The Boeing Company
Santa Susana Field Laboratory
5800 Woolsey Canyon Road
Canoga Park, CA 91304-1148

BOEING

Via FedEx

July 14, 2008
In reply refer to SHEA-107519

Mr. Norman Riley
SSFL Project Director
Dept. of Toxic Substances Control
1001 "I" Street
P. O. Box 806
Sacramento, CA 95812-0806

RE: Workplan – Groundwater Interim Measures
Santa Susana Field Laboratory, Ventura County, California

Dear Mr. Riley:

Pursuant to DTSC's letter of May 16, 2008, and on behalf of Boeing, NASA, and DOE, we are submitting the Workplan – Groundwater Interim Measures, Santa Susan Field Laboratory, prepared by MWH under the direction of the SSFL Groundwater Advisory Panel and dated July 2008. This workplan is being submitted under separate cover today.

We are currently obtaining permits for a new groundwater treatment system which is designed to meet the water quality discharge limits in our NPDES permit. Planning has begun for design changes required to address extracted groundwater from wells proposed in the subject workplan. Please note that groundwater extraction from wells WS-9A and RD-2 was suspended in 2007 because the existing treatment systems could not fully treat the extracted groundwater. This was related to the age and technology of the systems. In addition, more stringent water quality discharge limits were established by the Regional Water Quality Control Board and incorporated into the NPDES permit in November 2007.

The subject workplan specifies the preparation of annual reports including a performance assessment of the operational results and the effectiveness of the groundwater interim measures systems. In addition, ongoing investigations focused on confirming the characterization of contaminant nature and extent, as well as, fate and transport behavior in the Chatsworth formation are expected to verify the site conceptual model of plume retardation discussed in the present and prior workplans. We intend to submit an analysis of the effectiveness and the ongoing need for groundwater interim measures upon completion of that study in late 2009.

Finally, as described in the prior versions of this workplan and as required in DTSC's letter of November 19, 2007, the present workplan proposes the evaluation of longer term treatment technologies including bio remediation and potentially pilot studies to evaluate their potential effectiveness at SSFL. Upon approval of this workplan, we will begin that work.

Please address any questions regarding this workplan to Mr. David Dassler at (661) 210-5672.

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I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: [signature]
Name: Thomas D. Gallacher
Director, Santa Susana Field Laboratory
Title: Environment, Health and Safety
Date: 7/11/2008

DWD:bjc
Enclosures (as noted)

cc:	Mr. G. Abrams, DTSC, Sacramento	(8 hard copies, 12 CDs)
	Mr. T. Seckington, DTSC, Cypress	(2 hard copies, 2 CDs)
	Ms. S. Houghton, DTSC, Berkeley	(1 CD)
	Ms. K. Grisso, CH2M Hill	(1 CD)
	Mr. W. Jeffers, DTSC, Chatsworth	(1 hard copy, 1 CD)
	Mr. A. Elliott, NASA, MSFC	(1 hard copy, 1 CD)
	Mr. T. Johnson, DOE, SSFL	(1 hard copy, 1 CD)
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WORK PLAN (Revision 2)
GROUNDWATER INTERIM MEASURES
SANTA SUSANA FIELD LABORATORY

VENTURA COUNTY, CALIFORNIA

July 2008

Prepared For:
The Boeing Company
The National Aeronautics and Space Administration
The United States Department of Energy

Prepared By:
MWH
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Under the direction of the SSFL Groundwater Advisory Panel:
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Dr. David McWhorter, Distinguished Professor Emeritus, Department of Chemical and Agricultural Engineering, Colorado State University
Dr. Beth Parker, Professor and NSERC Industrial Research Chair in Fractured Rock Contamination Hydrology, School of Engineering, University of Guelph

MWH

PROFESSIONAL CERTIFICATION
WORK PLAN, GROUNDWATER INTERIM MEASURES
Santa Susana Field Laboratory

This work plan has been prepared by a team of qualified professionals under the supervision of the senior staff whose seal and signature appears below.

Simon Bluestone, P.G.

PROFESSIONAL GEOLOGIST
SIMON BLUESTONE
No. 6381
EXP 12/31/08
STATE OF CALIFORNIA

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ABBREVIATIONS AND ACRONYMS

1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
bgs	below ground surface
Boeing	The Boeing Company
cDCE	cis-1,2-dichloroethene
CalEPA	California Environmental Protection Agency
CFOU	Chatsworth Formation Operable Unit
cm/sec	centimeters per second
C/C_O	source concentration
CO_2	carbon dioxide
COPCs	chemicals of potential concern
D_e	effective diffusion coefficient
D_o	free-solution diffusion coefficient
DNAPL	dense non-aqueous phase liquid
DOE	United States Department of Energy
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
FSDF	Former Sodium Disposal Facility
gpd	gallons per day
IM	interim measures
K_b	bulk hydraulic conductivity
K_{bh}	bulk hydraulic conductivity horizontal
K_{bv}	bulk hydraulic conductivity vertical
LNAPL	light non-aqueous phase liquid
m	meter
MCL	maximum contaminant level
m/yr	meters per year
NASA	National Aeronautics and Space Administration
NDMA	n-nitrosodimethylamine
NRC	National Research Council

