMUs and AOCs							EA identifies 39 SWMUs and 5 RMUs.		First SWMU (SWMU F-14) closed under RSS1.		Sifting at SWMUs B-2, B-8, B-20/21, B-24, B-28, and DD for removal of Material Potentially Presenting an Explosive Hazard (MPPEH)			

Table 1.1 (cont)
Chronology of Remedial Activities at CSSA

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
General	Public meeting	Public meeting				Public meeting			Public meeting					Public meeting; RFI Work Plan approved
Groundwater	Quarterly on-post monitoring continues.													
	Quarterly off-post monitoring continues.													
					LTMO Evaluation					LTMO Evaluation				
SWMU B-3		Interim removal action of 696 cubic yards (CY) of hazardous and 1,242 CY of non-hazardous soil.			Bioreactor treatability study initiated.	Bioreactor treatability study continues.								
						Approximately 15,000 CY of contaminated soil removed.	Bioreactor construction complete; Udnerground Injection Control (UIC) permit authorized.					Building 260 constructed to house bioreactor controls.		
AOC-65	Soil gas survey conducted.	Interim removal action of 1,255 CY of non-hazardous soil; treatability studies begin.	SVE treatability study continues.									Additional interim removal; ISCO treatability study begins; UIC permit authorized.	ISCO treatability study continues	
B-20 OB/OD Area	Phosphate-Induced Metal Stabilization (PIMS) demonstration on lead-impacted soils.											Four SWMUs (B-2, B-8, B-20/21, and B-24) are combined with RMU-1 as part of the active firing range complex to be closed when range is no longer active.		
Other SWMUs and AOCs		12 sites closed under RRS1.	5 sites closed under RRS1.	6 sites closed under RRS1; 2 sites delisted.	TRRP effective for new remedial sites as of May 1, 2005. 11 sites closed under RRS1; 2 sites delisted; 3 sites closed with NFA.			2 sites closed under RRS1; 2 sites delisted; 1 site closed with NFA.	1 site closed under TRRP; 2 sites closed with NFA.	2 sites closed with NFA.	2 sites closed under TRRP; 11 sites closed with NFA.	5 sites closed with NFA.	1 site closed under TRRP; 3 sites closed with NFA.	2 sites closed with NFA

Since the Order was issued in 1999, CSSA has been aggressively closing sites under State of Texas regulations, with both TCEQ and USEPA oversight. A total of 84 sites, including 39 SWMUs, 41 AOCs, and five RMUs, were identified at CSSA since 1993, and investigations and interim removal actions (if warranted) were conducted at a total of 83 of those sites. As of July 2014, 77 sites were either delisted or closed to unrestricted use/unrestricted exposure (UU/UE) in accordance with TCEQ requirements. In 2012, four SWMUs (B-2, B-8, B-20/21, and B-24) were combined with RMU-1 as they are part of the active firing range. Soils at the remaining open sites that were combined with the active firing range will be addressed under a separate investigation when the range is no longer active.

The two remaining open sites at CSSA, SWMU B-3 and AOC-65, are the remaining sources of groundwater contamination, and will be the focus of groundwater remediation efforts going forward. Treatability studies to address the remaining open sites were initiated in 1996 (SWMU B-3) and 2002 (AOC-65) and continue to the present. Throughout the site closure and treatability study process, USEPA and TCEQ have actively participated in site investigation and treatability study planning, as well as provided extensive document review. Both agencies are well versed on the current status of soil and groundwater treatment efforts at CSSA. An RFI Work Plan (Parsons 2014b) was submitted to USEPA and TCEQ in April 2014, and was approved by USEPA on July 25, 2014 and by TCEQ on August 12, 2014.

1.1 RFI REPORT PURPOSE AND OBJECTIVES

The primary objective and purpose of the RFI is to characterize contamination, identify and evaluate associated hazards and risk(s), and provide documentation supporting necessary corrective action planning for CSSA. This RFI report characterizes the nature and extent of contamination at CSSA, compiles information to fill identified data gaps, and evaluates the potential hazards and risks to human health and the environment. The overall goal of this process is to obtain stakeholder concurrence on the final RFI report and to provide sufficient data to facilitate any future remedial action. Project stakeholders include CSSA, USEPA, and the Texas Commission on Environmental Quality (TCEQ).

1.2 RFI REPORT ORGANIZATION

The RFI is presented in the following sections and addresses the content requirements of the May 5, 1999 USEPA Order:

- Section 2 describes the history of activities conducted at CSSA and summarizes the results of previous investigations;
- Section 3 presents the nature and extent of soil and groundwater contamination at CSSA;
- Section 4 identifies potential human and ecological receptors that may be exposed to contaminated groundwater; and
- Section 5 summarizes the results of the RFI.

SECTION 2
BACKGROUND

2.1 SITE HISTORY AND DESCRIPTION

Due to the long history of remediation efforts at CSSA, numerous documents have been prepared related to:

- SWMU investigations and closures;
- Quarterly groundwater monitoring;
- Hydrogeological conceptual site model (HCSM); and
- Treatability studies.

These documents have been used as source documents for this RFI, and all are available in the Environmental Encyclopedia which serves as the Administrative Record (http://www.stanley.army.mil).

2.1.1 Site History

CSSA is located in northwestern Bexar County, about 19 miles northwest of downtown San Antonio. The installation consists of 4,004 acres immediately east of Ralph Fair Road, and approximately 0.5 mile east of Interstate Highway (IH) 10 (**Figure 1.1**). Camp Bullis borders CSSA completely on the east, and partially on the north and south.

The land where CSSA is located was used for ranching and agriculture until the early 1900s. During 1906 and 1907, six tracts of land were purchased by the U.S. Government and designated the Leon Springs Military Reservation. The land included military campgrounds and cavalry shelters.

In October 1917, the installation was re-designated Camp Stanley. Extensive construction started during World War I to provide temporary cantonments and support facilities. In 1931, the installation was selected as an ammunition depot, and construction of standard magazines and igloo magazines began in 1938. Land was also used to test, fire, and overhaul ammunition components. As a result of these historic activities, CSSA has a number of historical waste sites, including SWMUs and areas of concern (AOC).

Tables 2.1, 2.2, and **Figure 2.1** describe the status of the remedial sites at CSSA as of August 2014. As of August 2014, a total of 84 sites, including 38 SWMUs, 41 AOCs, and 5 range management units (RMU), were identified at CSSA and investigations have been conducted at a total of 79 of those sites (**Table 2.1**). In 2012, four SWMUs (B-2, B-8, B-20/21, and B-24) were combined with RMU-1 as they are part of the active firing range. This range will be closed in the future when it is no longer active. As of July 2014, 77 sites were closed and comprehensive treatability studies are underway at two sites (**Table 2.2**). The first site was closed in 1995, and the most recent closure (SWMU B-34) was approved by TCEQ in May 2014. Cleanup and closures were conducted in accordance with the State of Texas RCRA requirements.

Table 2.1
Status of Waste Sites at Camp Stanley Storage Activity as of August 2014

	Site Status		
	Closed or Delisted	**Part of Active Range Complex**	**Remediation Currently Underway**
Solid Waste Management Units			
SWMU B-1	✓		
SWMU B-2		✓	
SWMU B-3			✓
SWMU B-4	✓		
SWMU B-5	✓		
SWMU B-6	✓		
SWMU B-7	✓		
SWMU B-8		✓	
SWMU B-9	✓		
SWMU B-10	✓		
SWMU B-11	✓		
SWMU B-12	✓		
SWMU B-13	✓		
SWMU B-14	✓		
SWMU B-15/16	✓		
SWMU B-19	✓		
SWMU B-20/21		✓	
SWMU B-22	✓		
SWMU B-23	✓		
SWMU B-23A	✓		
SWMU B-24		✓	
SWMU B-25	✓		
SWMU B-26	✓		
SWMU B-27	✓		
SWMU B-28	✓		
SWMU B-29	✓		
SWMU B-30	✓		
SWMU B-31	✓		
SWMU B-32	✓		
SWMU B-33	✓		
SWMU B-34	✓		
SWMU B-71	✓		
Bldg 40	✓		
Bldg 43	✓		
DD	✓		
F-14	✓		
I-1	✓		
O-1	✓		
Coal Bins	✓		
Areas of Concern			
AOC-35	✓		
AOC-36	✓		
AOC-37	✓		
AOC-38	✓		
AOC-39	✓		
AOC-40	✓		

Table 2.1
Status of Waste Sites at Camp Stanley Storage Activity as of August 2014

	Site Status		
	Closed or Delisted	**Part of Active Range Complex**	**Remediation Currently Underway**
AOC-41	✓		
AOC-42	✓		
AOC-43	✓		
AOC-44	✓		
AOC-45			
AOC-46	✓		
AOC-47	✓		
AOC-48	✓		
AOC-49	✓		
AOC-50	✓		
AOC-51	✓		
AOC-52	✓		
AOC-53	✓		
AOC-54	✓		
AOC-55	✓		
AOC-56	✓		
AOC-57	✓		
AOC-58	✓		
AOC-59	✓		
AOC-60	✓		
AOC-61	✓		
AOC-62	✓		
AOC-63	✓		
AOC-64	✓		
AOC-65			✓
AOC-66	✓		
AOC-67	✓		
AOC-68	✓		
AOC-69	✓		
AOC-70	✓		
AOC-72	✓		
AOC-73	✓		
AOC-74	✓		
AOC-75	✓		
Range Management Units			
RMU-1		✓	
RMU-2	✓		
RMU-3	✓		
RMU-4	✓		
RMU-5	✓		

TABLE 2.2
STATUS OF SWMUs, AOCs, AND RMUs at CSSA

Unit No.	*Description*	*Investigation Report(s)*	*Recommendations*	Requested Action				*Closure Approved*	*Closure Type*
				RRS1	*NFA*	*Delisting*	*TRRP*		
B-1	Powder and ammo burn area (1954).	RFI/Closure Report July 2002	NA	**X**				November-02	RRS1
B-2	Small arms ammunition burning area (1954) - North Pasture	RFI/Closure Report June 2002 Closure Report March 2005	Closure once range is inactive						
B-3	Landfill area (garbage disposal and burning trash); filled in 1990-91.	RFI Report March 2005	Bioreactor remediation ongoing						
B-4	Classified burn area (documents and trash).	APAR October 2012	Closure				**X**	February-13	TRRP
B-5	Possible fired small arms ammo brass area. Not located.	RFI/Closure Report July 2002	NA	**X**				October-02	RRS1
B-6	Possible solid waste disposal area.	RFI/Closure Report July 2002	NA	**X**				October-02	RRS1
B-7	Possible fired small arms ammunition brass disposal area	RFI/Closure Report July 2002	NA	**X**				October-02	RRS1
B-8	Fired small arms ammo brass disposal area (piles of fire bricks, ammo shells) - North Pasture	RFI Report December 2003	Excavate as necessary once range is inactive						
B-9	Miscellaneous solid waste (metal and weapons) disposal area.	RFI/Closure Report September 2002	NA	**X**				March-03	RRS1
B-10	Ammunition disposal area.	RFI/Closure Report May 2003	NA	**X**				January-04	RRS1
B-11	Miscellaneous solid waste disposal (ammo, scrap metal, const. debris).	RFI Closure Report June 04	NA	**X**				September-04	RRS1
B-12	Landfill, WPA trash when igloos were being built	RFI Report April 2005	NA	**X**				July-05	RRS1
B-13	Trash dump area.	RIR April 2013	Closure		**X**			July-13	NFA
B-14	*Possible fired brass area - not located.*	Delisting Request November 2007	NA			**X**		February-08	Delisting
B-15/16	Landfill (target vehicles, weapons mounts)	RIR June 2011	NA		**X**			September-11	NFA
B-19	Solid waste disposal area (metals and weapons).	RFI/Closure Report June 2002	NA	**X**				September-02	RRS1
B-20/21	Former OB/OD area & ammunition disposal areas - North Pasture	RFI Report July 2002	Closure once range is inactive						
		Combined with B-20							
B-22	Burn area (artillery shells).	RFI/Closure Report August 2002	NA	**X**				December-02	RRS1

TABLE 2.2
STATUS OF SWMUs, AOCs, AND RMUs at CSSA

Unit No.	*Description*	*Investigation Report(s)*	*Recommendations*	**Requested Action**				*Closure Approved*	*Closure Type*
				RRS1	*NFA*	*Delisting*	*TRRP*		
B-23	Disposal trenches (two green canisters)	RFI Report April 2005	NA	**X**				July-05	RRS1
B-23A	Disposal Trench (glass ampoules of liquid)	RFI Closure Report September 2004	NA	**X**				March-05	RRS1
B-24	Spent ammo/rockets area - North Pasture	RFI Report May 2002	MC removal once range is inactive						
B-25	Possible disposal trench	RFI Report April 2005	NA	**X**				July-05	RRS1
B-26	Possible disposal trench	Delisting Report August 2004	NA			**X**		November-04	Delisting
B-27	Sanitary landfill, consisting of 5-6 trenches (6 ft deep, 3 ft wide).	RFI Report July 2002 RIR September 2011	NA		**X**			December-11	NFA
B-28	Disposal trenches (molten metal, ammo, ammo parts)	RFI Report April 2002 RIR July 2011	NA		**X**			November-11	NFA
B-29	Solid waste disposal area (in old quarry)	RFI Report April 2005	NA	**X**				February-08	RRS1
B-30	Solid waste disposal area	RFI Report September 2004	NA	**X**				February-05	RRS1
B-31	Lead shot/sand pipe bedding	RFI/Closure Report July 2002	NA	**X**				November-02	RRS1
B-32	Lead shot/sand pipe bedding	RFI/Closure Report January 2003	NA	**X**				November-03	RRS1
B-33	Lead shot/sand pipe bedding	RFI Report September 2004	NA	**X**				November-04	RRS1
B-34	Maintenance pit floor drain and discharge point	RFI Report August 2002	Closure		**X**			April-14	NFA
B-71	Livestock area. Inner cantonment, SW of Well 16.	APAR	NA				**X**	October 2011	TRRP
AOC-64	Area east of SWMU B-4; flares observed in the area	APAR	NA				**X**	October 2011	TRRP
Bldg 40	less-than 90-day accumulation container storage area	RFI/Closure Report September 2003	NA	**X**				January-04 and January-06	RRS1
Bldg 43	Inactive makeshift ammo demolition facility	RFI Report April 2005	NA	**X**				August-05	RRS1
DD	Dud ammunition disposal area	RFI Report January 2005	NA	**X**				April-05	RRS1
F-14	*Hazardous waste storage area (<90-day)*	RFI/Closure Report, 1995	NA	**X**				November-95	RRS1

TABLE 2.2
STATUS OF SWMUs, AOCs, AND RMUs at CSSA

Unit No.	*Description*	*Investigation Report(s)*	*Recommendations*	Requested Action				*Closure Approved*	*Closure Type*
				RRS1	*NFA*	*Delisting*	*TRRP*		
I-1	Inactive incinerator (built in 1943), currently used for transformer storage	RFI Report February 2003	NA				**X**	November-08	NFA
O-1	Waste liquid/sludge oxidation pond (1975)	RFI/Closure Report October 2000	NA	**X**				April-02	RRS1
Coal Bins	*Coal bins (no longer in use)*	Delisting Requested January 2003	NA			**X**		February-08	Delisting
AOC-35	Area immediately around Well 16. Northeast area of inner cantonment.	RFI/Closure Report October 2002	NA	**X**				February-03	RRS1
AOC-36	Area between Well 16 and B-3. Possible waste verified not present by magnetometer survey.	RFI/Closure Report April 2002	NA	**X**				August-02	RRS1
AOC-37	Livestock area. NW of Well 16 and N of Well D.	RFI/Closure Report June 2004	NA	**X**				January-05	NFA
AOC-38	Livestock area. Inner cantonment, SW of Well 16.	RFI Report September 2004	NA	**X**				February-05	RRS1
AOC-39	None. Area west of Well 16 between North Outer Rd and cantonment fence.	RFI/Closure Report April 2002	NA	**X**				September-02	RRS1
AOC-40	None. Area east of Well 16 between North Outer Rd and cantonment fence.	RFI/Closure Report May 2002	NA	**X**				August-02	RRS1
AOC-41	Gate area east of well 16. North Pasture, north of gate 6.	NFA Report April 2005	NA		**X**			July-05	NFA
AOC-42	None. South of SWMUs B-28 and B-19, west of B-4.	RFI Report October 2002 RIR August 2011	NA		**X**			December-11	NFA
AOC-43	Shallow trench without mounds. Metal, UXO. Located 50 ft south of B-7.	RFI/Closure Report October 2002	NA	**X**				February-03	RRS1
AOC-44	Fox holes and trenches south of B-9 along west slope of hill. UXO includes Stokes mortars and 20-lb bombs.	Delisting Report April 2005	NA			**X**		July-05	Delisting
AOC-45	Flat area with spent and undamaged bullets. Located east of B-31, near bend in road.	RIR July 2011	NA		**X**			October-11	NFA
AOC-46	Bermed area with stockpile of lead shot and sand. Located south of Engineering on east side of Thompkins Road.	RFI/Closure Report April 2005	NA	**X**				July-05	RRS1
AOC-47	Area of trenches and mounds (similar to B-15/16). South of B-15/16, in SW area of East Pasture.	RFI/Closure Report June 2002	NA	**X**				September-02	RRS1
AOC-48	Three N-S trending mounds and a construction debris pile. Located north of B-15/16.	Delisting Report August 2004	NA			**X**		November-04	Delisting

TABLE 2.2
STATUS OF SWMUs, AOCs, AND RMUs at CSSA

Unit No.	*Description*	*Investigation Report(s)*	*Recommendations*	**Requested Action**				*Closure Approved*	*Closure Type*
				RRS1	*NFA*	*Delisting*	*TRRP*		
AOC-49	Trench (4 x 7 ft) without surficial debris. Located SW of deer stand 41 in central East Pasture.	Delisting Report April 2005	NA			**X**		July-05	Delisting
AOC-50	Area with orange discolored material (most likely nickel penetrate) at ground surface. South of B-30 along gravel road.	RFI/Closure Report January 2005	NA	**X**				April-05	RRS1
AOC-51	East pasture, east of active range, approximately 25 acres, area around B-9	RIR July 2012	Closure		**X**			October-12	NFA
AOC-52	Area west of B-4 towards Salado Creek near trees, two trenches	RIR August 2011	NA		**X**			December-11	NFA
AOC-53	Building foundation near B-27 at Central Road and road to "D" Tank, batteries at rear of slab	RFI/Closure Report April 2005	NA	**X**				July-05	RRS1
AOC-54	Area near gutting pit, east of Welding Shop Building, right side of road batteries were stored in the area	Closure Report July 2004	NA	**X**				November-04	RRS1
AOC-55	Landfill, south of Tenberg Drive, east of Salado Creek	RFI/Closure Report Feb 04	NA	**X**				June-08	RRS1
AOC-56	Landfill, at intersection of Bernard Road and East Outer Road, surface depression on south side of intersection	Closure Report June 04	NA	**X**				September-04	RRS1
AOC-57	East of Building 98 and KOA Area, cleaning/maintenance activities performed at temporary structures	RIR May 2011	NA		**X**			September-11	NFA
AOC-58	Suspected disposal trench within Inner Cantonment	RFI Report October 2002 RIR August 2011	NA		**X**			December-11	NFA
AOC-59	Trench-type anomaly located west Test Pad in the East Pasture	RIR July 2011	NA		**X**			October-11	NFA
AOC-60	Trench located west of tunnel and entrance roadway in the East Pasture.	Delisting Report April 2005	NA			**X**		July-05	Delisting
AOC-61	Suspected landfill	RFI/Closure Report October 2002	NA	**X**				February-03	RRS1
AOC-62	Located west of monitoring well MW-2 and east of Salado Creek.	RIR August 2011	NA		**X**			December-11	NFA
AOC-63	Area consisting of 3 barrels containing rocks, south of deer stand 41 in the East Pasture.	APAR October 2008	NA				**X**	July-09	TRRP
AOC-65	A concrete pit area that housed a metal vat that contained TCE and PCE.	RFI Report August 2003	Additional investigation, ISCO remediation ongoing						

TABLE 2.2
STATUS OF SWMUs, AOCs, AND RMUs at CSSA

Unit No.	*Description*	*Investigation Report(s)*	*Recommendations*	Requested Action				*Closure Approved*	*Closure Type*
				RRS1	*NFA*	*Delisting*	*TRRP*		
AOC-66	Area north of Well 16 in the outer cantonment.	Closure Report June 04	NA	**X**				February-05	NFA
AOC-67	Concrete pad near Building 90 housed a vat containing cleaning solvents.	RIR July 2010	NA		**X**			September-10	NFA
AOC-68	Area includes metal slag/debris storage area from Wheelabrator operations next to Building 90-2.	RIR July 2010	NA		**X**			September-10	NFA
AOC-69	Located on west side of CSSA.	RIR June 2009	NA		**X**			October-09	NFA
AOC-70	Building used to mix pesticides. Near Building 1.	RIR June 2011	NA		**X**			September-11	NFA
AOC-72	Area containing concrete, possible asbestos. Located east of Building 94, in SW CSSA.	RIR March 2012	Closure		**X**			May-12	NFA
AOC-73	Ranch landfill with overgrown trenches. Near Well I1, in northwest corner of CSSA.	RIR September 2008	NA		**X**			January-09	NFA
AOC-74	Area with scattered building debris near Building 605 in the inner cantonment.	RIR February 2012	Closure		**X**			May-12	NFA
AOC-75	Area with high levels of mercury and barium.	RIR July 2013	Closure		**X**			November-13	NFA
RMU-1	Active firing range in the East Pasture	--	Investigation once range is inactive.						
RMU-2	Rifle range located in the inner cantonment.	RIR November 2011	NA		**X**			February-12	NFA
RMU-3	Firing range berm.	RIR May 2013	Closure		**X**			May-13	NFA
RMU-4	Former rifle range in East Pasture.	RIR October 2013	Closure		**X**			February-14	NFA
RMU-5	Former rocket range in North Pasture.	RIR June 2012	Closure		**X**			September-12	NFA

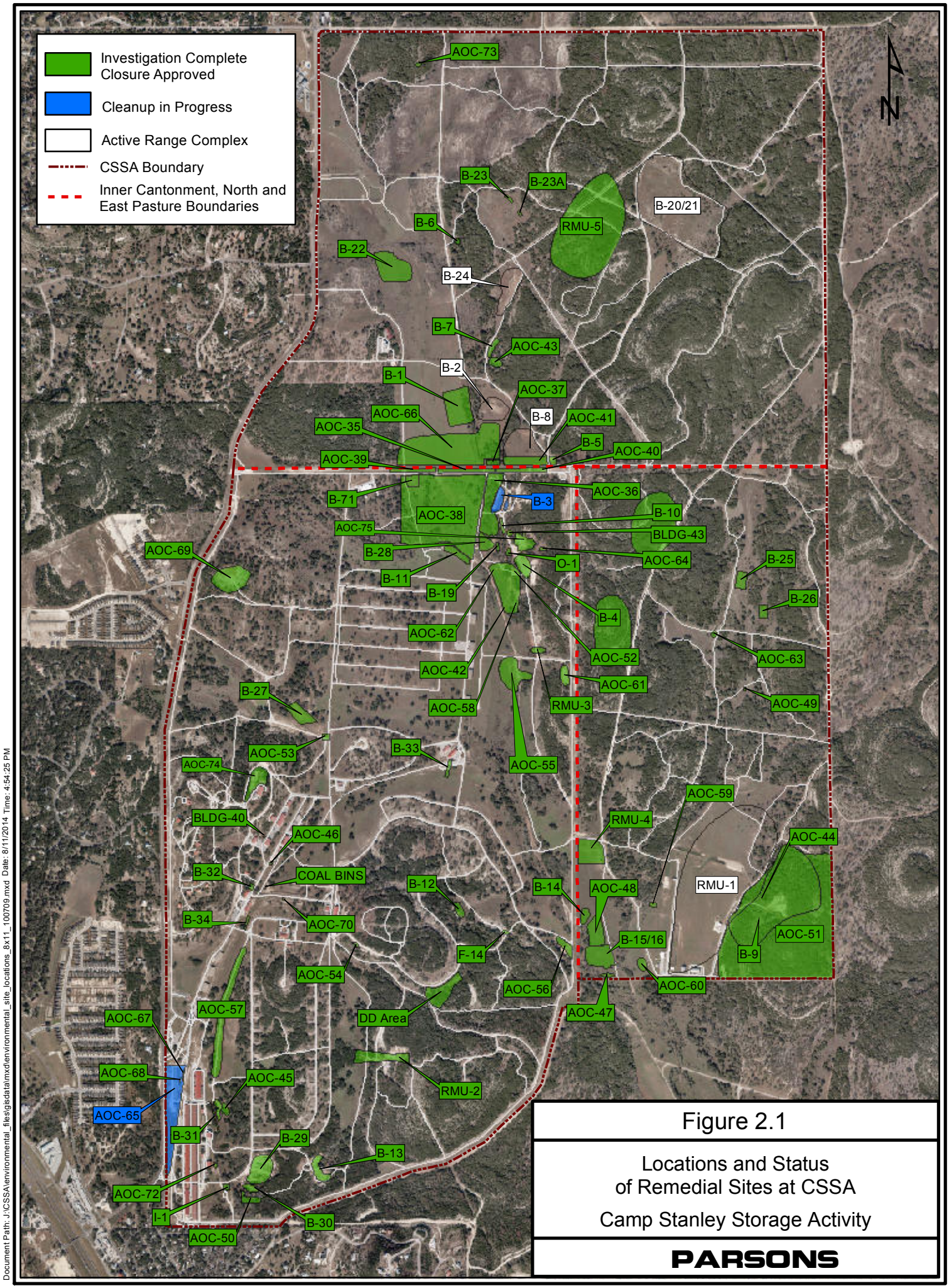

Figure 2.1

Locations and Status
of Remedial Sites at CSSA

Camp Stanley Storage Activity

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Since the Order was issued in 1999, CSSA has been aggressively closing sites under State of Texas regulations, with both TCEQ and USEPA oversight. A total of 84 sites, including 39 SWMUs, 41 AOCs, and five RMUs, were identified at CSSA since 1993, and investigations and interim removal actions (if warranted) were conducted at a total of 83 of those sites. As of July 2014, 77 sites were either delisted or closed to unrestricted use/unrestricted exposure (UU/UE) in accordance with TCEQ requirements. Over the course of these site closures, RCRA requirements have changed. Through May 2005, the clean-up or closure strategy for CSSA's SWMUs and AOCs followed TCEQ Risk Reduction Rules (30 Texas Administrative Code [TAC] §335 Subchapter S). Since May 2005, the clean-up and closure strategy for these sites has been in accordance with the Texas Risk Reduction Program (TRRP) 30 TAC §350, which became effective May 1, 2000. All sites in the process of being remediated using the Risk Reduction Standard 1 (RRS1) after May 1, 2000, were allowed to complete closure under those criteria until April 30, 2005. As of December 2013, TCEQ approved RRS1 closure of 37 sites, TRRP closure of 7 sites, de-listing of 7 sites, and No Further Action for 24 sites (**Tables 2.1 and 2.2**).

The present mission of CSSA is the receipt, storage, issue, and maintenance of ordnance as well as quality assurance testing and maintenance of military weapons and ammunition. Because of its mission, CSSA has been designated a restricted access facility. No changes to the CSSA mission and/or military activities are expected in the future.

2.1.2 Volatile Organic Compound Contamination at CSSA

In 1991, routine water well testing by the Texas Department of Health detected the presence of dissolved tetrachloroethene (PCE), trichloroethene (TCE), and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) in a CSSA water supply well (Well 16 [CS-16]) above maximum contaminant levels (MCL) and the well was taken out of service. Subsequent sampling showed volatile organic compound (VOC) contaminant concentrations greater than MCLs in several other wells. The potential sources of the waste constituents were believed to be the former oxidation pond (SWMU O-1) and Burn Area 3 (later renamed SWMU B-3); this is referred to as Plume 1 (**Figure 2.2**). Later, AOC-65 was identified as another source of groundwater contamination, referred to as Plume 2 (**Figure 2.2**). By 1999, VOCs had been detected in privately owned wells off-post. A synopsis of historical use and remedial activities at each of these sites is detailed below.

SWMU O-1. The oxidation pond, also referred to as SWMU O-1, was reportedly constructed in 1975 to receive waste from Building 90-1 (spillage, change-out, etc.). Building 90-1 was a gun bluing facility. The frequency of waste delivery to the pond varied upon the level of bluing activity. In 1982, an estimated 24,000 gallons were contained in the pond. During Fall 1985, the pond liner was damaged during bulldozing activities. No records are available to indicate whether or not disposal of the sludge or residue contained in the oxidation pond occurred before destruction of the liner. Several environmental investigations were conducted at the site, including soil gas surveys, geophysics, soil borings, and an electrokinetic treatability study. Eventually, the contents of the oxidation pond were excavated and backfilled with clean material.

Excavation of subsurface soil from the known extent of contamination within SWMU O-1 began on July 24, 2000. Excavation and removal of approximately 1,515 cubic yards (CY) of

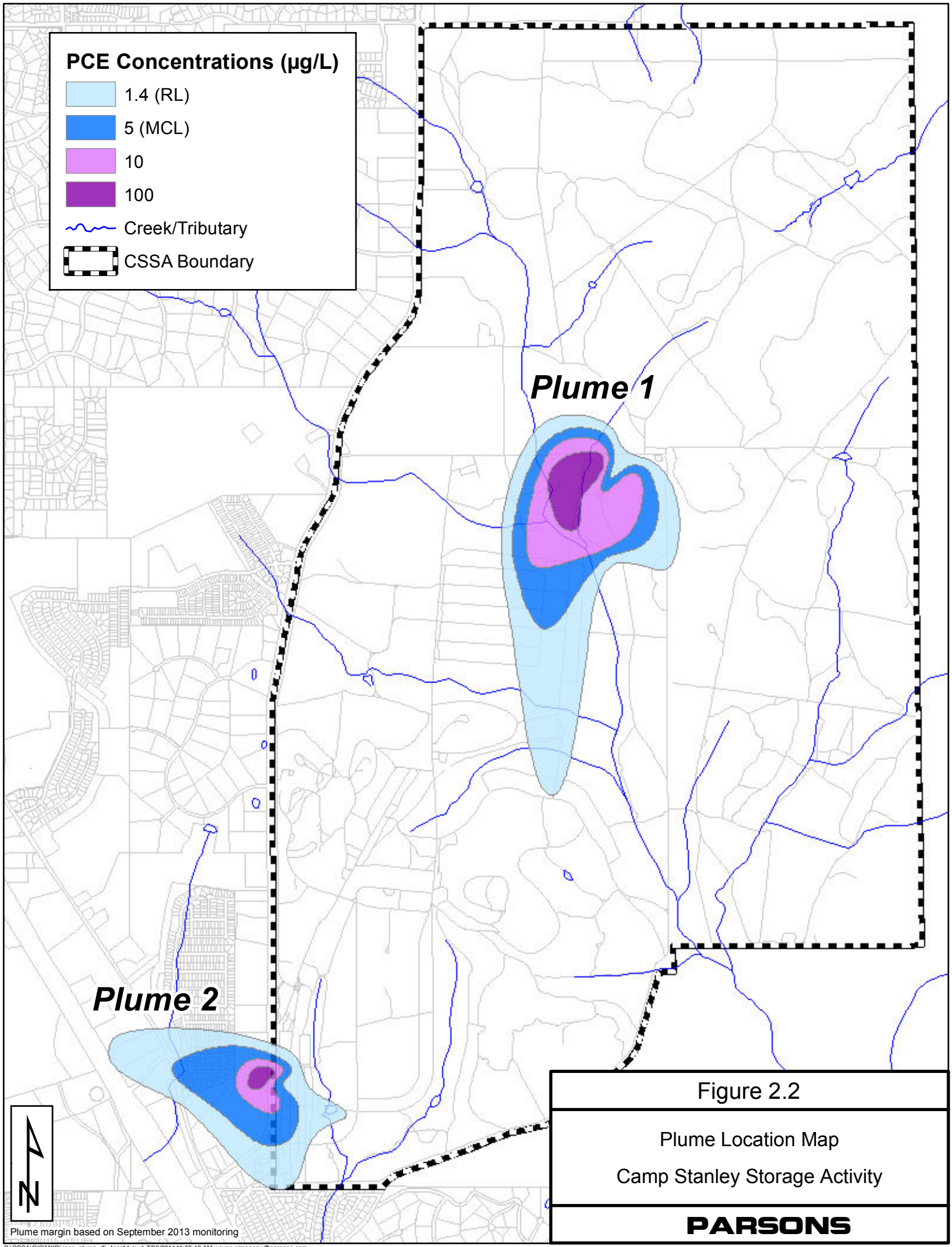

Figure 2.2

Plume Location Map

Camp Stanley Storage Activity

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contaminated soil were completed with soil material transported and disposed of at a permitted facility. The area of excavation encompassed approximately 7,000 square feet. Excavation continued until the soil was removed within and slightly beyond the lateral extent of contamination to a depth where bedrock was encountered. The resulting excavation was approximately 5 feet deep.

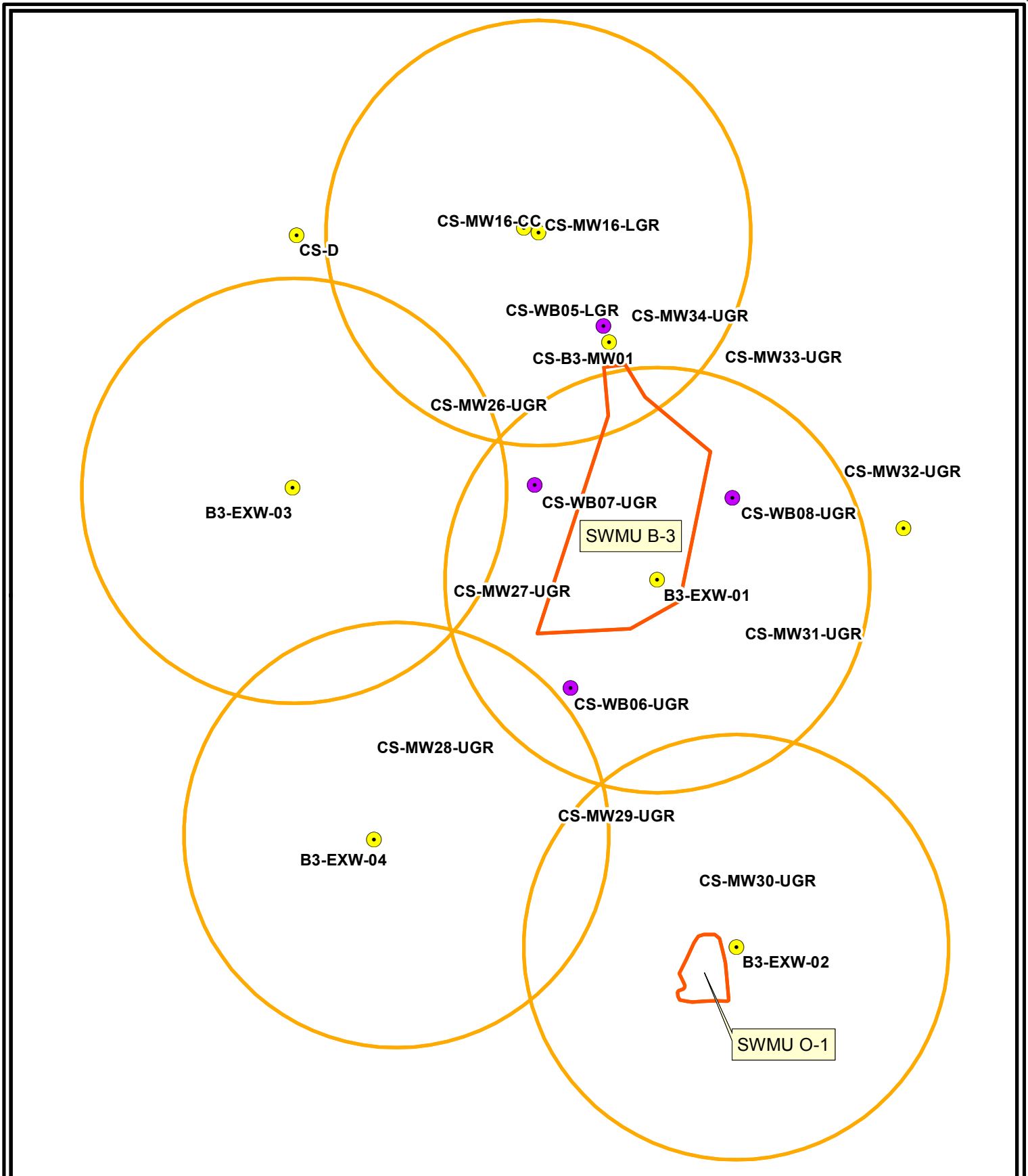
After confirmation samples had been collected, the excavation was backfilled to create a solid foundation for the overlying clay cover. A low-permeability clay liner was constructed over the site. Six inches of topsoil were placed on top of the clay liner, and a vegetative surface was established on the topsoil. CSSA sought a partial facility closure of the surface soil zone located within the boundaries of SWMU O-1. The cover serves to prevent infiltration of precipitation into and through the bedrock and remaining contaminated groundwater, thereby serving to mitigate, control, abate, and minimize spread of contamination in the groundwater below. The partial facility closure was approved by the TCEQ in April 2002.

The underlying limestone and the groundwater-bearing zones were not included in the partial facility closure. The limestone/groundwater zone is being addressed as part of the neighboring SWMU B-3 bioreactor system, described further below. A groundwater extraction well (B3-EXW02-LGR) has been drilled at the site, and is actively capturing contaminated groundwater for the SMWU B-3 bioreactor system.

SWMU B-3. SWMU B-3 was a landfill area thought to have been used primarily for garbage disposal and trash burning, presumably during the 1980's. Subsequent source investigations identified an area of open burn pits and disposal trenches containing PCE and its degradation products. The six trenches varied in depth from 5 to 15 feet, and were approximately 350 to 400 feet long and 12 to 20 feet wide. Groundwater beneath the landfill footprint occurs within a fractured bedrock aquifer composed of limestone and shales. The depth to the water table is typically 150 feet below ground surface (bgs), but can vary from 70 to 300 feet bgs depending on rainfall and recharge. Numerous environmental investigations have occurred at SWMU B-3, including soil gas surveys, geophysical surveys, soil boring and groundwater well installations, and soil vapor extraction (SVE) pilot study.

To remediate contaminated groundwater, an *in situ* "bioreactor" was created in 2007 by removing the waste in the disposal trenches, backfilling with a gravel/mulch mixture, and infiltrating contaminated groundwater (**Figure 2.3**). Microbial activity was augmented with addition of the KB-1 commercial culture of *dehalococcoides*. The current system distributes contaminated groundwater collected from seven extraction wells (CS-EXW01-LGR, CS-EXW02-LGR, CS-EXW03-LGR, CS-EXW04-LGR, CS-EXW05-LGR, CS-MW16-LGR, and CS-MW16-CC) located around the perimeter of the site into the bioreactor trenches where the water encounters microbial activity which degrades the organic contaminants. Approximately 50,000 gallons of contaminated groundwater from extraction wells is treated within the bioreactor each day. Groundwater from the extraction wells typically includes PCE and TCE in concentrations exceeding 100 parts per billion (ppb).

Samples collected from within the bioreactor indicate reductive dechlorination is occurring resulting in the production of *cis*-1,2-DCE, vinyl chloride, and ethene and low (~5 ppb) to non-detect concentrations of PCE and TCE. The decrease in VOC concentrations within the vadose zone beneath the bioreactor indicates the source material is being transformed within the



Aerial Photo Date: 2013

0 100 200 300 400 Feet

0 25 50 75 100 Meters

N

Westbay Multi-port Well

Supply/Monitoring Well

400 Ft. EX Well Radius

SWMU Boundary

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Figure 2.3

Bioreactor Layout and Extraction Well Radii of Influence
Camp Stanley Storage Activity

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bioreactor. Additionally, the injected waters conditioned to promote reductive dechlorination in the bioreactor have migrated from the vadose zone along fractures and preferred pathways into saturated portions of the aquifer resulting in an increase in vinyl chloride and ethene concentrations. In addition to a lateral bioreactor influence, as evidenced in VOC concentrations in shallow monitoring wells around the site, the development of a more vertical component of bioreactor influence is evident with an increase in observed concentrations of reductive dechlorination products at depth. Large increases in the reductive dechlorination product concentrations have been observed within samples originating as much as 300 feet bgs that prior to bioreactor operation had no detections of these components.

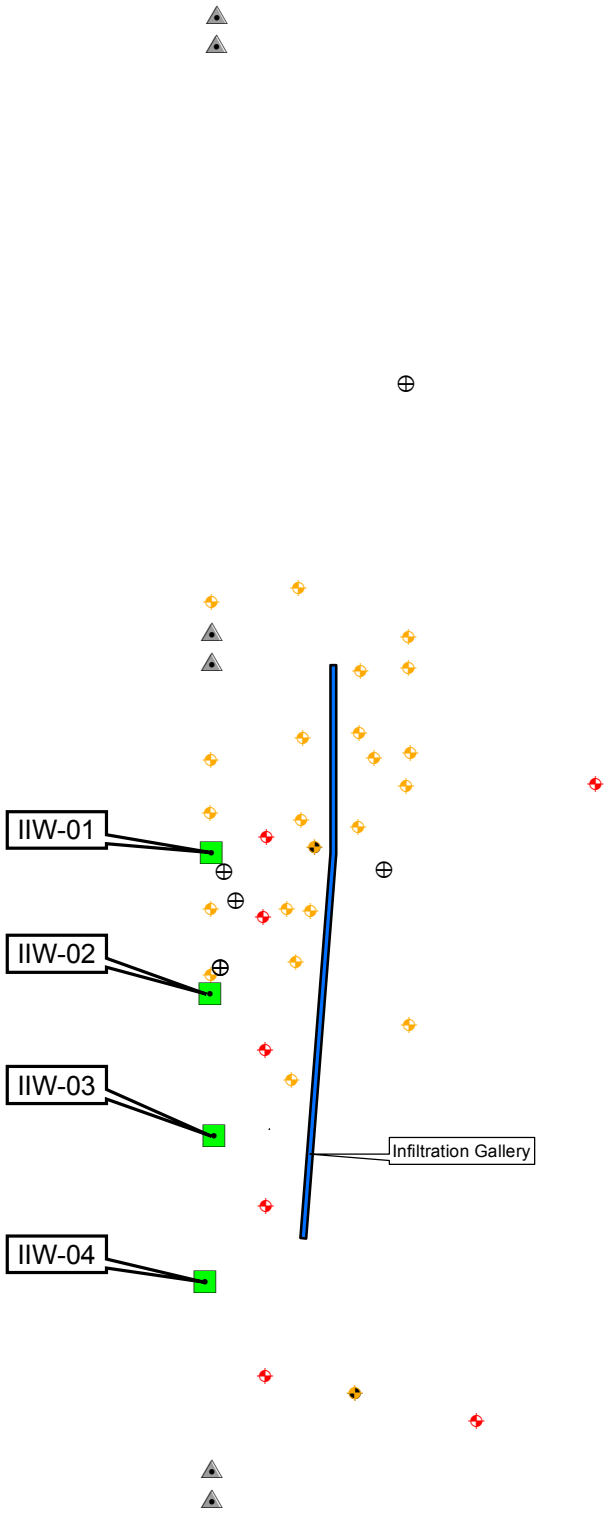
AOC-65. AOC-65, located along the southwestern side of CSSA, consists of Building 90 and potential source areas associated with Building 90. Building 90 was used for weapons cleaning and maintenance. A metal vat, used for cleaning with chlorinated liquid solvents such as PCE and TCE, was installed in the western vault at Building 90 (main portion of AOC-65) prior to 1966 and removed in 1995. In 1995, after removal of the former solvent vat, a metal plate was welded over the concrete vault, and PCE and TCE solvents were replaced with a citrus-based cleaner system.

In 1999, CSSA identified PCE-impacted drinking water off-post near AOC-65. The fractured nature of the underlying bedrock aquifer provided multiple flow paths for contamination within the vadose zone at AOC-65 to migrate both laterally as well as vertically. As a result, off-post VOC contamination in excess of the MCL was identified in both private and public water well systems. In response, CSSA implemented a proactive community relations plan to provide clean, potable water to the affected community and engaged in aggressive remedial investigations and treatability studies for AOC-65. These studies included source area identifications, soil boring and well installations, and pilot scale treatability studies.

A soil vapor extraction system proved ineffective after 10 years of operations due to large fluctuations in water levels within the aquifer. Extraction well screens and flow paths (fractures) were flooded during periods of higher groundwater elevations. An approach was designed for application of in situ chemical oxidation (ISCO) within AOC-65 by taking advantage of lessons learned from successful operation of the SMWU B-3 bioreactor. In 2012, the approach for injecting ISCO material at AOC-65 included the creation of a trench within a suspected point of release (i.e., drainage ditch) and backfilling this trench with alternating layers of ½-inch-sized gravel and compacted clay. Irrigation lines were installed within each of the gravel layers creating three separate infiltration galleries within the 15-foot-deep, 4.5-foot-wide, 320-foot-long trench. The infiltration galleries were configured to target injection in multiple fractures, some solutionally enlarged, that had been identified on the exposed trench walls.

Sodium persulfate activated via high pH was selected for application within the discrete galleries due to reaction life-span, solution density, and oxidation potential. In 2013, four injection wells in the upper portion of the bedrock vadose zone were installed along the post boundary to create a reactive curtain for intercepting potential PCE migration off-post (**Figure 2.4**).

Two ISCO injections of 10 and 22 tons of a 20 percent sodium persulfate solution occurred in 2012 and 2013, respectively. Groundwater samples collected at AOC-65 indicate the ISCO



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0 50 100 Feet

ISCO Injection Well

Infiltration Gallery

Monitoring Locations

Monitoring Well

VEW

Treatability Study Well

Westbay® - Multiport Monitoring Well

Peizometer

Figure 2.4

ISCO Treatability Area
at AOC-65
Camp Stanley Storage Activity

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solution followed preferential flow paths. This was inferred by the positive field identification of persulfate (oxidant) and elevated pH (activator), and the presence of reaction by-products within the monitoring well network. Continued monitoring will provide data for determining the overall effectiveness of the ISCO application and the need for further ISCO application(s).