ABBREVIATIONS AND ACRONYMS
(continued)

NSR	non-strippable residue
Panel	Groundwater Advisory Panel
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
R_m	matrix retardation factor
SCM	Site Conceptual Model
SSFL	Santa Susana Field Laboratory
TCE	trichloroethene
TIO	Technology Innovation Office
VOC	volatile organic compound
US	United States
ϕ_m	matrix porosity
ϕ_{fh}	bulk fracture porosity horizontal
ϕ_{fv}	bulk fracture porosity vertical
μg/L	microgram per liter
μm	micrometer (micron)
τ	tortuosity

1.0 INTRODUCTION

This groundwater Interim Measures (IM) work plan (Revision 2) presents a technology evaluation and implementation plan for interim measures to address chemicals of potential concern (COPCs) in Chatsworth formation[1] groundwater beneath the Santa Susana Field Laboratory (SSFL). This work plan was prepared in response to a directive from the California Environmental Protection Agency (CalEPA) Department of Toxic Substances Control (DTSC) in its letters of April 18, 2007 (DTSC, 2007a), November 19, 2007 (DTSC, 2007b) and May 16, 2008 (DTSC, 2008) as a part of ongoing Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) activities at SSFL. Copies of DTSC's letters are included in Appendix A. The SSFL is jointly owned by The Boeing Company (Boeing) and the federal government (administered by the National Aeronautics and Space Administration [NASA]), portions of which are or have been operated by Boeing. The U.S. Department of Energy (DOE) owns facilities and structures on a portion of the SSFL. However, there are no longer any active DOE operations and some of the facilities have undergone decommissioning and demolition.

The SSFL is located in the southeast corner of Ventura County, 29 miles northwest of downtown Los Angeles, California. The location of the SSFL and its surrounding vicinity is shown on Figure 1-1. Previous environmental investigations have shown that the Chatsworth formation beneath portions of the SSFL has been impacted by historic releases of chemicals from operational activities, with trichloroethene (TCE) being the compound detected at the highest concentration and with the greatest frequency. This work plan has been prepared by MWH under the direction of the SSFL Groundwater Advisory Panel on behalf of Boeing, NASA and DOE.

[1] The Chatsworth formation constitutes the bedrock that lies beneath the SSFL and consists predominantly of fractured sandstone with interbeds of siltstones and shales.

1.1 BACKGROUND INFORMATION

The occurrence of TCE in groundwater beneath the SSFL was first discovered in the early 1980s when water supply wells were sampled and analyzed for the presence of TCE and certain other volatile organic compounds (VOCs). Groundwater characterization activities at the SSFL using conventional fractured rock methods have been ongoing since about 1985. The Groundwater Advisory Panel[2] (Panel) was commissioned in 1997 to develop a groundwater site conceptual model (SCM) regarding the movement of COPCs in the Chatsworth formation. At the recommendation of the Panel, new methods including rock coring and crushed rock chemical extraction were used to characterize TCE in the fractured sedimentary rock of the Chatsworth formation during the late 1990's. In April 2000, a technical memorandum was submitted that presented the site conceptual model on the movement of TCE in the Chatsworth formation (Montgomery Watson, 2000a). The SCM was based on the Panel's understanding of TCE solute transport in fractured sedimentary rock (e.g., Chatsworth formation) and the available data as of late 1999.

Additional field programs have been performed since late 2000 to characterize groundwater at the SSFL consistent with work plans submitted to DTSC. The work involved applying both conventional and new investigation methods including retrofitting existing wells with multi level monitoring systems, coring and analysis of rock core for select VOCs and physical properties, and various methods of geophysical, hydrophysical and aquifer testing.

Much of the data that were collected, reduced and analyzed since 2000 were further evaluated and incorporated into an update of the groundwater SCM for contaminant transport (Cherry, McWhorter and Parker, 2007). The primary elements of the groundwater SCM have since been further refined, and are provided in Section 2.3.3 of this work plan.

DTSC's letter to Boeing dated April 18, 2007 (DTSC, 2007a) regarding interim measures activities established:

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[2] The Groundwater Advisory Panel consists of Dr. John Cherry, Distinguished Professor Emeritus, Department of Earth and Environmental Sciences, University of Waterloo, Dr. David McWhorter, Distinguished Professor Emeritus, Department of Chemical and Agricultural Engineering, Colorado State University, and Dr. Beth Parker, Professor, School of Engineering, University of Guelph.