Groundwater Contamination: Based on the observed groundwater contamination described above, 119 monitoring wells were installed on-post between 1996 and 2013. Off-post contamination was first reported by CSSA in December 1999 at a private well adjacent to the facility. CSSA has identified and sampled more than 60 off-post private, commercial, and public supply wells surrounding the post. Since that time, solvent contamination has been detected above the laboratory's method detection limits (MDL) in over 30 off-post groundwater supplies.

Contamination is most widespread within the Lower Glen Rose (LGR) water-bearing unit. Locally, the Bexar Shale (BS) serves as a confining unit between the water-bearing LGR and Cow Creek (CC) Limestone. Faults of the Balcones Fault Zone (BFZ) structurally influence and re-direct the groundwater flowpaths. Environmental studies demonstrate that most of the contamination resides within the LGR.

Plume 1 has advectively migrated primarily south-southeast toward Camp Bullis. A component of the plume has also migrated west-southwest toward CSSA well fields (CS-9, CS-10, and CS-11) and several off-post public and private wells. VOC concentrations over 500 µg/L are present in Middle Trinity aquifer wells near the source area. However, contaminant concentrations are below 1 µg/L over most of the Plume 1 area. In contrast, little to no contamination within the BS and CC Limestone has been consistently identified within Plume 1 except in association with open borehole completions. Trace concentrations associated with Plume 1 have been detected at off-post locations.

Contamination at Plume 2 originated at AOC-65, and spread southward and westward from the post. The greatest concentrations of solvents are reported at the near subsurface adjacent to the source area. Deeper in the subsurface, concentrations in excess of 100 µg/L have been reported in perched intervals above the main aquifer body in the LGR. However, as evidenced by the multi-port wells, once the main aquifer body is penetrated, the concentrations are diluted to trace levels. Off-post, concentrations in excess of MCLs have been detected in private and public wells with open borehole completions. All private groundwater wells with solvents present at concentrations greater than 90 percent of the MCL have been equipped with granular activated carbon (GAC) units and wells in the area are sampled quarterly. Only sporadic, trace concentrations of solvents have been detected in BS and CC Limestone wells within Plume 2.

2.1.3 Hydrology

Approximately 32,250 linear feet of ephemeral stream drainages on CSSA have defined channels. In particular, Salado Creek bisects CSSA, flowing east-southeast. These streams are ephemeral (run few days per year) and have no or indirect ties to permanently flowing surface waters.

2.1.4 Geology

CSSA is characterized by a rolling terrain of hills and valleys in which nearly flat-lying limestone formations have been eroded and dissected by streams draining to the east and southeast. CSSA is sited over Cretaceous-age deposits of the Travis Peak and Glen Rose

Formations of the Trinity Group. The predominant structural feature in the area is the BFZ escarpment. Normal faulting has occurred near the central area and the southern boundary of the installation. Faulting in the limestone units has juxtaposed strata of different ages, but fault scarps and traces are almost absent because many of the various calcareous lithologies weather similarly. The faults are northeast-southwest trending, but most are not as continuous as the fractures. Soil cover is relatively thin, and bedrock is frequently exposed in most areas other than stream valleys.

River and stream dissection of limestone is the major surface feature at CSSA. Most major rivers and streams originating in the Edwards Plateau northwest of CSSA tend to follow the NW-SE regional fracture patterns. Resistive limestone beds crop out as topographic highs across the landscape, resulting in the predominant physiography of hills and "saddles" which lead to stream valleys. Topographic relief across the area ranges from about 1,100 to 1,500 feet above sea level.

Stratigraphy

The oldest and deepest known rocks in the area are Paleozoic age (225 to 570 million years ago) schists of the Ouachita structural belt. They underlie the predominant Cretaceous-age carbonate lithology of the Edwards Plateau. At CSSA, the near-surface geology and aquifer are composed of Trinity Group carbonate bedrock, which includes the Glen Rose and Travis Peak Formations. In particular for CSSA, the units of interest are the Glen Rose Limestone, BS, and CC Limestone that form the Middle Trinity aquifer.

The upper member of the Trinity Group is the Glen Rose Limestone. The Glen Rose 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 thickness of this member at CSSA is estimated from well logs to be between 20 and 150 feet. The 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.

Underlying the Glen Rose Limestone is the Travis Peak Formation (and its downdip lateral equivalent, the Pearsall Formation), which attains a maximum thickness of about 940 feet and is divided into five members, in descending order: the Hensell Sand (and BS facies), the CC Limestone, the Hammett Shale (HS), the Sligo Limestone, and the Hosston Sand.

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 underlying CC Limestone is a massive fossiliferous, white to gray, shaley to dolomitic limestone that attains a maximum thickness of 90 feet down dip in the area. At CSSA, groundwater is produced from the LGR and CC intervals of the Middle Trinity Aquifer. The stratigraphically oldest rocks (Hammett Shale, Sligo Limestone, and Hosston Sand) comprise the Lower Trinity Aquifer, but are not developed at CSSA.

Structure

The predominant structural geologic features in the area are regional vertical fractures, the regional dip, and the BFZ escarpment. Regional fractures are the result of faulting in the Cretaceous sediments and in the deeper Paleozoic rocks. The two sets of fracture patterns trend northwest-southeast and northeast-southwest across the region. The regional dip is to the east and southeast at a grade of about 100 feet per mile near the fault zone in Bexar and Comal Counties, decreasing 10-15 feet per mile northwest of CSSA.

The BFZ is a series of high-angle normal faults that generally trend NE and SW. Total displacement in northwest Bexar County is approximately 1,200 feet. The faulting is a result of structural weakness in the underlying Paleozoic rocks and subsidence in the Gulf of Mexico basin to the southeast. The down drop blocks outcrop as progressively younger strata from northwest-southeast across the fault zone.

2.1.5 Hydrogeology

Groundwater occurrence and movement is highly variable due to the complex geologic environment. Three aquifers are present in the area of CSSA: the Upper, Middle, and Lower Trinity aquifers. These divisions are based on hydraulic continuity. The Glen Rose Formation and the Travis Peak and Pearsall Formations are the principle water-bearing units. As depicted on **Figure 2.5**, the Upper Member of the Glen Rose Formation composes the Upper Trinity Aquifer, and the Lower Member, a portion of the Middle Trinity Aquifer. The Pearsall Formation and its Travis Peak equivalent include a portion of the Middle Trinity Aquifer and the full Lower Trinity Aquifer. The Travis Peak Formation transitions into the Pearsall Formation in downdip locations very near, or just south of CSSA. Beneath these are metamorphosed Paleozoic rocks, which act as a lower hydrologic barrier. Only the Middle and Upper Trinity aquifers are typically addressed at CSSA.

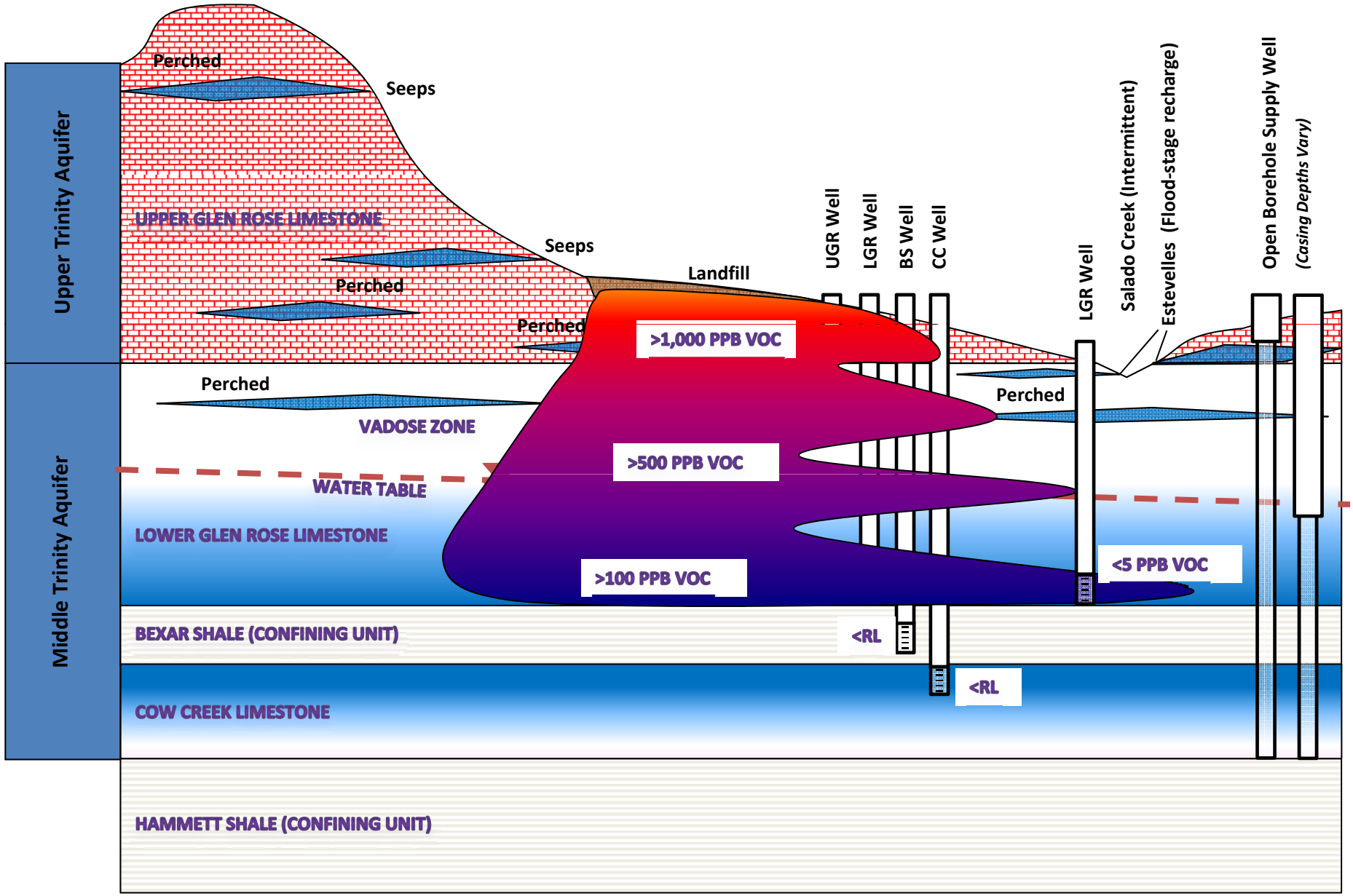
Middle Trinity Aquifer

The primary groundwater source at CSSA and surrounding areas is the Middle Trinity aquifer, consisting of the LGR Limestone, the BS, and the CC Limestone. The average combined thickness of the aquifer members is approximately 460 feet. In the vicinity of CSSA, the LGR portion of the Middle Trinity aquifer is recharged by direct precipitation on the outcrop and stream flow infiltration. Likewise, over the same area, the BS acts as a hydrologic barrier to vertical leakage except where faulted; therefore, most recharge to the CC Limestone comes from overlying updip formations. The bottom of the CC Limestone forms the base of the Middle Trinity aquifer.

Information regarding the subsurface at CSSA was compiled from borehole data, geophysics, and surface mapping to create a conceptual stratigraphic model. Nearly 90 percent of the land surface at CSSA is composed of the basal section of the UGR limestone, comprising the upper confining layer of the Middle Trinity aquifer. Data indicate that the underlying LGR is typically an average thickness of 320 feet. The BS is normally 60 feet in thickness, whereas the underlying CC Limestone unit is typically 75 feet in thickness.

The bulk of the main groundwater body occurs within the basal portion of the LGR and the upper portion of the CC Limestone. The occurrence of groundwater within these units was

Figure 2.5 CSSA Hydrogeologic Conceptual Site Model



implicitly related to the massive moldic porosity and karstic features associated with reef-building events and fossiliferous biostromes capable of storing large quantities of water. Occasionally, large volumes of groundwater can also be produced from well-developed reefs above the basal unit, or from significant perched fracture or karstic features. Otherwise, groundwater yields in the UGR and the top 250 feet of the LGR are minimal. Likewise, groundwater production from the BS is negligible.

Based on observation well measurements, regional groundwater flow is generally to the south-southeast (**Figure 2.6**). The LGR typically has a southward gradient that deviates around mounding that occurs at CSSA near the central and northern portions of the facility (CS-MW4-LGR).

Long-term monitoring shows that groundwater response to precipitation events can be swift and dramatic. Depending on the severity of a precipitation event, the groundwater response will occur within several days, or even hours. As an example, the BS exhibits the potential for either northward or southward flow, depending on the season. Likewise, the CC limestone exhibits erratic flow paths, with seasonally radial flows from mounded areas.

Significant precipitation events can result in dramatic aquifer response with regard to water levels. More than 80 feet of recharge has been measured in a well after a 4.5-inch precipitation event. Data obtained from the on-post well clusters indicate that for most of the year, a downward vertical gradient exists within the Middle Trinity aquifer. Differences in drainage rates often leave the head of the BS well above the head of the LGR and CC Limestone. The large differences in head suggest the BS reacts locally as a confining barrier between the LGR and CC Limestone.

Upper Trinity Aquifer

The Upper Trinity aquifer consists of the UGR Limestone. Recharge to the Upper Trinity aquifer is from direct precipitation to UGR Limestone outcrop and from stream flow infiltration. Movement of groundwater in the Upper Trinity is restricted to lateral flow along bedding planes between marl and limestone, where solution has enhanced permeability.

Static water levels in adjacent wells completed in different beds within the UGR are often different, demonstrating the possibility that beds are not hydraulically connected by avenues of vertical permeability. The only place where extreme development of solution channels is reported is in evaporite layers in or near the outcrop of the UGR Limestone.

Discharge from the Upper Trinity aquifer is predominantly from natural flow through seeps and springs and from pumping. The Upper Trinity aquifer is, in general, unconfined. Fluctuations in water levels in the Upper Trinity are predominantly a result of seasonal rainfalls and, in some areas, may be impacted by pumping from domestic and public wells. Upper Trinity water is generally of poor quality and most wells achieve only low production. Evaporite beds in the Upper Trinity introduces excessive sulfate into the water. Few wells obtain water solely from the Upper Trinity aquifer.

To the northwest of CSSA where the full thickness of the UGR exists, the aquifer is utilized as a primary drinking water supply. However, because the unit is so thin at CSSA, it normally does not store appreciable quantities of water. Therefore, it is not used for water supply in the

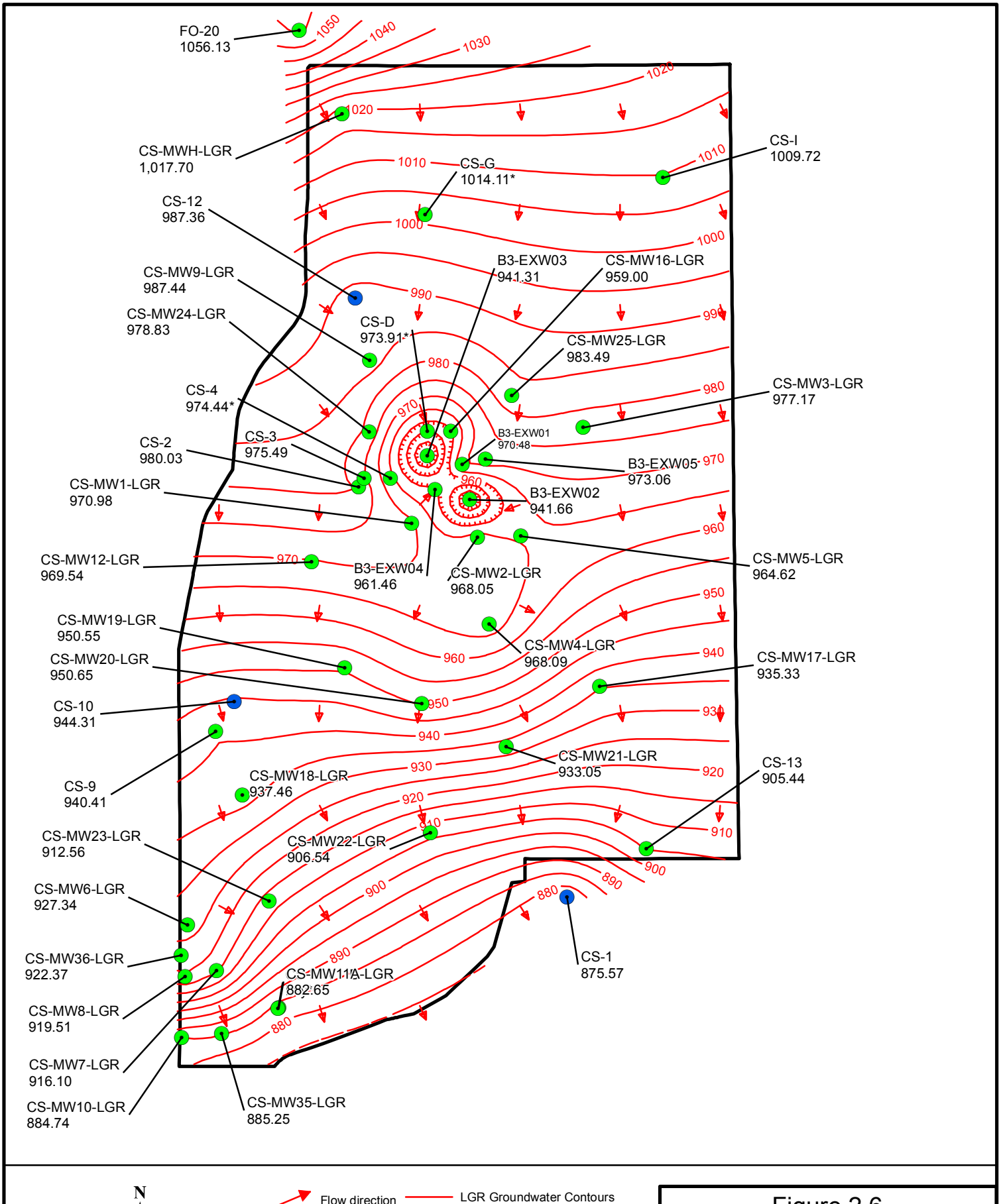


Figure 2.6

March 2014 Potentiometric Surface Map, LGR Wells

Camp Stanley Storage Activity

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vicinity of CSSA. But in some instances, off-post wells with minimal surface casing can receive contributing UGR groundwater into the open borehole well. The primary interest of the UGR at CSSA concerns environmental investigations addressing impacts to the uppermost occurrence of groundwater.

2.1.6 Hydrogeologic Conceptual Site Model

Figure 2.5 presents an HCSM for the occurrence of groundwater and contamination beneath the CSSA vicinity. Five stratigraphic units (UGR, LGR, BS, CC, and Hammett Shale) comprise the occurrence of shallow and deep groundwater within the Upper and Middle Trinity aquifers. The HCSM shows that variable thickness of the UGR (Upper Trinity aquifer) at CSSA is a result of the topography of the site. Generally speaking, the maximum thickness of the UGR would be 400 feet along the undeveloped hilltops of CSSA, with a postwide average thickness of 50 feet. In areas along stream channels such a Salado Creek, the presence of the UGR has been completely eroded away. Because the UGR has been dissected and eroded, the presence of groundwater is perched and laterally discontinuous across the facility. The UGR receives most of the direct precipitation that falls at CSSA (89 percent by areal extent), and discharges groundwater to the surface in the form of temporal seeps and springs along the rock outcrop during high rates of recharge or during flood-scale events. Specifically, after significant rain events, groundwater can be seen entering in Salado Creek in the form of bubbling "estevelles". Conversely, wells completed in the UGR often will go dry during periods of below-average rainfall.

The upper member of the underlying Middle Trinity aquifer is the LGR limestone, which normally occurs under a water table condition. However, perched zones are known to exist within the vadose zone above the water table. Like the UGR, these zones are also sensitive to drought, and will go dry as observed in CSSA wells. Based upon hydrophysical logging (HpL) conducted at multi-port well CS-WB04, the basal 50 feet of the LGR is the primary production zone of this unit, and accounts for more than 85 percent of groundwater produced from the LGR segment, and 79 percent from the entire Middle Trinity aquifer. While percolation of rainwater from the overlying UGR certainly contributes to the recharge of this unit, the rapid rate at which the LGR will recharge indicates that direct recharge on LGR outcrop areas (Cibolo Creek [off-post] and Salado Creek) are likely the primary mechanisms.

The shaley lithology of the BS interval serves as a confining unit between the more permeable limestones of the overlying LGR and underlying CC units. Water level measurements from four groundwater wells installed in this unit indicate the BS hydraulically separates the LGR and CC segments as a confining layer.

The CC segment of the Middle Trinity aquifer is under confined conditions due to the presence of the overlying BS and underlying HS shaley units. The upper 30 feet of the CC is its most productive interval, and accounts for approximately eight percent of Middle Trinity aquifer yield during the CS-WB04 HpL testing. Groundwater recharge to the CC unit occurs on a regional scale closer to outcrop areas and along river drainage basins. Localized minor recharge to the unit beneath CSSA is expected to occur via vertical leakage through the BS and HS confining units where the rock is structurally compromised by faults and fractures.

Figure 2.5 also conceptualizes the occurrence and transport of VOC contamination beneath CSSA. Nearly all VOC source releases (including B-3, O-1, and AOC-65) have occurred within

the UGR limestone. This includes landfill disposal units or direct surface discharges to the ground. The hydrogeologic CSM illustrates a VOC release from a surface impoundment such as SMWU B-3 or O-1 within the UGR. The CSM also conceptualizes the detection and monitoring of contaminated groundwater. CSSA utilizes monitoring wells that discretely monitor UGR and LGR perched zones above the water table, and interval-specific wells for the monitoring the LGR and CC production zones, as well as the BS confining unit.

Conceptually, a VOC release travels laterally with the natural dip of the bedrock, while also vertically migrating downward into lower strata where it encounters perched UGR and LGR groundwater in the vadose zone (above the water table). Groundwater wells that monitor perched UGR intervals often detect VOCs in excess of 500 ppb. To date, no dense, non-aqueous phase liquids (DNAPL) have been encountered at the site.

As contamination moves deeper into the subsurface, the plume will stratify based upon the lithology and permeability of the bedrock. Besides the natural porosity of the rock matrix, it is secondary porosity features such as fractures and dissolutioned (karstic) limestone that can dictate the flowpath and velocity of groundwater. Structural features such as faults can also re-direct groundwater flow because of the presence solutionally enlarged apertures, or even act as barriers because impermeable rock has been juxtaposed against more permeable rock.

As the plume disperses across perched units within the vadose zone, the VOC concentrations may range between 100 and 500 ppb (or considerably more) near the source areas, and much less at downgradient positions. Once the VOC contamination encounters the water table, the fate and transport mechanisms of advection, dilution, dispersion begin to dominate the regime. In most areas of Plumes 1 and 2, the VOC concentration is generally less than 5 ppb. The exception would be adjacent to source areas, where 200 ppb concentrations of VOCs still are present. Because of the hydraulic properties of the LGR production zone, this is also the interval that detectable concentrations of contamination are most widespread. Pumping action of nearby supply wells also increases the rate at which the plumes will disperse and travel.

VOC results from four BS wells and eight CC wells all support the conclusion that the BS confining unit is an effective hydraulic barrier to the continued downward migration of contaminants. Analytical results from the past 10 sampling results from eight wells are completely free of VOC contamination. The remaining two BS wells and two CC wells both have had trace detections (less than reporting limit [RL]) of VOCs in the past 10 sampling events.

Open borehole well completions are also shown on the CSM (**Figure 2.5)**, which may be typical for either a public supply well or privately owned well. Open borehole wells create a couple of unique situations that can factor into the exposure potential of groundwater consumers. Note that the amount of surface casing dictates if the perched groundwater is able to enter the borehole. In older wells, surface casing may be minimal, allowing contaminated perched groundwater to enter the borehole. Because of the natural downward gradient within a well, contaminated waters would co-mingle, causing localized contamination of LGR and CC groundwater adjacent to the well. Newer wells generally follow current regulations that mandate adequate surface casing to preclude the entrance of undesirable water into a well. While the regulatory perspective is to minimize comingling of lesser quality (Class 2 and Class 3)

groundwater with more pristine (Class 1) groundwater sources, the result is also effective for minimizing VOC contamination.

2.1.7 Surface Water and Groundwater Use

There are ephemeral streams at CSSA that flow after significant rainfall but, there are no perennial surface water sources at CSSA. Therefore, surface water is not a source of potable water at CSSA.

Both CSSA and the immediate surrounding areas use the Middle Trinity aquifer as a potable water source. This includes CSSA, commercial developments, private landowners, and until recently, several nearby public water systems. As of August 2014, there are three supply wells on-post (CS-1, CS-10, and CS-12) in use, one supply well on-post for emergency use only (CS-9), one planned for future use (CS-13), and approximately 55 private wells within one-quarter mile of the post boundary.

Several new housing developments neighboring CSSA are supplied by San Antonio Water System (SAWS). SAWS obtains its water primarily from the Edwards aquifer to the southeast. In addition, the neighboring City of Fair Oaks obtains its drinking water from both the Trinity aquifer and Canyon Lake, which the Guadalupe Blanco River Authority (GBRA) extracts and treats at the Western Canyon Water Treatment Plant.

2.2 PREVIOUS INVESTIGATIONS

Additional information on previous investigations at SWMU B-3, SWMU O-1, and AOC-65 is included in Section 2.1.2 above.

2.2.1 CSSA Groundwater Investigation Summary (1991 to Present)

Contaminants were initially detected in CSSA Well CS-16 during routine water supply testing in April 1991. Drinking water withdrawals at CS-16 ceased immediately. Follow-up sampling confirmed concentrations of trichloroethene (TCE) and tetrachloroethene (PCE) above drinking water maximum contaminant levels (MCLs) and the well was permanently taken out of service. Comprehensive investigation of groundwater contamination at CSSA began in 1992. The effort started with preliminary evaluations to establish the extent of the problem without invasive field techniques, namely analyzing groundwater samples from existing CSSA wells and geophysical surveys to identify potential contamination source areas. Samples from Well CS-D, located west of Well CS-16, also exhibited concentrations of PCE and TCE that exceeded MCLs. Camera surveys were also performed at CSSA wells to inspect the integrity of existing casings and to document general conditions inside the wells. Following this effort, the **Hydrogeologic Report for Evaluation of Groundwater Contamination** (ES, 1993) was submitted to the appropriate regulatory agencies for comment and approval.

A groundwater monitoring and reporting program was initiated in 1994 and established that groundwater flow gradients generally varied from south-southwest to south-southeast. The monitoring continued to show above-MCL volatile organic compound (VOC) contamination in Wells CS-16 and CS-D. Attempts to identify specific contaminated zones in several CSSA wells through discrete groundwater sampling proved inconclusive. Nevertheless, after review of geophysical and video logs, additional surface casing was installed to 200 ft below ground surface (bgs) in Wells CS-2, CS-3, CS-4, CS-16, and CS-D to seal off shallow water-bearing

zones that could have been contributing to migration of VOC contamination through open boreholes. Investigation activities continued in 1995, including additional downhole geophysical logging, discrete interval sampling, and well upgrades. In addition, periodic monitoring of several off-post domestic water supply wells was eventually initiated. At that time, none of the offsite wells sampled showed evidence of contamination.

Other work in 1995 relating to groundwater contamination issues focused on source characterization. To help identify potential sites, historical records were examined and interviews with CSSA employees were conducted to locate potential SWMUs and other AOCs. Sites were examined throughout CSSA where waste had been dumped and/or burned during past disposal activities. Areas showing unusual topography were also considered possible waste burial locations. Electromagnetic (EM) and ground penetrating radar (GPR) surveys were conducted at some of these sites in early 1995, followed by soil-gas surveys in areas where anomalies were identified.

Subsequently, SWMU B-3 and the abandoned oxidation pond SWMU O-1, located in the NE corner of the Inner Cantonment, were identified as potential VOC source areas. The pond once held waste fluids and sludge from CSSA's weapons bluing operations. The pond was abandoned and filled in 1985. At SWMU B-3 there had been a wide trench where solid and liquid wastes were apparently burned. The trench was backfilled in the early 1990's. Additional geophysical surveys, soil gas sampling, soil boring, and sampling continued at CSSA. Results indicated that SWMU B-3 and O-1 contained significantly higher concentrations of VOC contaminants than other sites. Analytical results showed PCE in SWMU O-1 soil samples and PCE, TCE, and *cis*-1,2-dichloroethene (DCE) in soil at SWMU B-3. Results of these investigations are provided in the **Technical Memorandum on Soil Boring Investigations** (Parsons ES, 1995b), the **Technical Memorandum on Surface Geophysical Surveys at High Priority Sites** (Parsons ES, 1995c), and the **Technical Memorandum on Surface Geophysical Surveys, Well 16 Source Characterization** (Parsons ES, 1995a).

Other activities completed at about this time included mapping of two fault zones through CSSA by Parsons. One narrow fault zone courses through the southern portion of CSSA trending SW-NE. A second, wider fault zone bisects CSSA immediately south of CS-16, trending west to east. At an October 1995 meeting involving EPA, TCEQ, Air Force Center for Environmental Excellence (AFCEE), CSSA, and their consultants, it was agreed that groundwater work at CSSA would continue to focus on source characterization. Quarterly groundwater monitoring and reporting continued.

In 1996, CSSA initiated additional source characterization at SWMU B-3 and O-1 in preparation for source removal. Additional detailed geophysical work was completed in areas around CS-16 and south to CS-1. CSSA had two monitoring wells (CS-MW1-LGR and CS-MW2-LGR) installed south of CS-16. The wells were drilled into the bottom of the LGR Formation (320 to 361 ft bgs) and completed with 140 and 141 ft of casing, respectively in 1999. These wells were recompleted with a 20-screen section in the bottom of the LGR. Periodic PCE and TCE concentrations above MCLs were found in both wells. The **Groundwater Investigation and Associated Source Characterization Report** (Parsons ES, 1996), which includes source characterizations of SWMU B-3 and O-1, was submitted to the regulatory agencies.

CSSA began groundwater monitoring using a low-flow system in early 1997. Camera surveys were completed in CS-1, CS-9, and CS-11, followed by upgrading that included carbon dioxide (CO_2) rehabilitation treatments. Ongoing work for SWMU and AOC site characterizations did not reveal additional potential sources contributing to the CS-16 area plume. However, past use of solvents in CSSA Building 90 was suspected as a potential source of contamination in the SW corner of the post. From 1998 through January 2004, CSSA continued monitoring water levels and conducting groundwater sampling on a quarterly schedule. Groundwater monitoring reports are included in **Volume 5** of the **CSSA Environmental Encyclopedia.**

In 2004, CSSA performed a Long-Term Monitoring Optimization (LTMO) study to evaluate the groundwater program in terms of both effectiveness and costs. 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 was evaluated quantitatively using statistical and spatial techniques. In addition, other important considerations associated with the monitoring network were addressed through a qualitative assessment of the network. The qualitative evaluation considered 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. Implementing these recommendations for optimizing the LTMO program at CSSA reduced the number of on- and off-post well groundwater samples per year by approximately 57 percent by adjusting sampling frequencies and eliminating spatially redundant wells. In 2005, both the EPA and TCEQ approved the LTMO recommendations for the on-post wells only. The revised sampling program was implemented in December 2005.

The LTMO evaluation was further updated in 2010 using groundwater data from monitoring conducted between 2005 and 2009. It has been approved by the TCEQ and USEPA and was implemented on- and off-post in June 2011. The approach and evaluation methodology was identical to the original effort conducted in 2004. Implementing these recommendations reduced on- and off-post sampling events by 24 percent and 28 percent, respectively. Likewise the reduction of Westbay multi-level sampling resulted in a 19 percent decrease in sampling events. Overall, the recommendations of the 2010 LTMO update reduced the CSSA groundwater monitoring frequency by 24 percent. Most of these reductions were based on changes to the sampling frequency of wells the monitoring wells.

One notable aspect of the 2010 LTMO update was the introduction of the 9-month "snapshot" event. 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 are also be sampled during the event to characterize the condition near the AOC-65 source area. The snapshot event allows for a regional condition to be assessed at specific time, which was lost in the original LTMO exercise. The 9-month frequency allows the aquifer to be assessed temporally over different climatic and hydrogeologic seasonal conditions.

In 1998 planning for the installation of several clustered monitoring wells throughout CSSA was also initiated. The intention of the well clusters was to assist in the ongoing characterization of groundwater contamination at CSSA. The wells provided for monitoring of the major water-bearing zones in the LGR, BS, and CC portions of the Middle Trinity aquifer. To date, 39 new monitoring wells have been installed exclusively within the LGR, BS, or CC portions of the Middle Trinity aquifer (**Figure 2.7**).

In 1999, an offsite well survey was conducted in the areas surrounding the CSSA facility. As many as 130 private or public supply wells were tentatively identified within one mile of CSSA. Of these, nearly 100 wells were positively identified and mapped. Most wells in the locality developed their water resources from the Middle Trinity aquifer. The typical well construction for the area includes an open borehole completion through the LGR, BS, and CC portions of the aquifer with minimal surface casing. This methodology ensured adequate yield, but could enhance the likelihood of cross-contamination between water-bearing units. As part of the quarterly monitoring program, select offsite wells were sampled for the presence of target contaminant analytes.

As a result of the 1999 well survey, CSSA initiated an offsite well sampling program in December 1999 (**Figure 2.7**). Based on this sampling, it was discovered that PCE and/or TCE was present in both public and private drinking water wells to the west and SW of the facility. These events lead to the search for another area of contaminant release, which ultimately lead to AOC-65, a solvent vat area in Building 90 where solvent had been used in the past.

Investigations performed at AOC-65 included soil borings, soil-gas surveys, multiple geophysical sensing techniques, and shear-wave seismic surveys. The objectives of those investigations were to identify pathways for migration specifically related to stratigraphic and structural features. Results of these investigations culminated with the installation of two pilot study vapor extraction systems. A weather station and transducers were installed at the site to aid in a groundwater recharge study.

In July and August 2001, two pumping tests were performed on CSSA wells CS-10 and CS-16. The tests were conducted to get a better sense of the hydraulic character of the Middle Trinity aquifer. The tests were conducted in wells that were open to both producing intervals of the aquifer: the Glen Rose Limestone and the CC Limestone. Groundwater pumping rates between 45 and 80 gallons per minute (gpm) were achieved, and measurable drawdown was observed at distances up to 700 ft away. Transmissivity values ranged between 1,600 and 2,300 gpd/ft (19.9 to 28.6 m^2/day), and aquifer storativity between 0.00008 and 0.005. Storativity, also known as the coefficient of storage, is a dimensionless number used to express the storage capacity of an aquifer. It is briefly defined as the volume of water taken into or released from storage per unit change in head per unit area. The resultant hydraulic conductivity ranged between 8.9 and 9.96 gpd/ft^2 (0.363 and 0.406 m/day).

All told, CSSA maintains and monitors 131 on-post wells. These wells include environmental monitoring, water production, and contaminant remediation. Depending on their specific use, their depth and well construction can vary greatly. Some wells are constructed to discretely monitor specific intervals, while other wells are open borehole construction, designed to maximize well yield and reduce well costs. Other wells are specific for the extraction of air or

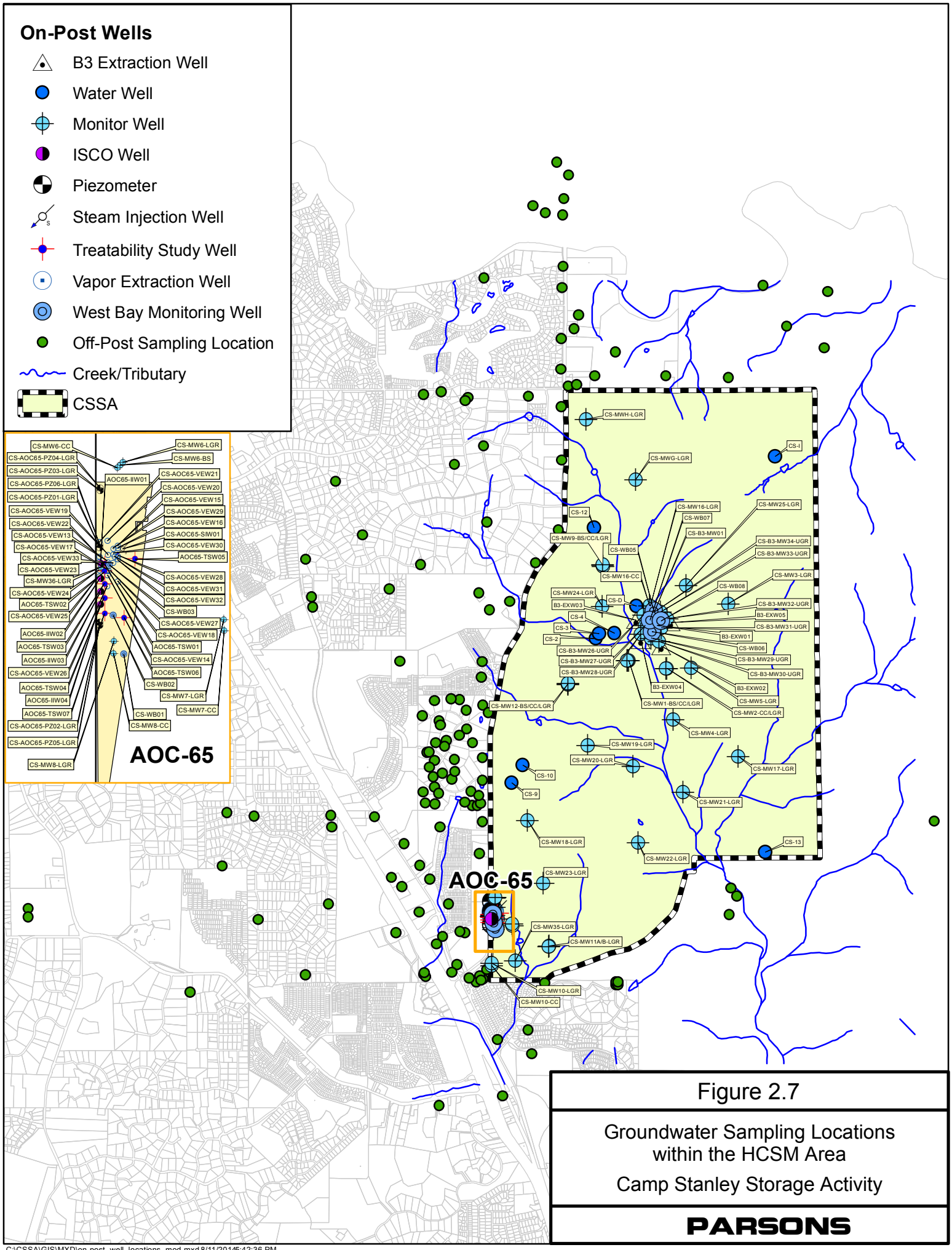

Figure 2.7

Groundwater Sampling Locations within the HCSM Area

Camp Stanley Storage Activity

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the injection of remedial media. Finally, CSSA has also implemented a multi-level monitoring technology that permits multiple zone monitoring within a single borehole.

Starting in 1996, the first of 66 environmental monitoring wells (defined as wells with casing and screen) were installed, and has continued through April 2011. With the exception of 27 shallow piezometers (PZ) completed within the perched segments of the UGR and LGR at AOC-65 or SWMU B-3, the remainder (39) of the observation wells monitor the LGR (26), BS (4), or CC (9) components of the aquifer. Twenty-three of these monitoring wells are arranged in 10 clusters of 2 or 3 wells each to observe different intervals of the Middle Trinity aquifer (e.g., LGR, BS, and CC wells). The remaining 16 monitoring wells are individually located throughout the base to monitor the LGR exclusively.

Forty wells have been installed at AOC-65 as part of remedial efforts, and have included vapor extraction wells, steam injection wells, and ISCO injection wells. And at SWMU B-3, five LGR wells have been installed to extract and recycle groundwater into the Bioreactor remediation system.

Another eight multi-port (Westbay) wells have been installed to discretely measure multiple zones throughout the Middle Trinity aquifer using single boreholes. These wells use an inflatable packer technology to isolate various sampling ports throughout the length of the borehole. The well design allows discrete measurements of hydraulic head and contaminant composition to be profiled throughout the length of the borehole. These multi-port wells are installed at the AOC-65 and SWMU B-3 remediation sites.

Additionally, six unused agricultural wells, two unused water supply wells, and three active and one future water supply wells are also used in monitoring the bedrock groundwater system. These wells are generally described to have an open borehole construction that uses a limited amount of surface casing to manage near-surface borehole instability and prevent less desirable upper strata groundwater from entering the well.

A chronology of work conducted in association with the groundwater investigation is provided in **Volume 1-1** of the **CSSA Environmental Encyclopedia.**

2.2.2 USGS Surface and Aerial Mapping

In 2003 CSSA contracted the U.S. Geological Survey (USGS) to perform surface geologic and EM mapping at the facility. Much of the planned activities will build upon, or be performed in conjunction with Camp Bullis. Other regional entities also contributing to the effort include the San Antonio Water System (SAWS) and the Edwards Aquifer Authority (EAA).

Surface Mapping

In 2004, the USGS published the "Geologic Framework and Hydrogeologic Characteristics of the Glen Rose Limestone, Camp Stanley Storage Activity, Bexar County, Texas" (Scientific Map 2831). This report, included as **Appendix A** describes the hydrogeologic units exposed at the ground surface at CSSA, and presents a map of these units. This geologic survey is a continuation of the mapping previously performed at the neighboring Camp Bullis facility. It is noteworthy to mention that this report primarily addresses the UGR, which comprises almost 90 percent of the exposed surface at CSSA. Except for the uppermost exposed interval, the LGR is not addressed in this report.

Based on mapping to the east on the Camp Bullis military installation, the UGR has been subdivided into 5 intervals (A-E) by the USGS. Of these intervals, E and C, are responsible for much of the near surface lateral movement of ground-water within the study area. A biostrome in interval D appears to have high porosity and permeability associated with fractures and molds which allow for substantial groundwater recharge from precipitation and run-off.

Interval A, which is a very permeable interval east at Camp Bullis (USGS, 2003), is mostly absent at CSSA due to erosion and plays a very minor role in recharge at/or near CSSA. Intervals B and C are also not present except upon the higher elevation hilltops. Faulting within and adjacent to CSSA is associated with the northeast-southwest extensional BFZ. This fault zone has resulted in high-angle normal down to the coast faulting. The displacement on most faults is 10 to 20 feet. Also present in the study area are fractures that are both parallel and perpendicular to the BFZ. The northwest-southeast fractures, which are perpendicular to the Balcones fault trend, appear to be the most permeable, probably due to east-west extension. Also presented is information about faults and fractures in the study area.

Aerial Mapping

CSSA and Camp Bullis also contracted with the USGS Crustal Imaging Team to perform an aerial EM (AEM) survey of both Department of Defense (DoD) facilities and private entities (SAWS/EAA). The process utilizes an EM drone towed in linear flight paths above the land surface by a helicopter. The method employs the same geophysical principles utilized by the resistivity surveys conducted at AOC-65, but at a regional scale. Research by the USGS in other parts of Central Texas (Seco Creek) demonstrates that the method is able to identify the major stratigraphic and structural features affecting the regional groundwater regime in the Edwards Aquifer. A poster publication of the results of the mapping are available online at http://pubs.usgs.gov/of/2005/1158/downloads/REPORTS/ofr_05_1158.pdf.

SECTION 3
NATURE AND EXTENT OF CONTAMINATION

3.1 CONTAMINANTS OF CONCERN

The COCs at CSSA are based on historically detected analytes (since the inception of the groundwater monitoring program in 1991) and process knowledge. Analytes detected above regulatory standards in soil and groundwater at CSSA are limited to a short list of chlorinated VOCs and metals. Appendix B includes a table of historical detections of contaminants in groundwater for both VOCs and metals. Of the analytes detected at CSSA, only a handful of organic and inorganic compounds exceed the appropriate Action Level (AL) or MCL as given in **Table 3.1**.

Table 3.1
Contaminant Detections in Groundwater Above MCLs,
1992-2014

VOCs		Metals	
Compound	**MCL (µg/L)**	**Compound**	**MCL or AL (mg/L)**
PCE	5	Arsenic	0.01
TCE	5	Cadmium	0.005
cis-1,2-DCE	70	Chromium	0.1
trans-1,2-DCE	100	Copper	1.3
		Lead	0.015
		Mercury	0.002
		Zinc	NA

The VOCs are components of solvents that were commonly used to clean grease and dirt from metal surfaces. At CSSA, solvents were used to degrease ordnance materiel. In 1995, CSSA discontinued the use of VOC solvents and replaced them with citrus-based cleaners. Until the late 1970s, there were no formal environmental regulations regarding the use or disposal of spent solvent. CSSA, like most other industrial facilities at the time, had no formal solvent disposal procedures. Based on investigations that have been completed-to-date, spent solvents may have been disposed of in SWMUs B-3 and O-1. SWMU B-3 was an on-site landfill where solvents were placed; it was closed in 1992. SWMU O-1 was a vinyl-lined oxidation pond that was used between 1975 and 1985 for the evaporation of spent liquids from ordnance maintenance activities. Another potential VOC source area has been identified near the SW corner of the facility. This area, designated AOC-65, is located at the Building 90 area, which is where solvents were used.