1. A requirement to resume groundwater extraction at wells RD-2 (WS-5 Treatment System) and WS-09A (Delta Treatment System) and to submit a letter to DTSC by April 25, 2007 confirming that both of these wells and treatment systems are operational and reporting the dates that each began operating

2. A requirement to submit to DTSC by May 18, 2007, a detailed list of all known contaminants and a discussion of the rationale for proposed inclusion in or omission from the suggested work plan list of contaminants

3. Revisions to a prior groundwater interim measures work plan that was included with post-closure permit renewal applications that were submitted by Boeing and NASA in late 2004.

In fulfillment of the first requirement, Boeing's letter to DTSC dated April 25, 2007 (Boeing, 2007a) confirmed the operational status of wells RD-2 and WS-09A, and the associated groundwater treatment systems. Boeing's May 17, 2007 letter to DTSC provided further information regarding repairs and operational status of well RD-2 and the associated groundwater treatment system (Boeing, 2007b).

In fulfillment of the second requirement, Boeing's letter to DTSC dated May 18, 2007 (Boeing, 2007c) presented a list inclusive of chemicals detected in at least a single groundwater sample collected from wells at or near the SSFL (regardless of concentration), and stated that all chemicals on this list would be considered during the preparation of the groundwater interim measures work plan. The chemical list is presented in Appendix B.

A groundwater interim measures work plan was submitted to DTSC in August, 2007 to address the third requirement above (MWH, 2007c). This work plan presented an approach for evaluating potentially applicable technologies for groundwater interim measures at the SSFL, the subsequent design and implementation of pilot tests to further assess their applicability, and implementing interim measures for groundwater. The evaluation of applicable technologies and the potential for pilot studies at DTSC's direction were further emphasized in DTSC's consent order of August 2007.

DTSC's response letter to Boeing, dated November 19, 2007 (DTSC, 2007b), required the submittal of a revised IM work plan that, in addition to the proposed longer-term study of potential groundwater remediation technologies described in the August 2007 IM work plan, addresses short-term IM implementation to achieve source zone remediation and plume front containment. The specific issues that DTSC's letter required to be addressed in a revised IM work plan included:

1. Descriptions of all contaminant plumes and source areas (including maps, figures, and narratives),
2. Proposals for IMs at the groundwater plumes and source areas to achieve source zone remediation and plume front containment,
3. A discussion of technologies evaluated and figures to support the technology or technologies selected,
4. Implementation plan for proven remedial approaches such as pump and treat where contamination migration potential is high,
5. IMs that can be operational and functional within one year,
6. A project schedule for implementation of the IMs including descriptions of tasks and deliverables expected.

A work plan was submitted to the DTSC on January 31, 2008 by the SSFL that was intended to fulfill the requirements specified by DTSC in its November 19, 2007 letter.

DTSC's May 16, 2008 letter requires the submittal of a new draft groundwater IM work plan by July 15, 2008 that addresses the issues cited and those in a memorandum from Thomas Seckington of the Geological Services Unit of DTSC that is dated April 24, 2008. The conclusion contained in the April 24, 2008 memorandum states: "Groundwater extraction should be initiated at all wells identified in the source areas and at plume fronts where the contaminants may be advancing. Groundwater pumping at these locations will be focused having limited reach and will not affect ongoing investigative activities." Furthermore, the April 24, 2008 memorandum specifically recommends that "groundwater extraction should be initiated at all groundwater monitoring wells within source zones, defined as any monitoring wells where the reported concentrations of TCE have been 1,000 micrograms per liter (µg/L) or higher and/or any monitoring wells where TCE concentrations and water levels are trending higher since shut-down of groundwater extraction wells." The April 24, 2008 memorandum also requires initiating groundwater extraction at the "solvent plume offsite to the northeast of the site…and…in the southernmost groundwater extraction (WS-9A) at the buffer zone."

1.2 WORK PLAN OBJECTIVE

The primary objective of this groundwater interim measures work plan is to comply with the requirements of DTSC as specified in their May 16, 2008 letter. A secondary objective of this work plan is to document the analysis that was performed in response to DTSC's November 19, 2007 letter on this subject. The November 19, 2007 DTSC letter required an evaluation of technologies potentially applicable and implementable within one year as interim measures to:

- Achieve source zone remediation and plume front containment,
- Describe the resultant recommendations for interim measures implementation, and
- Present a schedule for implementation of the recommended interim measures.

This work plan also includes a description and schedule for the implementation of the longer-term study of potential groundwater remediation technologies.