Volatile organic groundwater contamination at CSSA is caused by a group of chemical compounds commonly referred to as halogenated (chlorinated) solvents. PCE, TCE, and *cis*-1,2-DCE are the three most common VOCs found in the CSSA groundwater contamination plumes. Also, vinyl chloride (VC) is an important degradation product of halogenated compounds

because of its inherent toxicity, with an EPA drinking water MCL of 1 µg/L. Likewise, the EPA drinking water MCLs for PCE and TCE are both 5 µg/L and the MCL for *cis*-1,2-DCE is 70 µg/L. Concentrations below the MCL are considered safe for drinking water. While other VOC constituents have been detected in CSSA groundwater, these three compounds are by far the most pervasive and likely to exceed the MCLs. Other notable compounds detected in CSSA groundwater below the MCLs include bromodichloromethane, bromoform, chloroform, dibromochloromethane, dichlorodifluoromethane, DCE (1,1 and *trans*-1,2 isomers), methylene chloride, naphthalene, and toluene.

At CSSA the inorganic constituents in groundwater normally analyzed for include arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Although there have been some metals exceedances on-post, they have been sporadic and limited largely to wells located in the interior areas of the post. With the exception of lead, the remainder of the inorganic exceedences listed in Table 4.1 are relegated to two wells or less per instance.

Currently metals are not sampled at off-post locations due to the minimal or lack of on-post metals detections exceeding MCLs. With the exception of one location, historical samples obtained for off-post wells between 1995 and 2001 did not yield any metals concentrations above the MCLs. For the one well that exceeded the lead MCL, the 1996 follow-up sample resulted with no lead detection. Additional data from local water utility purveyors demonstrated that no public water wells exceed the MCLs for metals constituents.

3.2 EXTENT OF VOC CONTAMINATION

The HCSM used a layered approach to describe the hydrogeologic condition of the aquifer. The following sections describe the type and concentrations of VOC contaminants detected within the model layers when the HCSM was developed. Data points included groundwater samples collected from on-post monitoring wells and supply wells, and selected off-post domestic and public supply wells. Well types used to characterize the groundwater included on-post monitoring wells specifically screened within target intervals of the aquifer, as well as on- and off-post open boreholes completed in various intervals of the Middle Trinity aquifer. The groundwater plumes were characterized by more than 60 on-post wells and 60 off-post well locations.

A total of 57 on-post quarterly groundwater monitoring events have occurred between December 1999 and December 2013. Likewise, a total of 52 off-post quarterly events have occurred between September 2001 and December 2013. In this RFI, the contaminant plumes are defined by the most recent groundwater sampling results from 2013. These events have been selected since they represent the greatest density of sampling locations over the 14 years of periodic monitoring at CSSA. Since the objective of the off-post private and public wells is to provide a sustainable source of potable water, those wells are usually completed throughout the entire thickness of the Middle Trinity aquifer. Typical completions are open borehole, with older wells having as little as 10 feet of surface casing. Newer wells are more likely to have 200 more feet of surface casing. These well completions are designed to maximize quantities of available LGR and CC groundwater, whereas most CSSA wells individually monitor those units.

The LTMO study implemented in December 2005 and updated in 2010 determines the frequency that on-post wells are sampled. An overview of LTMO sampling frequencies for on- and off-post wells is given in **Table 3.2**. As shown in the table, well sampling frequencies can

range from 3 months (quarterly) to 18 months depending on their location and monitoring purpose. A key feature of the LTMO schedule is that all wells are sampled every 9-months to capture a "snapshot" condition of contaminant concentration and distribution. The 9-month frequency allows for seasonal variations to be monitored over the course of three years. The most recent snapshot event was collected in September 2013. For the purposes of this RFI, that event will be primarily utilized in the contaminant concentration and distribution portions of this report.

Table 3.2 2010 LTMO Recommended Monitoring Frequencies

	18-month	9-month	Semi-Annual + 9-month	Quarterly	Westbay[1] 18-month Schedule[1]	Westbay[1] 9-month Schedule[1]	Total
On-Post	**14**	**20**	**9**	**6**	**-**	**-**	**49**
Off-Post	**-**	**46**	**-**	**10**	**-**	**-**	**56**
Westbay[1]		**8***	**-**		**9**	**37**	**54**
	14	**74**	**9**	**16**	**9**	**37**	**159**

Notes: [1] *The Westbay schedule follows 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*

The wells are sampled using either dedicated low-flow pumps, high capacity submersible pumps, or dedicated solar-powered submersible pump. Samples are collected after field parameters (pH, temperature, conductivity) stabilized during well purging. Field parameters were recorded in the field logbook for each sampling event.

Figure 3.1 through **Figure 3.3** show the location and extent of the three most prevalent contaminants (PCE, TCE, and *cis*-1,2-DCE) detected within the Middle Trinity aquifer beneath CSSA in September 2013. The larger, centrally located area of contamination is referred to as Plume 1, while the latter in the SW quadrant is referred to as Plume 2. Plume 1 is a result of activities at SWMUs B-3 and O-1, and is mostly confined to within the limits of the facility. Some contaminant impact measured in off-post wells to the west of CSSA has been attributed to Plume 1. Contamination within Plume 2 is believed to originate from the industrialized portion of the facility at Building 90. Much of this plume appears to have migrated off-post to the west and south of CSSA.

In **Figures 3.1** through **3.3**, the lowest contour level was interpreted to represent the minimum plume area which accounted for any detection above a respective RL. The remainder of the groundwater plume has been mapped using logarithmic concentration lines to represent the varying ranges of contamination detected in sampled wells. Beginning at compound-specific RL (approximately 0.1 µg/L), each isoconcentration line increases exponentially by a factor of ten. This method of contouring allows for evenly-spaced isoconcentration lines in those source areas where there are drastic concentration changes in relatively small areas.

The inherent difference in well design off-post has made the occurrence of contaminants within each of the model layers difficult to define. While stratification of the contaminants within the geologic layers has been well-demonstrated on-post, it is difficult to be certain in

which interval the contamination is occurring in an open borehole well. Extensive groundwater sampling at cluster wells within the Middle Trinity aquifer has generally shown that VOC contamination occurs primarily in the LGR. Limited VOC concentrations have been reported in the BS and CC, but are typically below the CSSA RL.

One exception to this rule has been noted in the vicinity of former water supply well CS-16. This well was completed (open borehole) throughout the entire thickness of the Middle Trinity aquifer. It is believed that this construction style likely resulted in cross-contamination of the CC from the LGR. As a response to the potential for cross contamination, CS-16 has been re-completed by plugging of the BS and CC portions of the open borehole completion, leaving 114 feet of LGR open in the well, now redesignated as CS-16-LGR. To assess if cross contamination had occurred, a second well (CS-MW16-CC) was drilled in the vicinity of CS-16-LGR and is completed with 25 feet of screen in the CC. Sampling of CS-MW16-CC has indicated that PCE concentrations in excess of 200 µg/L within the CC at this location, and is evidence for the potential for inter-aquifer cross contamination within open borehole completions located proximal to contaminant source areas.

Based on these observations, this RFI has assumed that VOC contamination in open borehole completions, both on- and off-post are most representative of contaminant conditions within the LGR portion of the aquifer. While this does not preclude impact to the underlying strata, those affects are currently suspected to be minimal and localized in comparison to the contaminant concentrations in the LGR. Hence, the open borehole completions (both on- and off-post) are only considered in the LGR (Layer 2) portion of the model.

Wells with PCE detection above MCL
Wells with PCE detection above RL
Wells with PCE detection below RL
ND (< 0.06)

PCE Concentrations (µg/L)
1.4 (RL)
5.00 (MCL)
10.00
100.00

Parcels
CSSA
Salado Creek
Faults

*Bioreactor Wells Sampled October 2013

CS-MW16-LGR 83.04
WB05 * 143.16J
WB08 * 2.32
B3-EXW03 * 139.76
B3-EXW05 * 44.02
B3-EXW04 * 221.55J
B3-EXW02 * 79.03
WB07 * 331.75J
CS-MW1-LGR 11.92
CS-MW5-LGR 0.96F
WB06 * 66.95
CS-MW19-LGR 0.52F
CS-MW20-LGR 1.19F
FO-J1 0.24F
JW-7 0.32F
JW-8 0.26F
WB04 8.42
RFR-10 2.26
WB03 1.32F
SLD-01 0.14F
I10-4 1.7
CS-MW36-LGR 16.44
CS-MW7-LGR 0.68F
RFR-11 0.65F
CS-MW11A-LGR 0.97F
WB02 259.55
WB01 6.97
LS-1 0.72F
LS-6 0.68F
LS-5 1.01F
LS-7 1.87
CS-MW35-LGR 0.69F

Plume 1
Plume 2
1.4
1.4

Salado Creek
I-10
Old Fredericksburg Rd
Ralph Fair Rd

N
W
E
S

0 1,500 3,000 4,500 6,000 Feet

Inset Map B-3 Bioreactor

CS-MW16-LGR 83.04
WB05 * 143.16J
WB07 * 331.75J
WB08 * 2.32
B3-EXW03 * 139.76
B3-EXW05 * 44.02
WB06 * 66.95
B3-EXW04 * 221.55J
B3-EXW02 * 79.03

Inset Map AOC-65

WB03 1.32F
WB02 259.55
CS-MW36-LGR 16.44
CS-MW7-LGR 0.68F
RFR-10 7.41
WB01 6.97
WB04 8.42
CS-MW8-LGR 1.4

Figure 3.1
PCE Concentrations for LGR Wells, September 2013
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Wells with TCE detection above MCL
Wells with TCE detection above RL
Wells with TCE detection below RL
ND (< 0.05)

TCE Concentrations (µg/L)
1.00 (RL)
5.00 (MCL)
10.00
100.00

Parcels
CSSA
Salado Creek
Faults

CS-MW16-LGR 98.38
WB05 * 275.93J
WB08 * 5.44
B3-EXW03 * 149.54
B3-EXW05 * 63.2
B3-EXW02 * 92.15
WB07 * 422.82J
B3-EXW04 * 255.69J
CS-MW5-LGR 1.03
CS-MW1-LGR 17.69
WB06 * 55.93
WB04 8.31
WB03 2.2
RFR-10 2.26
CS-MW36-LGR 29.2
I10-4 1.7
CS-1 0.32F
RFR-11 2.12
WB02 11.11
WB01 11.49
RFR-12 0.52F
LS-6 2.12
LS-5 2.7
LS-7 0.19F

Plume 1
Plume 2

Salado Creek
I-10
Old Fredericksburg Rd.
Ralph Fair Rd.

N
W
E
S

0 1,500 3,000 4,500 6,000 Feet

Inset Map B-3 Bioreactor

CS-MW16-LGR 98.38
WB05 * 275.93J
WB07 * 422.82J
WB08 * 5.44
B3-EXW03 * 149.54
B3-EXW05 * 63.2
WB06 * 55.93
B3-EXW04 * 255.69J
B3-EXW02 * 92.15

Inset Map AOC-65

CS-MW36-LGR 29.2
WB03 2.2
RFR-10 2.26
WB02 11.11
WB04 8.31
WB01 11.49

Figure 3.2

TCE Concentrations for LGR Wells, September 2013

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Wells with cis-1,2-DCE detection above MCL

Wells with cis-1,2-DCE detection above RL

Wells with cis-1,2-DCE detection below RL

ND (< 0.07)

*Bioreactor Wells Sampled October 2013

cis-1,2-DCE Concentrations (µg/L)

1.2 (RL)

10.00

70.00 (MCL)

100.00

Parcels

CSSA

Salado Creek

Faults

Salado Creek

I-10

Old Fredericksburg Rd.

Ralph Fair Rd.

CS-MW16-LGR 84.59

WB05 * 328.66J

WB08 * 49.6

B3-EXW03 * 144.34

B3-EXW05 * 47.11

B3-EXW04 * 227.60J

B3-EXW02 * 87.41

WB07 * 582.81J

CS-MW1-LGR 14.37

CS-MW5-LGR 0.76F

WB06 * 174.69J

CS-MW2-LGR 0.51F

Plume 1

WB03 9.56

CS-MW36-LGR 0.78F

WB02 0.27F

WB01 0.40F

Plume 2

Inset Map B-3 Bioreactor

CS-MW16-LGR 84.59

WB05 * 328.66J

WB07 * 582.81J

WB08 * 49.6

B3-EXW03 * 144.34

B3-EXW05 * 47.11

WB06 * 174.69J

B3-EXW04 * 227.60J

B3-EXW02 * 87.41

Inset Map AOC-65

WB03 9.56

CS-MW36-LGR 0.78F

WB02 0.27F

WB01 0.40F

N

W E

S

0 1,500 3,000 4,500 6,000 Feet

Figure 3.3

cis-1,2-DCE Concentrations for LGR Wells, September 2013

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3.2.1 UGR (Layer 1)

Of the UGR intervals, only UGR(D) and UGR(E) have been investigated during RFI and groundwater investigation activities. These are the only intervals of the UGR that have lateral groundwater movement occurring without being cropped out by the intersecting land surface. Vertical movement of groundwater to lower strata also occurs in these intervals where the interval is bisected by faults or fractures. Drilling data suggests that the UGR units UGR(D) and UGR(E) yield very little water, except at times when significant precipitation has occurred. Groundwater occurrence within UGR(D) is probably laterally discontinuous and heavily dependent upon significant recharge and localized bioherms or fracture systems. Numerous RFI borings ranging in depths between 10 and 35 ft bgs has demonstrated that very little to no groundwater is readily available from the immediate near surface. Thus far, no freely yielding groundwater unit has been encountered within the UGR postwide. Past experience has shown that most 30-foot borings will eventually accumulate small quantities of water if allowed to stay open long enough.

Plume 1

With respect to investigational work within Plume 1 that addresses the UGR, the only location where significant data has been collected is in the vicinity of the source area at SWMU B-3. At this location, only a thin layer (less than 20 feet) has not been eroded from the area. Nonetheless, SWMU B-3 has been carved into UGR during past waste management activities. Because SWMU B-3 has been focused upon as a significant contaminant source area, work addressing the UGR has been conducted in this locality.

Original investigations and remedial actions at B-3 included the installation and operation of vapor extraction wells (VEWs) within the landfill trenches. Within the operational history of the vapor extraction system, sporadic groundwater samples collected from the VEWs resulted in *cis*-1,2-DCE being reported in excess of 27,000 µg/L, as well as nearly 3,000 µg/L of PCE. These VEWs were removed from service in 2006 when the excavation and disposal of the source area soils and debris was completed.

As part of remedial action monitoring, four Westbay multi-port wells (CS-WB-05, -06, -07, and -08) were installed around the perimeter of the SWMU. Three of these wells (WB-06 through WB-08) have discrete interval sampling points constructed within the UGR(D) and UGR(E) portions of the interval. In addition, eight UGR monitoring wells (B3-MW26-UGR through B3-MW34-UGR) are also located around the perimeter of the B-3 Bioreactor. Sampling results from these locations between October 2012 and October 2013 indicate maximum concentrations of *cis*-1,2-DCE (639 µg/L), *trans*-1,2,-DCE (8.50 µg/L), PCE (79 µg/L), TCE (96 µg/L), and VC (68 µg/L) are present at the margins of the SWMU. However, like AOC-65, the occurrence of perched groundwater within the UGR is sporadic and fully dependent upon significant precipitation to temporally saturate the interval.

Plume 2

Only a handful of wells near AOC-65 monitor the lower portion of interval UGR(D) and UGR(E). Specific investigations of interval UGR(E) in the vicinity of Plume 2 included the shallow PZs (-2, -4, and -6) and wells TSW-01 through -07 at AOC-65, and groundwater samples from these wells routinely result with solvent contamination that is in excess of the main

plume within the LGR. Some Westbay intervals are completed in the UGR(D) and UGR(E) zones but do not typically contain groundwater. At AOC-65 (Plume 2), lesser concentrations of PCE generally ranging between 30 µg/L and 60 µg/L are perched above the LGR. The greatest concentrations of solvents are reported within the near subsurface adjacent to the source area. These include 30,000 µg/L at CS-WB03-UGR-01 (March 2008) and 64,209 µg/L from well AOC65-TSW01, 30 days after an in-situ chemical oxidation (ISCO) injection treatment (August 2012).

During the July 2002 floods, this zone was saturated to the point where cascading groundwater and venting air could be heard in the open boreholes of AOC65-VEW13, -VEW14, -VMP6, -VMP7, and existing well AOC65–MW2B. Otherwise, this interval is generally low-yielding and is non-responsive except to the heaviest rain events (flood scale). However, groundwater does persist in these wells, in almost a sump-like fashion. Nearly 16 months of monitoring (March 2003 through June 2004) show that water levels are mostly unwavering in this zone. Once the 2002 flooding effect had dissipated, groundwater fluctuations within this zone at AOC-65 typically varied by only several tenths of feet. By way of comparison, the deeper PZs (-1, -3, and -5) screened at the base of LGR(B) fluctuated by more than 50 feet during the same 16-month monitoring period.

Westbay intervals such as CS-WB01-UGR-01 and LGR-01 showed little to no response to recharge and infiltration. Interval CS-WB02-UGR01 is almost always devoid of groundwater except after the heaviest of rains.

Between the September 2003 and September 2004 monitoring periods, the UGR(E) portion of the Westbay monitoring zones remained without groundwater except for one instance in July 2004 at CS-WB02-UGR01. At that time, 3.45 µg/L PCE and 2.12 µg/L TCE were detected in this portion of the stratigraphy. Similarly, nearly 9 inches of rain fell at the facility over an 11-day period in November 2004 which was temporarily sufficient to saturate the uppermost UGR-01 intervals in the AOC-65 multi-port wells. PCE results of 9.25 µg/L indicate that a persistent source still exists, and that periodic flushing by intense rainfall can mobilize these perched UGR contaminants that are probably otherwise bound to the matrix during the rest of the year.

3.2.2 LGR (Layer 2)

The LGR portion of the site has the greatest occurrence and concentration of contaminants associated with past disposal activities in the Plume 1 and Plume 2 source areas. PCE, TCE, and *cis*-1,2-DCE have been detected in both on- and off-post monitoring wells throughout the central and southern portions of the model area. Temporal data has been interpreted to show two distinct plumes, one located within the central portion of CSSA (Plume 1) and the other in the SW corner of the model area (Plume 2). In general, the on-post plumes are separated by a set of wells that are consistently at, or below the laboratory MDLs. These wells include from west to east: I10-8, I10-7, CS-MW6-LGR, CS-MW23-LGR, and CS-MW22-LGR. However, arguably the two plumes have co-mingled off-post to the west of CSSA in the vicinity of I10-4 and OFR-3. While the plumes still appear remain distinct with respect to TCE and *cis*-1,2-DCE, there no longer is a discernible boundary between plume margins with respect to PCE when reviewing the analytical data down to the MDL concentration level.

Plume 1

PCE

PCE within Plume 1 is centered around SWMU B-3, with the highest concentrations occurring at wells CS-16-LGR, CS-D, CS-WB05, CS-WB06, CS-WB07, B3-EXW01, B3-EXW02, B3-EXW03, and B3-EXW04 (see inset on **Figure 3.1**). These nine wells can typically have PCE concentrations that range between 100 and 500 µg/L. To the south, historical concentrations in excess of 10 µg/L are usually present at CS-MW1-LGR. Additionally, PCE concentrations in excess of the reporting limit (1.4 µg/L) can be expected to occur at CS-MW2-LGR, CS-MW5-LGR, and CS-MW20-LGR. The remainder of Plume 1 is defined by detections greater than the MDL (0.05 µg/L) but less than 1.4 µg/L. On-post, this includes a southerly component of groundwater flow towards wells CS-MW19-LGR, CS-MW20-LGR, and CS-MW17-LGR. And to the southwest, off-post wells with consistent trace (less than RL) detections of Plume 1 PCE include FO-J1, JW-7, JW-8, and RFR-14 in the Jackson Woods subdivision. At concentrations above the RL (1.4 µg/L) Plume 1 encompasses approximately 230 acres within the Inner Cantonment of CSSA.

The northern extent of Plume 1 within the LGR has been consistently defined by the lack of contamination at CS-G, CS-MWH-LGR, and CS-I. CS-MW9-LGR appears to be close to the plume margin, such that sporadic PCE concentrations just at the laboratory MDL have been reported (June 2003 through March 2011). Newer wells CS-MW21-LGR, -MW22-LGR, and -MW23-LGR have helped define the southern edge thus far with more than 20 rounds without a detection of PCE since their inception. And future supply well CS-13 at the southeastern boundary of CSSA thus far has been free of contaminants. The eastern portion of Plume 1 has not been defined by wells free of contamination above the MDL. Monitoring well CS-MW3-LGR establishes a control point to the NE, otherwise PCE concentrations near the on-post laboratory MDL of 0.05 µg/L appear to extend into the East Pasture as shown by results of CS-MW5-LGR, CS-MW4-LGR, and CS-MW17-LGR. The lack of contaminant detections along the northern portion of Ralph Fair Road defines the plume to the NW. The data indicates that municipal and private wells close to Fair Oaks Ranch have not been impacted by CSSA.

A PCE component of Plume 1 appears to migrate southwesterly beneath Ralph Fair Road near Jackson Woods. The migration of the plume in this direction may be attributed to several factors, including the natural groundwater gradient with a southwesterly vector, migration induced by long-time groundwater production from the CSSA well field (CS-9, CS-10, and CS-11), wells within Jackson Woods, and structural controls related to faulting or karstic features. The odd geometry of the plume suggests that structural controls may be a dominating force. Off-post detections in Plume 1 typically range between the MDL of 0.05 µg/L and 1 µg/L. Historically, wells (I10-8, I10-7, CS-MW6-LGR, CS-MW22-LGR, and CS-MW23-LGR define the margins between the PCE fractions of Plume 1 and Plume 2.

TCE

While it is postulated that TCE was used as solvent at the facility, TCE also occurs within the model area as a daughter product resulting from the reductive dehalogenation process of PCE. The distribution and occurrence of TCE readily mimics that of the PCE fraction of the plumes, and the total area of the plume is slightly less than the PCE fraction. As before, the TCE fraction of Plume 1 above 100 µg/L is centered around wells CS-16-LGR, CS-D, CS-WB05,

CS-WB06, CS-WB07, B3-EXW01, B3-EXW02, B3-EXW03, and B3-EXW04 (see inset on **Figure 3.2**). Other wells with concentrations in excess of the MCL (5 µg/L) include CS-MW1-LGR, B3-EXW05, CS-WB06, and CS-WB08. As with the PCE plume, the TCE plume is well defined to the north and west. However, the eastern and southern extents have not been completely defined by wells free of contamination. The plume has migrated southward onto Camp Bullis property, where trace TCE amounts have been seen in CS-1. As opposed to PCE, wells to the southwest in the Jackson Woods subdivision do not see consistent detections of TCE in groundwater. Less than three trace detections (below the RL) have been reported each in FO-J1, JW-8, JW-27, JW-30. Interestingly, TCE has not been reported above the MDL in any of the Jackson Woods wells since June 2005.

Cis-1,2-DCE

Cis-1,2-DCE occurs within the area as a degradation product resulting from the reductive dehalogenation process and dilution of parent compounds PCE and TCE. The presence of *cis*-1,2-DCE indicates that the anaerobic conditions of the subsurface are somewhat favorable, and that natural attenuation processes are occurring. The *cis*-1,2-DCE plume is co-located with the PCE and TCE fractions, but covers a significantly smaller area (**Figure 3.3**). As opposed to Plume 2, *cis*-1,2-DCE can be found in ratios that equal, or surpass, the concentrations of PCE and TCE within a well. Within Plume 2, the *cis*-1,2-DCE fraction is small in comparison to the other VOCs.