Section 2.0 of this work plan provides an overview of the nature of historical releases and plume evolution, as well as a specific description of each plume and associated source areas (required in the November 19, 2007 DTSC letter). Section 3.0 presents a discussion of current plume front conditions, a discussion of the evaluation and selection of technologies recommended for implementation as interim measures to achieve the goal of plume front containment, and the proposed schedule for implementation. Section 4.0 presents a discussion of current source zone conditions, and the evaluation and selection of potential interim measures technologies to achieve source zone remediation, and the associated implementation schedule. Section 5.0, provides a description of the long-term groundwater remediation technology evaluation, and the associated implementation schedule.

1.3 CONTEXT OF CONTAMINANTS IN GROUNDWATER BENEATH THE SSFL AND IMPLICATIONS FOR INTERIM MEASURES[3]

The current understanding of the nature, transport, fate and extent of SSFL-related contaminants in groundwater beneath the facility is based on SSFL site data and also, importantly, on

[3] This material was created by Drs. John Cherry, David McWhorter and Beth Parker with support from Richard Andrachek, P.E. of MWH.

academic research conducted by the SSFL Groundwater Advisory Panel members since 1992. The research involves analyzing the behavior and fate of dense immiscible-phase organic chemicals (e.g. chlorinated solvents) and dissolved contaminants in fractured porous rocks including sandstone and shale at many field sites. The research involves laboratory studies, concept development, numerical modeling, and acquisition of site-specific data by applying newly-developed field methods. The current understanding of the SSFL groundwater impact is part of a more general conceptual model for contaminant behavior and fate in fractured sedimentary rocks. Some of this research has been published in the peer-reviewed scientific literature, with the intent to publish additional material in the near-future.

In particular, the RFI and interim and corrective measures studies at the SSFL pose scientific and technical challenges that are exceptional because:

i. The contaminants exist almost entirely in the fractured bedrock matrix beneath the SSFL, and this rock matrix has relatively low permeability;

ii. Groundwater beneath the SSFL is mounded above the adjacent valleys with perceived groundwater flow in many directions from the facility that is further complicated by the strike and dip of the Chatsworth formation, structural features (i.e. faults), and the use of the underlying groundwater for historical facility supply and interim measures; and

iii. There are many areas where contaminated groundwater is intercepted by monitoring wells completed within the fractured bedrock, which originate from the various input locations that are spread across the three-mile wide facility.

Furthermore, the scientific literature concerning contaminants in fractured rock is deficient relative to conventional groundwater contamination problems involving contaminants in granular aquifers (i.e. non-indurated sand or gravel). Groundwater contaminant plumes in granular aquifers can be adequately delineated (i.e. the actual nature and spatial extent can be determined) and the delineation combined with predictions of future plume behavior based on the large body of scientific literature serves as the basis for regulatory decision-making. The scientific and regulatory communities have confidence with this type of plume delineation based on more than 30 years experience at numerous sites. However, this is not the case for contaminant plumes in fractured rock. Therefore, it is necessary to rely on concepts and investigative methods that are different from those applied at conventional sites, to develop the necessary understanding of the nature, transport, fate and extent of contaminants in the bedrock underlying the SSFL. Within the context of SSFL groundwater interim measures described in this work plan, items (i) and (ii) noted above are of particular importance as a backdrop to the potential need for and effectiveness of such activities. This is further discussed in subsequent sections of this work plan. Furthermore, there is commonly strong desire to implement remedial measures to accomplish source mass removal and plume front control, and ultimately plume remediation at contaminated sites on fractured sedimentary rock. However, such accomplishments have largely gone unachieved at these types of sites because of the inherent restrictions on technology performance imposed by the fact that nearly all of the contaminant mass resides in the low permeability rock matrix. Therefore, the remedial accomplishments at other sites with these similarities to the SSFL are strongly relevant to the selection of and performance expectations for remediation technologies in the Chatsworth formation.

The understanding of the nature, transport, fate and extent of contaminants in the bedrock at SSFL is a result of two activities: (1) university-based research conducted by Drs. Parker, Cherry and McWhorter concerning the distribution, transport and fate of immiscible-phase liquids and dissolved contaminants in fractured porous geologic media, and (2) field studies conducted at the SSFL by consultants commissioned by Boeing and guided by the Groundwater Panel to acquire data to test and expand on the SCM. The initial generic ideas for the SCM concerning the behavior of chlorinated solvents and many other organic contaminants in fractured sedimentary rock such as sandstone were contained in the following publications: Parker, Gillham and Cherry (1994) and Parker, McWhorter and Cherry (1997). These publications are generic in the sense that they were not based on studies specific to any particular field site but they use typical sedimentary rock properties. In 1997, Rocketdyne (purchased by Boeing in 1998) invited Parker and Cherry, then at the University of Waterloo and McWhorter, then at Colorado State University, to include the SSFL in their research program concerning organic contaminants in fractured geologic media and Boeing provided funding to support some of this research. Hence, the SSFL became included with several other contaminated field sites across the United States and Canada that have been used for research to develop a general conceptual model for these contaminants in fractured sedimentary rock (Parker, 2007). This general model encompasses the various site- specific models, one of which is the SSFL. This broad research program is supported financially by government agencies and various corporations including Boeing. The contaminated sites all have in common the strong influence of diffusion-driven mass transfer on the transport and fate of soluble contaminants. This research program involves graduate student thesis studies (e.g. at SSFL – Sterling, 1999; Hurley, 2003 and Pierce, 2005) and also work by collaborating faculty members, research associates and others. To acquire the field and lab data needed to develop and assess conceptual models, new data acquisition methods have been developed and applied at the field sites, most of which have been applied at the SSFL . Therefore, the understanding of the contaminants in the groundwater beneath the SSFL is founded on leading edge research that is continually being advanced as the state-of-the-science evolves. Although the research is still on-going at all of the field sites, much of what is known about the contaminant behavior at the SSFL also applies to all sites that fall within a similar hydrogeologic framework. The strong commonalities between the various field research sites in which certain panel members have been involved adds confidence to the reliability of the site-specific understanding for the SSFL.

2.0 DESCRIPTIONS OF PLUMES AND SOURCE AREAS

It is important to note that the terminology developed and used in the regulatory framework for "source zone" and expectations for plume behavior has been developed within the context of conditions for contaminant characteristics in granular aquifers, not fractured porous rock.[4] The nature of the contaminant mass and phase distribution in fractured porous rock are distinctly different from the granular aquifer scenario. Specifically, the use of the term "source zone" for dense chlorinated solvents such as TCE, typically implies the zone impacted by the non-aqueous phase liquid (i.e. DNAPL). The DNAPL mass dissolves into the groundwater and is transported down the flow path creating a plume. At the SSFL, as well as many other fractured porous rock sites where TCE (or other chlorinated DNAPLs) has been present in the fracture network for a couple of decades or more, the DNAPL phase has long since completely dissolved and much of the former DNAPL mass remains as dissolved and sorbed mass in the area of former DNAPL, while the remainder has been transported by groundwater flow to create the plume. The transport of TCE by advection is strongly retarded due to transverse diffusion into the porous, low permeability matrix blocks between the fractures. The appreciable matrix porosity and the presence of organic carbon provide large storage capacity for the TCE mass resulting in the strong attenuation of concentrations throughout the contaminated volume of aquifer, rather than from plume volume expansion. One net result is that the entire contaminated volume of the fractured porous rock, which includes the area of former DNAPL, is comprised of only dissolved and sorbed mass, whether in the area within or close to where DNAPL entered the groundwater system or farther down the flow path near the middle of the plume or at the plume periphery. Another net result is that strong matrix diffusion causes plumes to evolve to a quasi-steady-state position (stable position). Essentially, the entire contaminated volume is now effectively plume mass because there is no longer any DNAPL present, with concentrations within the original DNAPL-impacted volume strongly diminished due to transverse diffusion rather than from advection. Therefore, the current and future behavior of these TCE plume(s) in this fractured

[4] The material in the first two paragraphs of this section was created by Drs. John Cherry, David McWhorter and Beth Parker with support from Richard Andrachek, P.E. of MWH.

porous rock is distinctly different from TCE plume (and related source zone) behavior in granular aquifers.

As required by the DTSC, interim measures proposed in this work plan primarily address the portion of the plumes near where DNAPL likely entered the ground surface in that these zones have higher concentrations in wells compared to the portions of the plume farther down the flow path. The expectation of this pump and treat "containment" as an interim measure is apparently based on the granular aquifer conceptual model. In the granular aquifer scenario it is expected that groundwater extraction will reduce the mass flux (or discharge) to the plume thus allowing the portion of the plume beyond capture to disconnect and flush out of the system. However, the site data on the contaminant mass distribution in the groundwater beneath the SSFL provides a much different perspective concerning expectations for the beneficial effects of groundwater extraction. In fractured porous rock, the portion of the plume at its periphery will not likely move farther down the flow path due to the strong retardation affect of the transverse diffusion into the matrix occurring throughout the entire plume with or without groundwater extraction. It is this same mass storage within the bedrock matrix that will also prevent any appreciable or measurable improvements in plume concentrations as measured in samples collected from wells because of reverse diffusion from the matrix. This will also prevent substantial improvement in groundwater quality within the volume of the plume from which groundwater would be extracted. This is because the mass removed by extraction is small compared to the mass stored within the matrix, which will cause a rebound in concentrations once extraction is stopped. After an appropriate period of time, monitoring results from this proposed groundwater extraction interim measure should be assessed to ascertain which conceptual models (granular aquifer or fractured porous rock) is supported by the interim measure results. If the fractured porous medium model is supported, appropriate changes in the interim measures approach should be made.