Once again, the greatest concentration of *cis*-1,2-DCE above the MCL of 70 µg/L is centered around wells CS-16-LGR, CS-D, CS-WB05, CS-WB06, CS-WB07, B3-EXW01, B3-EXW02, B3-EXW03, and B3-EXW04 (see inset on **Figure 3.3**). *Cis*-1,2-DCE concentrations in excess of 10 µg/L routinely occur at CS-MW1-LGR, B3-EXW05, and CS-WB08, followed by detections above 1 µg/L at CS-MW2-LGR and CS-MW5-LGR. Detections less than the RL (1.2 µg/L) repeatedly occur at CS-4 and CS-MW4-LGR.

The margins of the on-post *cis*-1,2-DCE plume is confined by no detections in wells CS-MW9-LGR, CS-3, CS-2, CS-MW12-LGR, CS-MW19-LGR, CS-1, CS-MW17-LGR, and CS-MW3-LGR. An isolated off-post location associated with Plume 1 also occurs in Jackson Woods across Ralph Fair Road. Four wells, including Fair Oaks Ranch municipal well FO-J1 and private wells JW-8, JW-9, and JW-30, have had sporadic detections of *cis*-1,2-DCE less than the RL since 2001.

Plume 2

PCE

PCE releases associated with past hazardous materials operations at Building 90 (AOC-65) have affected the LGR portion of the aquifer at the SW portion of CSSA and beyond. Geographically, the plume is smaller than Plume 1. The area of PCE contamination extends from Building 90 southward beneath Leon Springs Villa and westward to Interstate 10. The bulk of the contaminant mass is centered near the presumed source area located at Building 90. Multi-port well CS-WB03 is located adjacent to the source area (**Figure 3.1**) and provides a good glimpse at the vertical distribution of contamination, as shown on **Figures 3.4** and **3.5**.

Figure 3.4 Vertical Distribution of PCE in Multi-Port Wells – June 2013

Figure 3.5 Vertical Distribution of TCE in Multi-Port Wells – June 2013

Adjacent to the source area (CS-WB03), concentrations between 1,000 µg/L and 30,000 µg/L PCE can be found within the UGR to a depth of approximately 40 feet. In the uppermost portion of the LGR at 40 to 100 feet below grade, PCE concentrations can range from 150 µg/L to 2,500 µg/L. Below 100 feet, the VOC levels within the LGR continue to attenuate with average PCE concentrations ranging between 15 µg/L and 40 µg/L.

As stated previously, Plume 2 appears to be distinct from Plume 1 as indicated by a line of northern wells free of PCE contamination (I10-8, I10-7, CS-MW6-LGR, CS-MW22-LGR, and CS-MW23-LGR). To the south, the extent of PCE detection has historically included municipal wells LS-1, LS-2, LS-3, LS-4 and HS-2. Beyond that, wells DOM-2, I10-10, and BSR-4 in the vicinity of Leon Springs south of CSSA have not had any reported detections of VOCs. To the east, the plume has only been demarcated by a series of wells with PCE concentrations below the MCL (CS-MW7-LGR, CS-MW11A/B-LGR, and CS-MW35-LGR). Concentrations in these wells are typically trace detections below the RL (1.4 µg/L), but have ranged upwards to 2.78 µg/L at CS-MW35-LGR.

The western extent is defined by a lack of PCE detections in The Oaks Water Supply Corporation (OW) across Interstate Highway 10 from CSSA. The supply system includes eight Middle Trinity aquifer wells that have been sampled since February 2011. During that initial sampling event, two wells (OW-Barnowl and OW-HH2) reported trace detections of PCE at 0.15F and 0.20F, respectively. However, ten subsequent quarterly samples have not detected any trace of VOCs in any of the OW supply wells. In September 2013, a trace detection of PCE was reported in western well SLD-01, approximately 2.7 miles west of CSSA. This has been the only report of VOCs in this well since the beginning of sampling in September 2011.

In general, the plume morphology has remained consistent between December 2002 and September 2013. The area of the LGR aquifer impacted by Plume 2 PCE concentrations above the RL is approximately 130 acres. PCE groundwater contamination in excess of 1.4 µg/L extends westward from the CS-MW8 cluster to I10-4, and southward to the CSSA property boundary. Within this area, PCE concentrations within the LGR exceed the federal MCL of 5 µg/L on a regular basis. Private wells consistently in excess of 5 µg/L occur 1,500 ft west-SW of Building 90 at RFR-10 and OFR-3.

TCE

In the SW corner of CSSA, the TCE degradation plume is co-located within the main PCE plume body in the LGR (**Figure 3.2**). Typically 12 wells are in excess of 1 µg/L, underlying 115 acres of land. Seven wells (CS-MW36-LGR, CS-WB01 through CS-WB04, OFR-3, and RFR-10) routinely exhibit concentrations in excess of 5 µg/L. Multiple wells (CS-MW36-LGR, I10-9, LS-5, LS-6, RFR-11, and RFR-12) and selected intervals of multi-port wells CS-WB01, CS-WB02, and CS-WB04 typically have higher ratios of TCE relative PCE. Over the course of thirteen years, LS-6 and RFR-11 have made the transition of being PCE-dominated to TCE-dominated.

***Cis*-1,2-DCE**

In comparison to Plume 1, *cis*-1,2-DCE is not nearly as pervasive within Plume 2, and thusly its distribution and relative concentration is not as prevalent as PCE or TCE. Where *cis*-1,2-DCE can be found in Plume 1 at relatively equal concentrations with PCE and TCE, its ratio

is much less in Plume 2. Specifically at Plume 2, *cis*-1,2-DCE has been detected in four multi-port wells (CS-WB01 through CS-WB04) and on-post monitoring wells CS-MW36-LGR, CS-MW6-LGR (June 2001 only), CS-MW8-LGR (March 2003 only). And off-post, trace detections (less than RL) have been reported at LS-1, OFR-3, and RFR-10.

3.2.3 Bexar Shale (Layer 3)

Plume 1

To date, only four monitoring wells (CS-MW1-BS, CS-MW6-BS, CS-MW12-BS, and CS-MW9-BS) have been installed to exclusively monitor the BS. While many open borehole wells penetrate the unit within the RFI area, they have been included with the previous discussions regarding the LGR plumes. PCE, TCE, and *cis*-1,2-DCE are only detected within the BS at CS-MW1-BS. With the exception of *cis*-1,2-DCE (1.38 µg/L) and toluene (26 µg/L) at CS-MW1-BS, the VOC concentrations were reported at trace levels between the MDL and RL. While the representations of a single-point plume likely do not represent the true distribution of trace contamination within the BS, the current subsurface studies thus far indicate that the BS has been minimally impacted. As an example, trace detections of VC have been consistently reported in CS-MW12-BS (11 of 18 samples) and less often in CS-MW9-BS (December 2002 and March 2003). The occurrence of VC in the BS is notable considering the rarity of detections within the LGR and CC as compared to its occurrence in the BS.

Plume 2

Only one BS well (CS-MW6-BS) is located in the vicinity of AOC-65. During the monitoring period (December 2002 through December 2013), trace detections of toluene, naphthalene, methylene chloride and *cis*-1,2-DCE have been reported in groundwater samples from that well. The occurrence of these compounds is sporadic, and some compounds may be associated with laboratory contamination (methylene chloride). The same compounds at comparable concentrations have also been reported in the LGR and CC counterpart wells at the CS-MW6 monitoring cluster.

3.2.4 Cow Creek (Layer 4)

To date, a total of eight wells have been completed exclusively within the CC Limestone. Both methylene chloride and toluene are the primary VOC analytes detected within the CC wells, usually at trace concentrations below the CSSA RL. Infrequent and isolated detections PCE, TCE, and VC have been reported at trace concentrations within the CC portion of the Plumes 1 and 2 areal extents. The exception to this generalization is where long-term cross-connection between the LGR and CC has occurred within open borehole well completions (CS-MW16 area).

Plume 1

Prior to September 2003, a solitary trace detection of *cis*-1,2-DCE was reported in CS-MW9-CC during the March 2003 event. While trace detections of methylene chloride and toluene have been reported in the CC wells, the lack of PCE, TCE, and *cis*-1,2-DCE in this unit was notable. By September 2003 well CS-MW16-CC had been incorporated into the monitoring network and changed the perception of on-post contamination within the CC unit.

Investigation data indicate that the CC has been impacted near Plume 1. However, current distribution data shows that the CC portion of Plume 1 is mostly confined to the area near the source, specifically near well CS-MW16-CC and nearby multi-port well CS-WB05 at the Bioreactor. At this time it is unclear whether contaminants have migrated downward through the BS, or whether inter-aquifer contamination has occurred as a result of open borehole completions in former water supply wells. The findings at CS-MW16-CC and CS-WB05 would seem to indicate that open borehole cross-contamination between units was a prime mechanism for the vertical migration of contaminants. This is supported by the hydraulic data that indicates that a downward vertical gradient exists over much of the year, and lack of significant CC contamination elsewhere on the post.

Through more than 10 years of Plume 1 monitoring, the target analytes (PCE, TCE, and DCE) have never been reported in CS-MW9-CC (upgradient), CS-MW1-CC (downgradient), and MW2-CC (downgradient). A single trace detection of vinyl chloride (0.14 µg/L) was reported once in CS-MW12-CC (downgradient) in December 2013.

Plume 2

For the December 2002 through December 2012 groundwater monitoring events, Plume 2 within the CC is characterized by a sporadic occurrences of PCE, TCE, and *cis*-1,2-DCE at trace concentrations slightly in excess of the MDL. Between September 2004 and December 2009, PCE and TCE had been consistently detected in well CS-MW8-CC at trace concentrations below the RL. However, these detections have subsided since that time. Routinely, trace concentrations of methylene chloride and toluene are also reported in the CC strata within the confines of Plume 2. While the VOC detections within the CC is puzzling, it may be related to the occasional northward gradient that has been observed within CC wells around AOC-65, or to open borehole construction of former supply wells (such as CS-6, which was plugged in 1996), or active municipal and domestic supply open borehole wells in the area.

3.3 EXTENT OF INORGANIC CONTAMINATION

As previously discussed in Section 3.1, inorganic concentrations of arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc are routinely sampled from on-post wells. Although there have been some metals exceedances above the MCL on-post, they have been sporadic and limited largely to wells located in the interior areas of the post. **Table 3.3** summarizes the detections of inorganic compounds above either the MCL or action level (AL). **Figure 3.6** illustrates the wells with historical inorganic concentrations above the MCL.

Lead has the highest frequency of detection and widest distribution of any inorganic detected in CSSA groundwater, though detections above the action level have been sporadic, both temporally and spacially. Of the 15 wells with lead detections above the action level of 0.015 mg/L (of 51 total sampled), nine of them are older agricultural or domestic water supply wells that have open borehole completions. Concentrations above the MCL have ranged from 0.015 mg/L (CS-1 and CS-9) to 0.25 mg/L (CS-2, its only above-action level detection, which occurred in 1995).

It would seem that the open borehole wells with minimal surface casing are most prone to the lead detections at CSSA. Materials issues associated with well casing, piping, or the pumping apparatus may also play a role in the detection of lead in these wells. The inactive

agricultural wells are now used for environmental groundwater monitoring, while most of the production wells (CS-1 and CS-10) are still actively utilized.

Table 3.3 Historical Occurrences of Inorganics above the MCL (1995-2014)

Table 3.3 Continued

Figure 3.6 Historical Occurrences of Inorganics above the MCL (1995-2014)

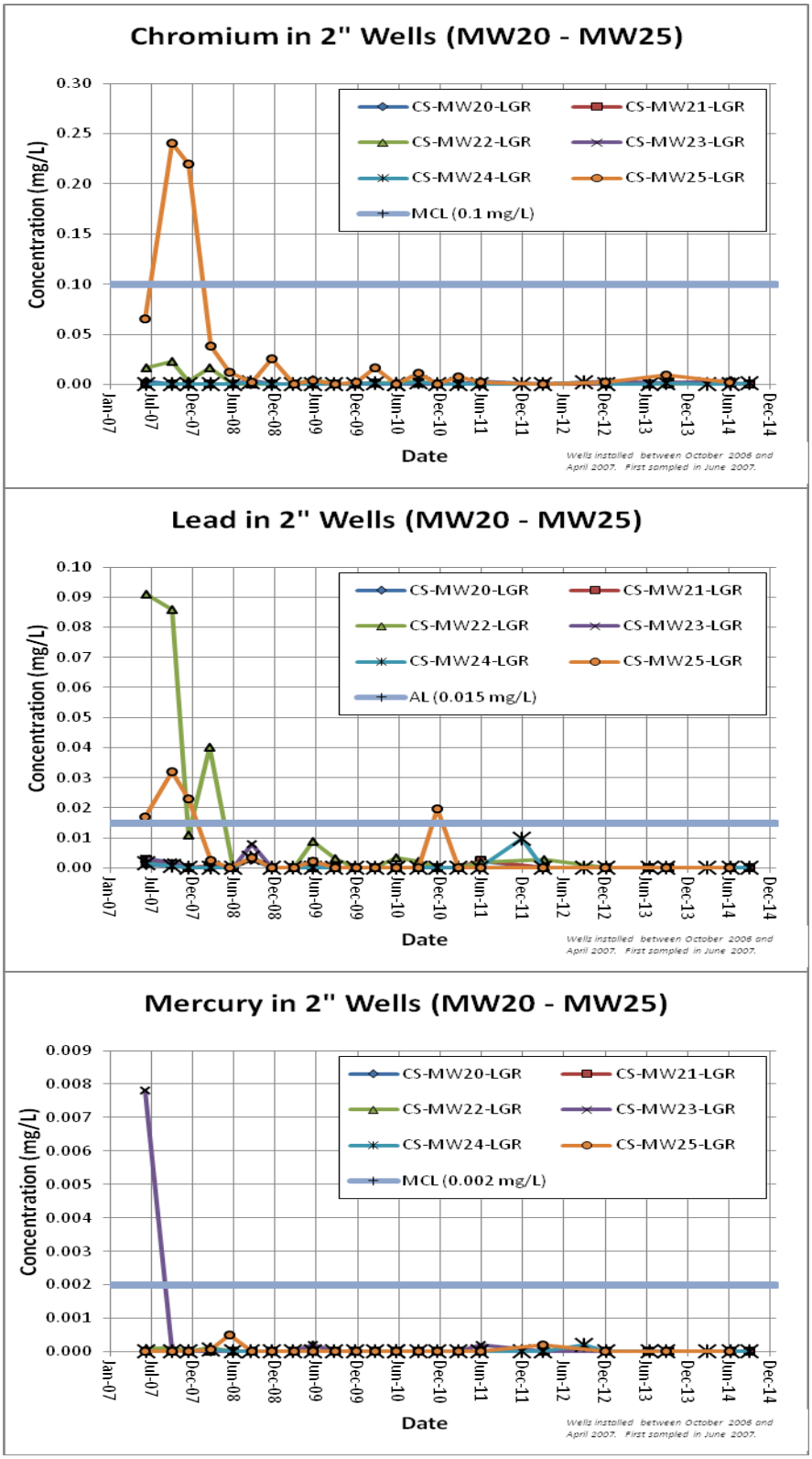
In 2007, six new LGR wells (CS-MW20-LGR through CS-MW25-LGR) were drilled at CSSA. The initial sampling results in June 2007 indicated the presence of mercury, chromium, and lead in three of these wells (CS-MW22-LGR, CS-MW23-LGR, and CS-MW25-LGR). Inorganics above the MCL or AL included mercury in CS-MW23-LGR, chromium in CS-MW25-LGR, and lead in CS-MW22-LGR and CS-MW25-LGR. As shown in Figure 3.7 and Appendix B, the notable trend of these wells over 21 (or more) sampling events is that following the initial quarterly sampling events (four or less), the concentrations of all these metals decreased below their MCL/AL criteria. In particular:

- Mercury was only reported once above the MCL during the initial June 2007 sampling event at CS-MW23-LGR, with no detections in the following 20 sampling events.
- Initially chromium exceeded the MCL in CS-MW25-LGR during the 2nd and 3rd sampling event, but has not been reported above the MCL in the 18 sampling events following December 2007.
- Three of the initial four sampling events at CS-MW22-LGR resulted in lead concentrations in excess of the AL. The 17 subsequent sampling events following March 2008 have all been below the AL.
- Lead in CS-MW25-LGR groundwater was above the AL for the first three sampling events, with only one occurrence since that time in December 2010.

The notable trend of these particular wells is that inorganic constituents in groundwater have attenuated within a year of their initial sampling event in June 2007. With the exception of a single detection of lead above the MCL in December 2010, this set of wells has not exceeded regulatory thresholds since March 2008. At least two wells (CS-MW22-LGR and CS-MW25-LGR) are in the proximity of known inorganic contamination sites (SMWUs DD and B-8, respectively).

Another commonality between these six wells is that they are the only 2-inch diameter LGR monitoring wells on-post. This set of wells was a departure from the traditional 4-inch monitoring wells usually installed at CSSA. The benefit the lower cost 2-inch wells provided was installation of an increased number of monitoring points. From an installation perspective, the 2-inch and 4-wells differed by well development methodology. The traditional 4-inch wells are developed with high capacity submersible pumps after the installation of the well casing and gravel pump. However, the depth and narrow diameter of the 2-inch wells precluded the use of a high capacity development pump. Therefore, each boring for the 2-inch well was developed by air lifting and high capacity pumping prior to the installation of the well materials. This difference in well development styles may account for an attenuation trend that is noted in Figure 3.7 as the natural groundwater conditions was restored to the screened intervals of these wells.

Figure 3.7 Occurrences of Inorganics in 2-inch Wells (2007-2014)



Since 1995, cadmium has only been reported above the MCL of 0.005 mg/L three times out of more than 1,000 basewide samples collected, with concentrations ranging between 0.007 mg/L and 0.008 mg/L. These include singular detections in wells CS-2 (1995), CS-MWH-LGR (1996), and CS-MW2-CC (2007). Chromium is similar in nature with only four detections in wells CS-MW1-LGR (2009), CS-MW9-LGR (2013), CS-MW25-LGR (two in 2007). These concentrations have ranged between 0.102 mg/L and 0.24 mg/L, with an MCL of 0.1 mg/L.

One instance of mercury has been reported above the MCL (0.002 mg/L) at CS-MW23-LGR in June 2007 (0.0078 mg/L). Thus far, the detection has been an isolated occurrence and non-repeatable. However, mercury has been frequency detected in former water supply well CS-9 since June 2006, when the well was rehabilitated and deepened. Mercury has been reported above the MCL (0.002 mg/L) in CS-9 in 10 of the last 16 sampling events (June 2006 through December 2012). Mercury concentrations have ranged from 0.0022 mg/L (2010) to 0.018 mg/L (2011).

Prior to the CS-9 well rehabilitation effort in June 2006, inorganic exceedences of lead and mercury had not been an issue. During that effort, the well was deepened to expose more of the CC production interval. During that exercise old pieces of broken column pipe and presumably a former well pump were encountered within the accumulated sediment in the base of the borehole. The legacy equipment could not be recovered from the borehole, so it was encapsulated in Portland cement. However, since the time the equipment was exposed by the drilling action, the well has had lead and mercury issues. As a result, supply well CS-9 has been deactivated from the potable water supply system.

Currently metals are not sampled at off-post locations due to the minimal or lack of on-post metals detections exceeding MCLs. With the exception of one location, historical samples obtained for off-post wells between 1995 and 2001 did not yield any metals concentrations above the MCLs. For the one well that exceeded the lead MCL, the 1996 follow-up sample resulted with no lead detection. Additional data from local water utility purveyors demonstrated that no public water wells exceed the MCLs for metals constituents.

3.4 CONTAMINANT FATE AND TRANSPORT CONCEPTS

The fate of a contaminant in the environment is the length of time it is present in an unsafe form. The environmental fate considers whether a contaminant is persistent in environmental media, and into which media a contaminant will partition. Specific properties of the media and the contaminants determine which mechanism will have the dominant effect on the length of time a contaminant remains in the environment. Factors that affect the fate of a contaminant in the environment include mass transport and chemical degradation. These concepts are discussed in the following sections.

3.4.1 Mass Transport

Mass transport is the movement of hazardous constituents within a medium, or from one medium to another. Media that act as migration pathways include soil/rock in the unsaturated zone, groundwater, surface water, or air. Soil and rock properties such as chemistry and organic content, air temperature and pressure, and soil and water quality affect migration of contaminants. The characteristics of the contaminants also affect the potential for contaminant migration.

Primary transport mechanisms that may occur in the CSSA study area are volatilization, dispersion, dissolution, advection, and adsorption. Adsorption refers to the binding of metals or organic compounds to the soil, sediment, or rock. Some compounds adsorb more strongly to the clay fraction of a soil or sediment, while many organic compounds and some metals adsorb more strongly to the organic fraction. In these cases, the higher the organic content in the soil, the less mobile these constituents will be. Sorption is defined as the accumulation of a chemical in the boundary region of the soil-water system. Factors affecting sorption include the physical makeup of the geologic media through which the contaminants are moving. The clay content, the specific surface area, and the cation exchange capacity of the media affect the sorption of a contaminant.

Advection, sorption, dispersion, and diffusion are processes that are more descriptive of contaminant migration in groundwater than soils. As mass transport process, advection contributes to the physical spreading of contaminated groundwater by carrying it with the inherent groundwater flow. The groundwater flow velocity depends on physical characteristics of the medium such as hydraulic conductivity, gradient, and effective porosity. Contaminants undergoing adsorption during advection will move at a rate less than the groundwater velocity. The retardation factor, R, describes the proportion of a contaminant undergoing adsorption during advection. For example, if the retardation factor is 2, the pollutant will move half as fast as the water.

Dispersion is also a mass transport process. Mechanically, dispersion is the spreading out of a contaminant plume caused by differences in water velocities in larger or smaller pores of the soil or rock. Typically, the effects of advection are much greater than the effects of dispersion in most cases. However, if groundwater velocity is very low, dispersion may be the dominant transport mechanism. Finally, diffusion is the molecular movement from areas of high concentration to areas of low concentration within a single medium. Diffusion is the dominant mechanism only when velocity and retardation factors are negligible.

3.4.2 Contaminant Degradation

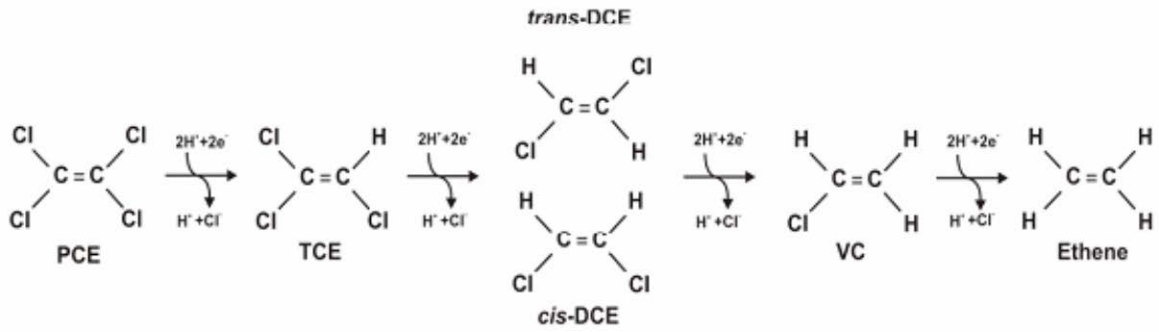
Degradation is likely to be the primary mechanism affecting the fate of contaminants in groundwater. Properties of organic compounds that are used to assess degradation include the degradation rate, the solubility, and the toxicity of the compound to bacteria in soil. The fate of metals is controlled by other properties. Metals may be converted into more innocuous forms by complexation and precipitation. Complexation is the mechanism by which metal ions are bound by larger molecules present in the aqueous fraction of the system. Precipitation is the formation of an insoluble metal compound.

PCE was the primary solvent used at CSSA, with some records indicating that TCE may have also been used for a period. Typically, TCE and *cis*-1,2-DCE are natural degradation products of PCE. These compounds result from of dehalogenation (dechlorination) processes that occur in aerobic or anaerobic metabolic environments. The degradation of PCE can lead to the production of seven chlorinated volatile hydrocarbons. The transformation pathway for various chlorinated volatile hydrocarbons in environment is shown in **Figure 3.7**.

Research has shown that there are several mechanisms, which result in the dehalogenation (e.g., dechlorination) of some classes of organic contaminants. These include stimulation of metabolic sequences through introduction of electron donor and acceptor combinations; addition

of nutrients to meet the needs of dehalogenating micro-organisms, possible use of engineered micro-organisms, and use of enzyme systems capable of catalyzing reductive dehalogenation (EPA, 1991).

Figure 3.8 Transformation Pathways for PCE within Environmental Systems



An organic chemical is said to be reduced if it undergoes a net gain of electrons as the result of a chemical reaction (electron acceptor). Conversely, an organic compound is said to be oxidized if it undergoes a net loss of electrons (electron donor). Under aerobic environmental conditions, oxygen commonly acts as the electron acceptor when present. However, when oxygen is not present or has been depleted, microorganisms can use organic chemicals or inorganic anions as alternate electron acceptors under metabolic conditions referred to as fermentative, denitrifying, sulfate-reducing, or methanogenic. Generally, organic compounds present at a contaminated site represent potential electron donors to support microbial metabolism. However, halogenated compounds can act as electron acceptors, and thus become reduced in the reductive dehalogenation process, which is the replacement of a halogen on an organic molecule by a hydrogen atom (EPA, 1991).

The process listed in **Figure 3.8** shows PCE converting to TCE via reductive dehalogenation. Likewise, TCE is reductively dehalogenated to either 1,1-DCE, *cis*-1,2-DCE, or *trans*-1,2,-DCE with hydrogen (H_2) and hydrochloric acid (HCl) by-products. In general, reductive dehalogenation of tetra- and tri-halogenated carbon atoms (PCE and TCE, respectively) is easier than di- or monohalogenated molecules, which is why many metabolic reactions appear to stall at the generation of DCE isomers. In the presence of favorable conditions, the DCE isomers can reductively dehalogenate to vinyl chloride, which is then easily converted to ethane via further reductive dehalogenation.

The environmental conditions in the subsurface at CSSA have favored the reductive dehalogenation processes that convert PCE to TCE, then DCE. The generation of *trans*-1,2-DCE is less common, and is specifically limited to wells within the Plume 1 vicinity (CS-16-LGR, CS-D, CS-MW1-LGR, and CS-MW2-LGR). Trace concentrations slightly greater than the laboratory method detection limits (MDL) of vinyl chloride have been reported in as many as 11 monitoring wells. Many of these occurrences were single detections at a well location, but do indicate that a minor amount of DCE is being reduced to vinyl chloride by dehalogenation. However, for the most part, the degradation process at CSSA appears to stall after the generation of *cis*- and/or *trans*-1,2-DCE. Concentrations of PCE, TCE, and DCE exceed MCLs within the RFI area. At sites like SWMU B-3 where active remediation is occurring, VC is present in all

four of the Westbay multi-port wells and injection trench well sumps in excess of the MCL (2 µg/L). At AOC-65, only a handful of vinyl chloride trace concentrations have been reported at levels below the RL in the multi-port wells (CS-WB01, CS-WB03, and CS-WB04).

3.5 CONTAMINANT FATE AND TRANSPORT AT CSSA

This section conceptualizes the fate and transport mechanisms that are active at CSSA, and have ultimately dictated the distribution of contaminants within the Middle Trinity aquifer. The contamination will be addressed by source area and plume to help tie together the observations and measurements that have been collected during the course of the investigations. As described in previous sections, the occurrence of VOCs seems primarily limited to the LGR section of the Middle Trinity aquifer, and is reflected as such in the graphics. The occurrence of significant CC contamination is associated with well CS-MW16-CC as a result of the long-term open borehole completion of former CS-16 next to the SWMU B-3 source area. The occurrence of PCE contamination above the MCL of 5 µg/L within Plume 1 is contained within the facility. Plume 2 has migrated off post which has resulted with off-post MCL exceedances at the southwest corner of CSSA.

3.5.1 Source Area

Since 1996, extensive investigations have been completed to identify and define the potential source areas responsible for the occurrence of Plume 1 in CSSA groundwater. A series of geophysical surveys, soil-gas surveys, soil characterizations, and source removal investigations has led to the conclusion that SWMUs B-3 and O-1 were responsible for the VOC contaminants detected in well CS-16 and elsewhere since 1991. The actual contaminant source included solvents that were either disposed into an oxidation pond (O-1 or used as an accelerant for refuse burning within landfill cells (B-3). Likewise, beginning in 1999, investigations were completed to identify and define the potential source areas responsible for the occurrence of Plume 2 in CSSA groundwater. The actual contaminant source included solvents that were used and stored in vats within the building, or associated with discharges from a drain line to the nearby drainage ditch.

Regardless of the site, once the solvents were introduced to the environment, it was subjected to volatilization, and sorption to organic fractions of the soil and/or rock, or it migrated deeper into the stratigraphic profile by gravity, flushing, or meteoric waters. For the portion of contamination that remained within the source area, that fraction proved to be susceptible to volatilization and degradation. Soil-gas surveys and near-surface sampling has demonstrated that significant quantities of solvents remain within the disposal units, and that the degradation process of PCE is occurring, primarily due to large concentrations of DCE isomers now measured within the subsurface. For these portions of the solvent release, CSSA has implemented source removal via vapor extraction and waste removal by excavation and disposal at both plume source areas. In addition, CSSA constructed a Bioreactor at SWMU B-3 (Plume 1) in 2007 to stimulate biologic processes metabolically degrade the solvent contamination by metabolic processes. More recently, CSSA has implemented an ISCO initiative at AOC-65 to chemically oxidize the source area solvents to reduce the overall contaminant mass in the subsurface.

3.5.2 Vadose Zone

For the fraction of contaminants that mobilized beyond the source area, the solvents may migrate as a dense, non-aqueous phase liquid (DNAPL), and/or it may partition to the groundwater and soil-gas phases of the environment. Of particular interest is the determination if DNAPL still is present in the subsurface, providing a continual source for groundwater contamination. Its presence can be determined by direct observation in soil or groundwater, or by inference based upon contaminant concentration within an affected media. Current guidelines suggest that DNAPL may be present when contaminant concentrations are found in excess of one percent of their solubility in water.

For PCE, TCE, and *cis*-1,2-DCE, a one percent concentration of their solubility in water corresponds to 1,500 µg/L, 11,000 µg/L, 35,000 µg/L, respectively. Thus far, only PCE has been consistently encountered in the vadose zone above the one percent solubility guideline. At AOC-65, concentrations up to 30,000 µg/L have been reported at CS-WB03-UGR01 (March 2008) and 64,210 in TSW01 (August 2012). Likewise, PCE concentrations above 1,500 µg/L have also been reported in SWMU B-3 vadose monitoring zones which occasionally yield groundwater after prolific precipitation events. The occurrence of contamination in groundwater above this one percent threshold are indicators that DNAPLs do persist in the near-surface soils/rock, and that continual flushing of DNAPL is occurring from the contaminant source areas.

Because DNAPLs have a specific gravity greater than water, they are able to penetrate through and below perched groundwater bodies and fractured strata that may otherwise be relatively impervious to groundwater. Within the vadose zone, a DNAPL will migrate downward, while succumbing to the mechanisms of dispersion and diffusion. Within fractured bedrock, these processes can be complicated by the erratic network or fractures and karstic features that act as preferred migration pathways. The chaotic nature of fracture and karst patterns are not well understood, but are expected to be the primary mechanism that allowed contaminants to seemingly migrate upgradient to CS-16 where it was detected in 1991. The long-term pumping of CS-16 as a supply well likely provided enough capture gradient to assist the northward migration of contaminants.

Along these pathways, DNAPLs can pool, where they may either enter the actual matrix of the rock, or be flushed by infiltrating water. The flushing effect is crucial for the solvent contamination to reach the main body of the aquifer. During precipitation events, infiltrating groundwater picks up and pushes the solvent advectively in the path of least resistance downward. In the instance of B-3 Bioreactor, the backfilled nature of the overlying source area can exacerbate the recharge effect because the higher porosity backfill (bark mulch) is expected to accumulate and transmit greater quantities of groundwater downward than what may be expected within the natural stratigraphic horizon, thereby delivering the substrate to deeper portions of the affected area. In contrast, CSSA placed an impermeable cap on O-1 prior to closure in an effort to reduce, if not eliminate those recharge pathways to minimize the amount of recharge through the source area.

3.5.3 Phreatic Zone

Dispersion of the solvent occurs as it migrates downward through faults, fractures, and karstic voids. The depth that groundwater occurs can fluctuate drastically with seasonal rainfall.

For this report, the main body of the LGR aquifer is considered to be the basal 60 ft of the unit. However, groundwater does occur as much as 200 ft above the main body of the aquifer. Water-bearing strata and structure perched above the basal aquifer tends to be low-yielding, and its presence directly correlates to the recent environmental conditions.

Discrete interval groundwater sampling around AOC-65 indicates that the higher concentrations of solvent contamination are often associated with the lower yielding units that are stratigraphically higher than the main aquifer body. While the contamination dilutes and attenuates in the basal unit around AOC-65, this is clearly not the case within Plume 1. Wells CS-16-LGR, CS-MW1-LGR, CS-MW2-LGR, CS-MW5-LGR, extraction wells CS-EXW01 through EXW05 have demonstrated that groundwater contamination in excess of the MCLs exists within the main body of the aquifer. This would indicate that the source of contamination was either large enough to allow DNAPL to penetrate deep to this depth, or sufficient time has elapsed to carry the bulk of contamination downward into the LGR. However, concentrations within the Middle Trinity Aquifer do not indicate that DNAPL is present in the main body of the aquifer.

3.5.4 Plume 1 Groundwater

While the concentrations detected in groundwater do not strongly suggest that DNAPL is present within the production zone of the aquifer (less than 1 percent of the solvent solubility), significant residual contamination must persist near the source area. Slugs of contaminated percolating recharge continue to diffuse into the main body of the aquifer, where it is advectively transported in down gradient vectors. Along the main gradient path, sampling results indicate that a PCE dilution/attenuation factor of roughly 15 is occurring over the 1,530-foot distance between the plume center (CS-WB07 at 282 µg/L) and southward (CS-MW1-LGR at 17 µg/L). With the exception of the interior of plume centered around SWMU B-3, the remaining groundwater wells outside of 2,500 feet of the source area are below MCLs.

Advectively transported groundwater plumes in granular media tend to be long and narrow, which does not describe the PCE plume shown in **Figure 3.1**. Dispersion of the contaminants is occurring within Plume 1 by multiple paths of advection, likely due to structural features within the rock. Flow through these structural features, such as karst or fractures, may be controlling factors during abnormally high and low precipitation cycles, and may account for the multiple directions of plume migration. Notable is the SW migration of Plume 1 from the source area. It is hypothesized that the continual long-term pumping of the CSSA well field (CS-9, CS-10, and CS-11) and residential wells in Jackson Woods subdivision have resulted in migration of a portion of the plume southwestward along the fractures associated with faulting. The collective pumping of the communities and residences west of Ralph Fair Road has likely facilitated the migration of the contaminant plume along preferential pathways.

The geometry of the plume is also probably a function of the types of well construction used in the area. Most of the CSSA monitoring wells are constructed to monitor relatively short segments of the aquifer. The design is appropriate in reducing the possibility of further cross-contamination between strata, but also limits the amount of detections that may be measured at a location. This point has been well demonstrated at CS-MW8 where significant contamination was encountered in the upper 300 ft of strata, yet the final 25 ft monitoring point within the main aquifer body is essentially free of contamination. Given that most off-post wells are open

borehole completions with minimal surface casing, these wells are more susceptible to detections of contaminants that occur within upper strata of the Glen Rose.

The presence of open borehole completions is also suspected to result in the minimal contamination of the underlying BS and CC. Within an open borehole, the predominant downward vertical component of flow allows for the co-mingling and loss of LGR groundwater into the CC Limestone. Conceptually, this draining effect through fully penetrating small diameter boreholes is minimal given the large area of the site.

The natural attenuation of the PCE and TCE solvents appears to be occurring within the aquifer. The presence of *cis*-1,2-DCE within the Middle Trinity aquifer is attributable to the reductive dehalogenation of PCE and TCE. Those fractions of the plumes appear to coincide with the location of Salado Creek. As a recharge feature with potentially increased porosity, Salado Creek may facilitate the favorable conditions required for the metabolic reduction of the solvents. To date, only very few instances of vinyl chloride have been detected in groundwater samples outside of the remediation areas, indicating that the natural attenuation of PCE is stalling at *cis*-1,2-DCE. This can occur within a plume as the available electron donors are consumed during the biodegradation process.

3.5.5 Plume 2 Groundwater

Plume 2 appears to quite smaller than Plume 1. Drilling at the AOC-65 source area has shown that significant impact to the upper strata of the UGR and LGR has occurred. The results of multi-level monitoring in the Westbay wells clearly depict how contaminant concentrations attenuate with depth. In the CS-WB03 example given in **Figure 3.7**, In the UGR zone, PCE concentrations have ranged between 1,700 µg/L and 30,000 µg/L. Whereas the immediately underlying LGR zones (LGR01 and LGR02) typically range between 140 µg/L and 2,500 µg/L. Below that depth, the remainder of the LGR zones (LGR03 through LGR09) are all less 100 µg/L, with concentrations progressively decreasing with depth. Since March 2011, the PCE concentration in lowermost zone (LGR09) has typically been below the MCL.

A series of investigations which included seismic, direct current resistivity, AEMs, and ground truthing by drilling has indicated that a series of stepwise normal faults occur within the Plume 2 vicinity. Given the location of the source area at Building 90, the contaminant plume has spread in all directions southward of the source area. Within the LGR unit, the center of the plume has appeared to have moved westward towards RFR-10, rather than southward as would be expected by advection with the overall regional groundwater gradient.

Several faults inferred by the USGS (**Figures 3.1, 3.2, and 3.3**) are located in the same area as Plume 2, and the distribution of contaminants is suspected to be related these fault locations. Wells with more elevated concentrations (RFR-10, RFR-11, LS-6, and LS-7) are positioned very close to the known faults. The orientation of the faults line up favorably between the Building 90 source area and wells with known contamination above the MCLs. The measured concentrations of contaminants within Leon Springs Villa and Hidden Springs probably resulted from the advective forces associated with the overall regional gradient towards the south and enhanced by groundwater pumping for potable water systems. Contaminated groundwater, which has migrated southward across fault planes, is notably lower in overall concentrations, and are diluting as they are dispersed.

As with Plume 1, the shape of the plume is also probably a function of the types of well construction used in the area. Most of the CSSA monitoring wells are constructed in such a fashion to observe relatively short segments of the aquifer. The design is appropriate in reducing the possibility of further cross-contamination between strata, but also limits the amount of detections that may be measured at a location. Given that most off-post wells are open borehole completions with minimal surface casing, these wells are more susceptible to detections of contaminants that occur within upper strata of the Glen Rose.

The presence of open borehole completions is also suspected to result in the minimal contamination of the underlying BS and CC in the vicinity of Plume 2. Within an open borehole, the predominant downward vertical component of flow allows for the co-mingling and loss of LGR groundwater into the CC limestone. Conceptually, this draining effect is minimal given the large area of the HCSM. CSSA has demonstrated that wells with adequate casing are far less susceptible to producing contaminated water that resides in the upper strata of the LGR.

Natural attenuation processes presumably are in effect given the presence of TCE and *cis*-1,2-DCE within Plume 2. Data indicates that dehalogenation is occurring within the interior of the plume where favorable anaerobic conditions are present. As with Plume 1, there seems to be insufficient electron donors to continue the degradation beyond *cis*-1,2-DCE. As would be expected, the relative contaminant concentrations in groundwater are inversely proportional to distance from the source area.

Table 3.4 lists the average concentration of PCE and TCE within the multi-port monitoring zones at Plume 2. The data reflects the dates between January 2004 and March 2014, and represent data collected after the timeframe at which natural groundwater conditions had been restored following installation activities. As seen in **Table 3.4**, relative contaminant concentration decreases away from the source area (near CS-WB03) towards the south (CS-WB01) and southwest (CS-WB04). The table also indicates that the degradation of PCE to TCE is occurring as the plume migrates downgradient. In the UGR and LGR monitoring zones were both PCE and TCE are present, the average ratio of PCE to TCE decreases from 9.63 at the source area (CS-WB03) to 1.58 at the furthest downgradient position (CS-WB04). These relationships indicate that within 500 feet, the contaminant plume has degraded such that TCE has become the major constituent within select intervals.

Table 3.4 Ratio of PCE and TCE in Multi-Port Zones

Other generalized conclusions based on the ratio analysis in **Table 3.4** is that PCE is the predominant component of contamination in the upper zones (UGR[E], LGR[A], and LGR[B]), whereas TCE becomes an equivalent, or primary constituent in the lower portion of the aquifer (LGR[C] through LGR[F]). The data suggests that less biodegradation is happening in the upper strata that is only periodically saturated, and the solvent contamination persists in its original chemical form of PCE. It would also appear that undegraded PCE can travel some distance from the source area to CS-WB04 (>1,200 feet) with minor degradation in the uppermost intervals. This may suggest that the PCE is highly mobile during flood (flushing) events through preferential pathways, covering large distances quickly before degradation mechanisms can occur. However, this premise is based upon a single occurrence of PCE (9.51 µg/L) in CS-WB04-UGR after extreme precipitation events in November 2004. The occurrence and transport of VOC contamination beneath CSSA is described in Section 2.1.6. Nearly all VOC source releases (including B-3, O-1, and AOC-65) have occurred within the UGR limestone.

SECTION 4
POTENTIAL RECEPTORS

CSSA is located in northwestern Bexar County approximately 19 miles NW of downtown San Antonio. At one time located in a rural setting, sprawling development of the San Antonio metroplex has encroached upon the facility, placing it adjacent to residential and commercial properties. This section describes the potential risk to human and ecological receptors from exposure to the remaining COCs at CSSA.

4.1 HUMAN RECEPTORS

Based on the current land uses, potential on-post receptors include current/future residents, current/future commercial/industrial workers (including military personnel), current/future site visitors/recreational users (including hunters), future construction/excavation workers, and ecological receptors. Potential receptors off-post include current/future residents, current/future commercial/industrial workers (including agricultural workers and ranchers), current/future site visitors/recreational users, future construction workers, and ecological receptors.

A human health risk assessment (HHRA) was conducted in 2013 to satisfy the requirement set forth by the Order (Parsons 2014a). The risk assessment was approved by USEPA on April 21, 2014. Because the SWMUs, AOCs, and applicable RMUs have undergone remediation associated with closure under RRS and TRRP (except those sites associated with RMU-1), the soil exposure pathways are incomplete exposure pathways for all receptors. Additionally, no contaminants of potential concern (COPCs) were identified in the indoor air, so the inhalation of volatiles from vapor intrusion into indoor air exposure pathways are incomplete.

Six groundwater COPCs were evaluated in the HHRA: cis-1,2-DCE, PCE, TCE, vinyl chloride, lead, and mercury.

The cumulative hazard risk ratios for noncarcinogenic contaminants of concern for the off-post wells were less than 1, indicating no noncarcinogenic hazard is expected due to exposure to the groundwater as a potable water source. Lead was evaluated separately from other COPCs. The lead risk ratios for the off-post wells were less than 1, indicating no hazard is expected due to exposure to lead in potable groundwater.

Based on the results of the HHRA and a review of the risk assessment objectives, unacceptable risks to human health may occur in some locations off-post from exposure to contaminants in groundwater at CSSA (**Figures 4.1** through **4.5**). Cumulative carcinogenic risks greater than the USEPA acceptable range of 1×10^{-4} to 1×10^{-6} were calculated in several off-post wells (**Figures 4.1** and **4.2**). The highest cumulative carcinogenic risk calculated using the PCLs was in well RFR-10, while the highest cumulative carcinogenic risk calculated using the RSLs was in well LS-5. As described previously, the risk assessment evaluated samples collected before GAC treatment. Both wells RFR-10 and LS-5 are equipped with GAC units.

Unacceptable risks to human health may occur in some locations on-post from exposure to contaminants in groundwater at CSSA (**Figures 4.1** through **4.5**). There are several locations on-post with cumulative noncarcinogenic hazards greater than 1 (**Figures 4.3** and **4.4**). The highest cumulative hazard was calculated in well CS-9. Additionally, cumulative carcinogenic risks

Figure 4.1 Carcinogenic Risk Based on TRRP PCLs for Current/Future Residents

Figure 4.2 Carcinogenic Risk Based on USEPA RSLs for Current/Future Residents

Figure 4.3 Noncarcinogenic Hazard Based on TRRP PCLs for Current/Future Residents

Figure 4.4 Noncarcinogenic Hazard Based on USEPA RSLs for Current/Future Residents

Figure 4.5 Lead Hazard for Current/Future Residents

greater than the USEPA acceptable range of 1×10^{-4} to 1×10^{-6} were calculated in several on-post wells (**Figures 4.1** and **4.2**). The highest cumulative carcinogenic risk was calculated within the LGR geologic unit of Westbay well CS-WB05-LGR.

Hazards due to exposure to lead in groundwater may occur in some on-post locations. The highest lead hazard was calculated for well CS-11 (**Figure 4.5**).

4.2 ECOLOGICAL RECEPTORS AND SENSITIVE ENVIRONMENTAL RESOURCES

4.2.1 Ecological Receptors at CSSA

CSSA supports a variety of wildlife similar to the surrounding region. Several game species are known to occur at the installation, including: white-tailed deer (*Odocoileus virginianus*), axis deer (*Axis axis*), wild turkey (*Meleagris gallopavo*), dove (*Zenaida macroura*), ducks, quail, rabbits (*Lepus californicus* and *Sylvilagus floridanus*), squirrel (*Sciurus niger*), raccoon (*Procyon lotor*), and coyotes (*Canis latrans*). Other species that may be found at CSSA include skunk (*Mephitis mephitis*), opossum (*Didelphis marsupialis*), ring-tailed cat (*Bassariscus astutus*), bobcat *(Lynx rufus*), and a variety of rodent species (SAIC, 1997b).