Appreciable data sets are available regarding the occurrence and distribution of TCE and other COPCs in the groundwater beneath the SSFL as comprehensively summarized in the Site-wide Groundwater Characterization Work Plan (MWH, 2008). The current understanding of the occurrence and distribution, nature and extent, and transport and fate of COPCs based on the interpretation of these data sets is discussed below.

2.1 TCE OCCURRENCE AND DISTRIBUTION IN GROUNDWATER

The current interpretation of the areas of TCE-impacted groundwater generated from sources located within the SSFL is depicted in plan view in Figure 2-1. These areas include TCE at concentrations above 5 μg/L, which is the California maximum contaminant level (MCL) for drinking water. A number of factors were considered in the configuration of the areas of impacted groundwater depicted in this figure and include the following:

- Primary TCE use areas as reported in SSFL historical documents,
- TCE results from soil vapor sampling completed as part of the surficial media operable unit characterization program,
- The location and timing of historical and current groundwater extraction,
- Site topography,
- Geologic features including finer-grained lithologies and some faults, and
- Results from the analysis of nearly 9,800 groundwater samples from the existing network of 400 monitoring locations, and from 50 spring/seep samples for the occurrence and concentration of TCE (and other VOCs).

Sixteen separate areas of primarily TCE-impacted groundwater are shown on Figure 2-1. These areas are labeled 1, 3 through 13, and 15 through 18. Two other areas of impacted groundwater are also shown on the figure that are not coincident with TCE and are labeled 2 and 14 in Figure 2-1. These two areas are discussed in Section 2.2 below.

A tabulated summary of the 16 areas of TCE-impacted groundwater and the 2 areas of groundwater impacted by other COPCs not coincident with TCE is provided in Table 2-1. Information that is included on the tabulated summary includes:

- The primary COPCs encountered,
- Information of the input locations (source areas), if available,
- A description of the areal extent of impacted groundwater, including an estimate of the size of the area (in plan view),
- A description of the physical setting with regards to remoteness and terrain,
- A comment about the relative proximity of the area to potential receptors, and

- Notes on whether groundwater extraction had occurred from within or near the area of impacted groundwater.

In addition to the plan view figure depicting the areas of impacted groundwater, a series of ten cross-sections has been created. The cross-sections are shown on Plates 2-1 and 2-2. These cross-sections provide the following information: geology (including stratigraphy and structure), well completions, and groundwater elevations and TCE concentrations from the third calendar quarter of 2007 if available. If groundwater elevations or TCE concentrations were not available from the third quarter 2007 monitoring and sampling event, then the most recent prior results are presented in the cross-sections.

In summary, the information on the occurrence and distribution of TCE in groundwater at the SSFL indicates that a total area of about 528 acres of land is underlain by groundwater containing TCE at concentrations greater than 5 μg/L. The three largest areas of impacted groundwater lie beneath the northeast portion of the SSFL, beneath the Alfa and Bravo test areas, and beneath the Coca/Delta/STL-IV test areas. Vertically, TCE has been encountered in rock core porewater samples to depths approaching 1000 feet beneath the Delta test area.

Supporting information on TCE concentrations (and other select VOCs) over time, well completions and hydrographs for most of the wells at and around the SSFL that have been sampled was provided in Appendix A of the Site-wide Groundwater Characterization Work Plan (MWH, 2008). The well data sheets presented in that document can be used to assess temporal changes in concentrations of TCE and other halogenated ethenes, halogenated ethanes and halogenated methanes, and the influence of fluctuating water levels on the measured concentrations.

2.2 OCCURRENCE AND DISTRIBUTION OF OTHER COPCS IN GROUNDWATER

There are only a few locations at the SSFL where other COPCs are present in the groundwater that are not coincident with areas of TCE-impacted groundwater. These areas of impacted groundwater containing concentrations of COPCs above screening levels[5] include perchlorate in Happy Valley in Area I and site-derived tritium near Building 10 in Area IV of the SSFL. Information specific to these two areas of impacted groundwater are summarized in Table 2-1. The area of land beneath which these two constituents have impacted the groundwater above screening levels totals about five acres. Where it is not contiguous with the Northeast TCE plume, the vertical impacts in the Happy Valley perchlorate plume (Plume 2) exist above a depth of about 40 feet. The vertical impacts exist between depths of about 35 feet below ground surface (bgs) where groundwater is first encountered to about 175 feet bgs in the area of site-derived tritium Plume 14.

A comprehensive review of available analytical results from the monitoring wells was undertaken to evaluate the occurrence and distribution of COPCs in groundwater at the SSFL. A series of tables and maps were generated as a result of this review. These tables and maps were provided in Appendix B of the Site-wide Groundwater Characterization Work Plan (MWH, 2008). That appendix also included a description of the methodology that was applied to create the resultant documentation. The maps depict the historical maximum concentrations of various COPCs detected in the monitoring network at the SSFL. These results were used to support the approach of using TCE as the indicator chemical for the most-distant transport (i.e. furthest extent) in that concentrations of other constituents detected in groundwater lie within the areas of TCE-impacted groundwater, except for the two locations noted in the previous paragraph.