Bird surveys conducted at CSSA between mid-March and early June of 2005 and 2007 documented 106 bird species at the installation. The list of observed species is provided in the species and habitat distribution report (Parsons, 2007c). The list includes two federally listed endangered species, the black-capped vireos (BCVI) (Vireo atricapillus) and golden-cheeked warblers (GCWA) (Dendroica chrysoparia). These two species are discussed in more detail Section 4.2.2.

4.2.2 Threatened or Endangered Species

The *Final Integrated Natural Resource Management Plan* (INRMP) for CSSA (Parsons, 2013) provides a detailed analysis of federal and state listed species with potential to occur in Bexar County, Texas. This information was obtained from the U.S. Fish and Wildlife Service (USFWS, 2004) and the Texas Parks and Wildlife Department (TPWD, 2005). Several surveys have been conducted at CSSA for threatened and endangered (T&E) species. A general habitat evaluation was conducted in December 1992 and detailed bird surveys were conducted in the spring of 1993 (Stewardship Services, 1993). Based on the known distributions, habitat requirements and existing habitat at CSSA, the listed species are not expected to occur at the installation, with the exception of two: the BCVI and GCWA.

Endangered Species Act (ESA) of 1973 and Army Regulation (AR) 200-3 require the Army to protect animal and plant species that are federally listed as endangered or threatened. The ESA specifically requires agencies not to "jeopardize" the continued existence of any listed species, or to destroy or adversely modify habitat critical to any listed species.

Presence-absence surveys for BCVI and GCWA are conducted in the spring every other year, and past surveys were conducted between April and July in 2005, 2007, 2009, 2011, and 2013. **Figure 4.6** shows primary and secondary bird habitats identified during the 2013 bird survey. In 2013, a total of 36 GCWA and no BCVI were observed at CSSA. This represents is a 27% increase in GCWA from 2011. Although no BCVI detections have occurred at CSSA since

the 2005 survey, suitable habitat is found at various locations in the East Pasture, North Pasture, and Inner Cantonment.

None of the caves or karst features on-post are likely to contain state-listed threatened or endangered karst species due to CSSA's probable location outside of the zones where they occur (Veni 2001). However, during a downhole video camera survey of wells at CSSA, an unidentified salamander was observed in well CS-2 (Parsons 1996). This unidentified salamander could have been a Comal blind salamander or another rare troglobitic salamander. The Comal blind salamander is a state-listed species. The Comal blind salamander occurs in two caves on Camp Bullis and one cave on private property just north of CSSA's northern boundary (Veni 2002).

4.2.3 Ecological Exposure Pathways

The oral exposure route is the primary route of exposure for wildlife. Oral exposure occurs through dietary ingestion of plant or prey tissues containing COPCs that have bioaccumulated in tissue from the source media. Oral exposure can also occur through ingestion of the source media, such as incidental ingestion of the media from feeding, burrowing, or grooming behaviors. Because the oral exposure route is the primary exposure route for wildlife, toxicological data for most common COPCs are available to evaluate risk.

Dermal exposure is assumed to be negligible since COPCs are unlikely to be absorbed through skin. The feathers of birds and the fur of mammals reduce the likelihood of significant dermal exposure by limiting the contact of skin with contaminated soil. Furthermore, data necessary to estimate dermal exposure for wildlife species is generally not available (USEPA, 1993).

Inhalation exposure is assumed to be negligible because the inorganic COPCs identified at CSSA (metals) are not volatile and because there is abundant vegetation (native grass cover) to minimize the potential for inhalation of volatile compounds and particulates. In addition, in comparison to dietary and incidental ingestion, the effects of exposure through inhalation of COPCs are minimal. Toxicity data necessary to estimate inhalation exposure are generally not available for wildlife (USEPA, 1993).

There are no complete exposure pathways for ecological receptors at CSSA. Because the SWMUs, AOCs, and applicable RMUs have been closed under RRS and TRRP (except those sites associated with RMU-1), surface soil and subsurface soil exposure pathways are incomplete.

Salado Creek flows intermittently east-southeast through CSSA (Figure 3.1) There are no perennial surface water features on-site. The interaction between groundwater and surface water is insignificant for the following reasons:

- Surface water flow is very rare and only occurs after significant rainfall events. When there is surface water flow, the streams are typically "losing" streams, losing their water to groundwater.
- Streatms "gain" water from groundwater very infrequently, only after very significant rainfall events (i.e., 100-year flood levels).

- During events when groundwater would be released to surface water, the stream flow is so high that the contribution of groundwater to surface flow is low. Therefore, any release to surface water during rain events would be diluted.
- Aeration of surface water during overland flow would cause VOCs to volatilize from the surface water.

Therefore, contamination in the groundwater is not expected to migrate to the intermittent surface water and sediment and exposure pathways are incomplete for ecological receptors.

Finally, because the shallow groundwater at CSSA is greater than 50 feet bgs and the interaction between groundwater and surface water is insignificant, ecological receptors are not expected to come into contact with groundwater. Because there are no complete exposure pathways for ecological receptors, an ecological risk assessment was not conducted as part of the baseline risk assessment (Parsons 2014a).

4.2.4 Sensitive Environments

CSSA is not located within a national park, national wildlife refuge, national forest, state, or county park (USFWS, 2012b; National Park Service [NPS], 2012; U.S. Forest Service, 2012). There is no federally designated critical habitat for any T&E species within CSSA (USFWS, 2012a).

4.2.5 Wetlands

Wetlands are land areas that are transitional between terrestrial and deep-water habitats in which the water table usually is at or near the surface or in which the land is covered by shallow water. Approximately 4.3 acres of CSSA's over 4,000 acres are considered wetlands. Wetlands field surveys were conducted at CSSA in 1995 and 1996. Based on the survey results, four jurisdictional wetlands totaling 1.1 acres and seven non-jurisdictional wetlands totaling 3.2 acres are present CSSA. The non-jurisdictional wetlands are all man-made impoundments. However, two impoundments are classified as jurisdictional because they intercept flows from defined channels, springs, or seeps. The other jurisdictional wetlands appear to be associated with either springs or seeps. Jurisdictional delineations were accomplished in the 1980s, well before the Rapanos and SWANCC US Supreme Court cases limited jurisdiction to exclude isolated wetlands, thus it is questionable whether these areas are truly jurisdictional wetlands. The Army Corps and USEPA are now in the process of proposing a new jurisdictional rule that may eventually clarify this issue.

Approximately 32,250 linear feet of ephemeral stream drainages on CSSA have defined channels and are potentially jurisdictional waters of the U.S. (SAIC 1997). However, since these streams are ephemeral (run few days per year) and have no direct or indirect ties to permanently-flowing surface waters, it is questionable whether they are truly jurisdictional waters (**Figure 4.6**).

4.2.6 Cultural and Archaeological Resources

There are 40 known archeological sites at CSSA, seven of which are potentially eligible for listing in the National Register of Historic Places (NRHP) (Kibler and Gardner 1998; Scott *et al.* 1998; Parsons 2014c). Of these sites, 19 are considered historic sites and 21 are considered prehistoric sites. The prehistoric sites were interpreted as open campsites or lithic scatters and

historic sites were either classified as pre-military (before 1906) or military (1906-1945). Military components represented World War I training trenches, utilities, and infrastructure, facility plans, housing properties, service/support properties, and unidentified property types. The pre-military sites included a 19th Century homestead and 20th-century ranches. If work was necessary in one of CSSA's archeological or historical sites, advance coordination with the Texas Historic Commission was required.

4.2.7 Current and Projected Land Use

The present mission of CSSA is the receipt, storage, issue, and maintenance of ordnance as well as quality assurance testing and maintenance of military weapons and ammunition. The facility currently has 14 residences that are occupied by on-site workers and their families. Part of CSSA is undeveloped woodland and is used seasonally for hunting. No changes to the CSSA mission and/or military activities are expected in the future. Camp Bullis borders much of CSSA to the north, east, and south (see Figure 1.1). The area surrounding CSSA is residential with ranching and agricultural land intermingled with the developed communities. Although residential development could continue in the future on the west and south sides of CSSA, no other changes in land use off-post are expected in the future.

Figure 4.6 Environmentally Sensitive and Military Safety Areas at CSSA

SECTION 5
RFI SUMMARY AND CONCLUSIONS

5.1 SUMMARY AND CONCLUSIONS

CSSA is located in northwestern Bexar County approximately 19 miles NW of downtown San Antonio. At one time located in a rural setting, sprawling development of the San Antonio metroplex has encroached upon the facility, placing it adjacent to residential and commercial properties. The CSSA mission, receipt, storage and issuance of ordnance, materiels, as well as, quality assurance testing and maintenance of military weapons and ammunition, is associated with the maintenance of ordnance materiel, the use of industrial solvents as a degreasing agent was implemented from the 1950's through 1990. Citrus-based solvents have now replaced chlorinated solvents. As a result of past operations, releases of PCE to the environment have occurred from multiple source areas within CSSA.

The release of contamination to the environment occurred at several locations, including leaks, spills, and discharges from Building 90 (AOC-65) were degreasing operations occurred, and at landfill/surface impoundments (SWMUs B-3 and O-1) where solvents were discharged. SWMU O-1 was a lined oxidation pond that received waste fluids from the Building 90 operations. Nearby at B-3, spent solvents would be utilized as an accelerant for burning refuse within landfill cells.

The release of solvents to the environment has resulted in contamination of the Middle Trinity aquifer, which is the primary drinking water source for the area. The Middle Trinity aquifer is composed of calcareous mudstones and limestones of the LGR Limestone, BS, and CC Limestone. Locally, the BS serves as a confining unit between the water-bearing LGR and CC limestones. The site is located within the BFZ, which structurally influences and re-directs the groundwater flow paths.

The detection of solvent contamination (PCE and daughter products TCE and *cis*-1,2-DCE) was first reported by the TDH in 1991. Beginning in 1992, CSSA undertook a series of investigations to identify potential source areas for the groundwater contamination, which identified B-3 and O-1 as likely candidates. Starting in 1996, the first of 56 monitoring wells were installed. Well installation has continued through September 2003. Off-post contamination was first reported by CSSA in 1999 at private well LS-7. Since that time, solvent contamination has been detected in 30 off-post private and public water supplies. The U.S. Army has installed point-of-use treatment systems at six off-post well locations where concentrations exceed 80 percent of the federal MCL (5 µg/L) for PCE and TCE.

Most water production wells are completed as open boreholes to maximize groundwater yield, and they include varying lengths of surface casing to facilitate borehole stability or isolate less desirable groundwater strata. Observation wells at CSSA consist of cased and screened wells that discretely monitor 25-foot segments of the LGR, BS, or CC Limestone. Often, these wells are arranged in clusters at a single location. By monitoring the individual members of the aquifer, an assessment regarding the occurrence and distribution of contaminants within the Middle Trinity aquifer can be ascertained.

Based upon measurements at observation wells, the regional groundwater flow is generally to the south-SE. The LGR typically has a southward gradient that is deviated around mounding which occurs at CS-MW4-LGR and CS-G. The BS has exhibited the potential for either northward or southward flow, depending upon the season. Likewise, the CC has exhibited erratic flow paths with seasonally radial flow from mounded areas, to a northeastward flow possibly related to off-post pumping along Ralph Fair Road.

Long-term monitoring shows that groundwater response to precipitation events can be swift and dramatic. Depending on the severity of a precipitation event, the groundwater response will occur within several days, or even hours. Average precipitation events do not invoke much response from shallow PZs within the LGR, yet main aquifer body wells will respond within a week. Such observations seem to indicate that the preponderance of recharge observed occurs elsewhere upon the outcrop, and not necessarily within CSSA.

For the entire Middle Trinity aquifer, data obtained from the on-post well clusters indicate that for most of the year, a downward vertical gradient exists within the Middle Trinity aquifer. Differences in drainage rates often leave the head of the BS well above the head of the LGR and CC. The large differences in head suggest that the BS locally acts a confining barrier between the LGR and CC.

The average precipitation at CSSA is typically above 32 inches per year. The 30-year record (1971-2000) results in a mean annual rainfall average of 37.36 inches in Boerne, Texas. The CSSA weather station reported a 31.46 annual average between 1999 and 2006. As little as 17 inches and as much as 52 inches of precipitation have been reported within an individual calendar year. In an attempt to estimate an annual water balance, approximately 67 percent of the annual precipitation is expected to be lost to evapotranspiration. Another 29 percent is assumed to be lost to surface runoff annually, while the remaining 4 percent recharges the Middle Trinity aquifer (based upon published literature values). Assuming these estimates are valid, CSSA can be expected to consume between 8 percent and 25 percent of its annual recharge. Likewise, within the model area between 31 percent and 95 percent of the estimated recharge volume can be consumed by the collective groundwater consumers. These values are likely biased low since groundwater is obviously removed from storage during periods of drought, meaning the discharge will exceed recharge. CSSA implements a drought management plan to better manage its groundwater resources during times of reduce precipitation.

At CSSA, the VOC COCs are PCE, TCE, and *cis*-1,2-DCE. These COCs exceed federal MCLs in relatively small areas. In terms of contamination, PCE and to a lesser extent TCE are the parent products while TCE and *cis*-1,2-DCE are by-products resulting from biodegradation processes. Thus far, only sporadic trace detections of vinyl chloride have been reported. The lack of widespread vinyl chloride detections indicate that the reductive chlorination processes may have stalled with the production of *cis*-1,2-DCE, which is indicative to lack of potential electron donors within the system. Or, the other plausible explanation is that the notable lack of VC is due a process that rapidly degrades the VC to ethene, especially along the aerobic margins of the plumes.

VOC contamination from the past disposal activities as resulted in multiple groundwater units, referred to as Plume 1 (B-3 and O-1) and Plume 2 (AOC-65). Contamination is most widespread within the LGR water-bearing unit. Environmental studies have demonstrated that

most of the contamination resides within the LGR, therefore the open borehole completions are considered to represent that unit.

At Plume 1, areas in excess of the MCL occur around wells CS-D, CS-MW1-LGR, CS-MW2-LGR, and the CS-MW16 cluster. Concentrations in excess of 200 µg/L have been reported at CS-D, CS-16-LGR, and CS-MW16-CC near the source area. This plume has advectively migrated southward to CS-1 at Camp Bullis, and west-SW toward CSSA well field (CS-9, CS-10, and CS-11) and several to 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 within the BS and CC has been consistently identified within Plume 1.

Contamination at Plume 2 originated at or near Building 90, and has spread southward and westward from the post. The greatest concentrations of solvents are reported at the near subsurface adjacent to the source area (22,000 µg/L at CS-WB03-UGR01). Within the post, concentrations in excess of 100 µg/L have been reported in perched intervals above the main aquifer body. However, as evidenced by the multi-port wells, once the main aquifer body is penetrated, the concentrations are diluted to trace levels. Off-post, concentrations in excess of the MCLs has been detected in private and public wells with open borehole completions. Concentrations exceeding 25 µg/L have been reported 1,200 ft west-SW of CSSA at RFR-10. Vertical profiling within that well show that discrete intervals within uncased upper strata contribute PCE concentrations over 90 µg/L. Only sporadic, trace concentrations of solvents have been detected in BS and CC wells within Plume 2.

The style of well completion can affect the concentration detected at a location. At CSSA, monitoring wells have been purposely designed to case off contamination present within upper strata in an effort to reduce cross-contamination between water-bearing units. This style of well has typically resulted in a groundwater sample from the main portion of the aquifer that has little to no contamination present. In contrast, most off-post wells are designed to maximize yield from all portions of the aquifer, resulting in the co-mingling of stratified groundwater with varying degrees of contamination. Within an open wellbore, the net effect is that perched waters with high concentrations of solvents are contaminating relatively pristine groundwater held within the main body of the aquifer. This scenario, coupled with the tendency of downward vertical flow, has potentially created pockets of cross contamination into the basal unit of the LGR, BS, and CC members of the Middle Trinity aquifer.

Results from the AOC-65 study seem to indicate that the bulk of contamination is locked within the upper 300 ft of strata, and may have a tendency to move laterally rather than vertically. This is supported by the elevated concentrations detected in the upper portions of the RFR-10 borehole. The method by which the contamination is transmitted horizontally is unconfirmed, but is likely related to the extensive NE-SW faulting in the area, possibly secondary dissolutioning along these preferential planes, and pumping of off-post wells.

Historical sampling activities had shown sporadic detections of lead above the action level of 0.015 mg/L in mostly older open borehole wells, such as former agricultural and potable supply wells. It would seem that the open borehole wells with minimal surface casing are most prone to the lead detections at CSSA. Materials issues associated with well casing, piping, or the pumping apparatus may also play a role in the detection of lead in these legacy wells. However, through 2006 the network of monitoring wells specifically installed for groundwater

characterization had not indicated any persistent inorganic concerns in the aquifer. The fundamental difference between the monitoring wells and the legacy wells is there constructed design. Newer wells are comprised of PVC casing and stainless steel screens that monitor 25-foot segments of the Middle Trinity aquifer. In comparison, the legacy wells are open borehole completions that have the capacity to be influenced by perched zones above the main aquifer body.

New 2-inch wells drilled in 2007 initially indicated potential problems with inorganics in the LGR groundwater may exist near former munitions disposal sites. Wells CS-MW22-LGR and CS-MW25-LGR are located in the vicinity of SWMU DD and B-8, respectively. The first four quarters of sampling of these wells showed repeatable detections of lead above the 0.015 mg/L action level. However, subsequent sampling of these wells (17 additional quarters since 2008) has demonstrated that the lead concentrations initially reported have attenuated to levels below the AL with the exception of one isolated AL exceedance of 0.0198 mg/L lead at CS-MW25-LGR. Likewise, the initial chromium concentrations above the MCL in CS-MW25-LGR has followed suit and have attenuated to below the MCL since December 2007 (18 additional sampling events). Finally, a single detection of mercury was reported during the initial sampling of CS-MW23-LGR above the MCL, but has been at, or below the method detection limit in the subsequent 20 sampling events. The graphs shown in Figure 3.7 clearly show how these inorganic detections have attenuated since the first year of quarterly sampling. While some of these wells are nearby known former munitions sites, the overall attenuation trend in the six wells may suggest that a differing well development strategy for the narrow diameter wells resulted in longer times for the restoration of representative groundwater conditions in the LGR. Since 2008, inorganics in these three wells are no longer considered an issue because there has been only one isolated AL exceedance at CS-MW25-LGR in 2010 in 21 sampling events.

The presence of contaminated groundwater and the findings of the HHRA make the no-action alternative infeasible, and it is recommended that a CMS be conducted to evaluate possible corrective measures alternatives that could be implemented to address the remaining contamination at CSSA. The collected data and the associated characterization described in this report is considered sufficient to characterize remaining contaminated media at CSSA, to identify and evaluate any associated potential risks, and to support the recommended CMS. This RFI Report, including the risk assessment and the associated CMS recommendation comply with CSSA's corrective action obligations as described in the Order.

SECTION 6
REFERENCES

Ashworth 1983. *Groundwater Availability of the Lower Cretaceous Formations in the Hill Country of South-Central Texas*. John B. Ashworth, Texas Water Development Board, Report 273, 1983.

Hammond 1984. H*ydrogeology of the Lower Glen Rose aquifer, south-central Texas*. W.W. Hammond, The University of Texas at Austin, Ph.D. dissertation, 1984.

Engineering-Science 1993. *Environmental Assessment*, Camp Stanley Storage Activity, Boerne, Texas. Parsons Engineering Science, Inc. September 1993.

Kibler and Gardner 1998. Archeological Survey and National Register Testing at Camp Stanley Storage Activity, Bexar County, Texas.

Parsons 1995a. *Technical Memorandum on Surface Geophysical Surveys, Well 16 Source Characterization*. Prepared for the Department of the Army Camp Stanley Storage Activity, Boerne, Texas. Parsons Engineering Science, June 1995.

Parsons 1995b. *Technical Memorandum on Soil Boring Investigations, Well 16 Source Chracterization*. Prepared for the Department of the Army Camp Stanley Storage Activity, Boerne, Texas. Parsons Engineering Science, June 1995.

Parsons 1995c. *Technical Memorandum on Surface Geophysical Surveys at High Priority Sites*. Prepared for the Department of the Army Camp Stanley Storage Activity, Boerne, Texas. Parsons Engineering Science, October 1995.

Parsons 1996. *Groundwater Investigation and Associated Source Characterizations*. Prepared for the Department of the Army Camp Stanley Storage Activity, Boerne, Texas. Parsons Engineering Science, June 1996.

Parsons 2013. *Integrated Natural Resource Management Plan.* Prepared for Camp Stanley Storage Activity, Boerne, Texas. February 2013.

Parsons 2014a. *Baseline Risk Assessment.* Prepared for Camp Stanley Storage Activity, Boerne, Texas. January 7, 2014.

Parsons 2014b. *RFI Work Plan.* Prepared for Camp Stanley Storage Activity, Boerne, Texas. April 2014.

Parsons 2014c. *Integrated Cultural Resource Management Plan.* Prepared for Camp Stanley Storage Activity, Boerne, Texas. April 2014 Update to March 2009 ICRMP.

NPS, 2012. List of National Parks by State. http://www.nps.gov/applications/parksearch/geosearch.cfm. Accessed April 10, 2012.

SAIC 1997. *Wetlands and Waters of the U.S. Delineation Report. Camp Stanley Storage Activity ICNRMP, Bexar County, Texas*. Prepared by Science Applications International Corporation. Submitted to the U.S. Army Corps of Engineers, Fort Worth District, 1997.

Scott, *et al.* 1997. *Archeological Survey and Testing at Camp Stanley Storage Activity*, Bexar County, Texas. Prepared by Prewitt and Associates, Inc. for CSSA, 1997.

United States Environmental Protection Agency (USEPA), 1991 *Reductive Dehalogenation of Organic Contaminants in Soil and Groundwater*, EPA/540/4-90/054, January 1991.

USEPA, 1999. *Administrative Order on Consent. Docket No. RCRA-VI 002(h)99-H FY99. In the Matter of: Camp Stanley Storage Activity, Boerne, Texas,* United States Environmental Protection Agency, May 1999.

U.S. Forest Service, 2012. Map of National Forests and Grasslands; http://www.fs.fed.us/recreation/map/xtx_la_ms.html, Accessed April 10, 2012.

USFWS, 2012a. Critical Habitat Portal Database. http://crithab.fws.gov/. Accessed April 10, 2012.

USFWS, 2012b. National Wildlife Refuge System. http://www.fws.gov/refuges/profiles/ByState.cfm?state=TX. Accessed April 10, 2012.

USGS, 2003. *Helicopter Electromagnetic and Magnetic Survey Data and Maps, Northern Bexar County, Texas.* Open-File Report 05-1158. 2003

USGS, 2004. *Geologic Framework and Hydrogeologic Characteristics of the Glen Rose Limestone, Camp Stanley Storage Activity, Bexar County, Texas (Scientific Map 2831).*

APPENDIX A

GEOLOGIC FRAMEWORK AND HYDROGEOLOGIC CHARACTERISTICS OF THE GLEN ROSE LIMESTONE, CAMP STANLEY STORAGE ACTIVITY, BEXAR COUNTY, TEXAS

(USGS 2004)