2.3 SUMMARY OF CURRENT UNDERSTANDING OF THE NATURE AND EXTENT OF COPCS IN SSFL GROUNDWATER

This section of the work plan provides a descriptive summary of the current understanding of the nature and extent of COPCs in the groundwater beneath the SSFL. Much of the text provided below was taken from *Overview of the Site Conceptual Model for the Migration and Fate of Contaminants in Groundwater at the Santa Susana Field Laboratory* that was authored by the

[5] Screening levels include federal and state primary and secondary maximum contaminant levels for drinking water, drinking water notification levels, taste and odor thresholds, and public health goals.

SSFL Groundwater Advisory Panel (Cherry, McWhorter and Parker, 2007). A more complete description of the basis for the following text can be found in that document.

Analysis of groundwater samples collected from monitoring wells since the mid-1980's at many locations on the SSFL property shows the existence of persistent contamination by chlorinated solvents, primarily TCE. TCE was used in the solvent phase (i.e. oily liquid) and field data indicate that releases directly to the ground resulted in its movement as a separate-phase liquid (i.e. DNAPL) into the subsurface where it entered the interconnected fracture network of the underlying bedrock. As such, its nature and extent will be used as a descriptive surrogate for all COPCs as discussed below.

Upon entry, the TCE DNAPL spontaneously imbibed into the unsaturated bedrock matrix. Penetration of DNAPL into the unsaturated rock matrix was restricted due to the relatively high vadose zone water content (about 70 percent). Equilibrium partitioning of the DNAPL in the vadose zone bedrock occurred resulting in the mass transfer of TCE into the vadose zone porewater, air and sorption onto natural organic matter. Where TCE inputs were limited, appreciable mass could be present in the unsaturated zone and act as a source to the groundwater via its transport by recharge waters and partitioning from the vapor phase. Upward vapor transport to the ground surface would also occur. At locations where repeated inputs occurred, the DNAPL readily flowed through the vadose zone and into and through the groundwater.

Although much of the field data that currently exists for SSFL was acquired during the course of TCE investigations, the other site-related COPCs (e.g. perchlorate, 1,4-dioxane, n-nitrosodimethylamine [NDMA], metals, and radionuclides [including tritium, strontium-90 and cesium-137] could also be transported into the unsaturated bedrock and the bedrock groundwater. Each chemical might enter the subsurface under different conditions. Conditions affecting their entry include:

- Phase (e.g., DNAPL, light non-aqueous phase liquid [LNAPL], dissolved phase, dissolution of solids at the ground surface and transport via recharge waters)
- Varying input volumes (or mass) and concentrations
- Timeframe of releases
- Each chemical's unique physical properties

The exact circumstances of the first three of these conditions at the SSFL cannot be conclusively determined.

2.3.1 Nature of TCE in Groundwater

In the context of potential for off-site migration, TCE is the worst-case COPC relative to the other chemicals because it penetrated much deeper into the Chatsworth formation due to its initial migration in the DNAPL phase, because a much larger TCE mass was released to the subsurface at many more locations throughout the SSFL, because of its occurrence and concentration in groundwater, and because of its chemical characteristics, including:

- The ratio of its aqueous solubility to its drinking water standard
- Its low viscosity and high specific gravity
- Its volatility and relatively low vapor inhalation threshold

Hence, TCE will be used as the basis for discussion in the following paragraphs.

The TCE DNAPL initially present in the fracture network below the water table subsequently dissolved into the groundwater. Advection transported the dissolved TCE along the flow path in the fracture network, while the resulting aqueous concentration gradient caused the simultaneous transfer of dissolved TCE mass into the adjacent pore space of the bedrock matrix by molecular diffusion. Sorption of TCE by naturally occurring organic carbon within the rock matrix has increased both the rate and magnitude of TCE diffusion into the rock matrix.

The low-permeability matrix blocks exhibit a large capacity for storage of dissolved and sorbed TCE mass relative to the DNAPL-mass storage capacity of the fractures. This fact, coupled with the decades that have passed since the bulk of the TCE DNAPL was released to the subsurface, makes it likely that the DNAPL (i.e. the immiscible phase) has completely dissolved so that the majority of TCE mass from the DNAPL now resides in the matrix blocks between the fractures. This conclusion is supported by numerous measurements of rock core (nearly 5,000 samples) from 12 continuously cored holes at 10 locations where DNAPL entered the bedrock decades ago (Hurley, 2003; Hurley, et. al, 2007a, 2007b and 2007c; and Parker, Cherry and McWhorter, 2008). These measurements indicate that a large volume of TCE DNAPL that reportedly entered the subsurface at the many input locations can be reasonably accounted for by the total dissolved and sorbed mass now found in the rock matrix at and near the input locations. This conclusion is further supported by the fact that TCE DNAPL has not been observed in any water sample or rock core sample collected at the site. Additionally, the results of rock core analyses for TCE have shown that only a handful of core samples from the C-6 corehole at the Delta Skim Pond exhibit porewater concentrations that approach TCE solubility and might be indicative that very limited residual amounts of immobilized TCE DNAPL may still reside within the matrix pore space at these locations, perhaps as a discontinuous film on some of the pore walls. Aside from these few samples, all of the rock core and groundwater analytical data indicate that although there is considerable TCE mass present, there is no longer TCE DNAPL in the system. Nearly all of the TCE currently in the system resides as dissolved and sorbed mass within the bedrock matrix.

2.3.2 Extent of TCE in Groundwater

Groundwater flowing through the fractures in the source zone transported dissolved TCE down the flow path within the fracture system, creating a contaminated zone comprised of dissolved and sorbed contaminant mass referred to as the plume. Many measurements of chemicals in samples of rock and groundwater from wells and seeps/springs indicate that migration of plumes at the SSFL has nearly stabilized. The dissolved TCE transported in the fractures creates transverse concentration gradients along the plume flow paths resulting in the diffusion of TCE from the flowing groundwater in the fractures into the relatively stagnant pore water in the rock matrix. Diffusion of TCE (and all other solutes) into the rock matrix also slows the rate of dissolved TCE transport within the fracture network (by orders of magnitude) relative to the rate of groundwater flow.

The transport of other SSFL COPCs (e.g. perchlorate, 1,4-dioxane, NDMA, metals, and radionuclides including tritium, strontium-90 and cesium-137) is also strongly influenced by matrix diffusion. Strontium, cesium and many other inorganic constituents are also strongly influenced by sorption. The properties of the rock matrix that most strongly influence diffusion are the matrix porosity and the ratio of pore-scale diffusion distance to macroscopic distance (tortuosity). These properties apply in a similar manner to all contaminants in aqueous form. At each location where a COPC entered the Chatsworth formation, it is reasonable to expect that a plume exists and that the plume evolved in the direction of the predominant groundwater flow paths in the interconnected fracture network. Many of the plumes likely occur only at relatively shallow depths, particularly those formed from non-DNAPL type inputs. Others that formed due to DNAPL inputs can be shallow, intermediate or deep depending on the local conditions at the input locations. The lateral extent to which plumes have migrated also varies depending on local hydrogeologic conditions.

The bulk hydraulic conductivity of the Chatsworth formation beneath SSFL is low to moderate, which causes the water table beneath the SSFL to be positioned at elevations much higher (1800 to 1900 feet) than in the adjacent valleys of Simi and Chatsworth (900 to 1000 feet elevation). The low rate of groundwater recharge into the Chatsworth formation on the mountain top and the moderate bulk hydraulic conductivity of the mountain result in small volumetric rates of groundwater flow. The occurrence of numerous shale and mudstone strata in the sandstone sequence contributes to the low bulk hydraulic conductivity of the mountain. A major shear zone runs through the SSFL and several extensive faults have been identified. These features can influence the hydraulic conductivity, gradient and directions of groundwater flow at the local scale, but show no evidence of providing extensive, rapid (and thus distant) transport pathways either across or along their planes. A gradual decrease in the bulk hydraulic conductivity with depth is also expected to influence the three-dimensional flow of groundwater. The bulk hydraulic conductivity of the Chatsworth formation is highly sensitive to fracture aperture and spacing, and it is well established that fracture apertures become smaller with increasing lithostatic load. As fractures tend to close with depth, the bulk hydraulic conductivity approaches the conductivity of the matrix, which also must decrease somewhat with depth. Other factors being equal, the most active groundwater flow occurs at shallower depths, and flow becomes increasingly sluggish at greater depths due to fracture closure under the influence of the increasing lithostatic load.

The transport and fate of contaminants described above applies throughout the SSFL property and adjacent areas even though there is substantial variability in the hydrologic nature of the geologic units across the site. Detailed investigations of hydrogeologic properties and the nature and extent of TCE in the groundwater in the northeast and northwest portions of the SSFL, and the site-derived tritium plume in Area IV, have been conducted. These locations were selected to span the range of hydrogeologic variability at the SSFL. The areas of TCE and site-derived tritium in the northwestern part of the site occur where the bulk hydraulic conductivity is relatively low, likely due to fewer and/or smaller fractures. In the northeast, the TCE plume is located in an area where the bulk hydraulic conductivity is moderate and the fractures are more closely spaced and/or larger. The northwest plumes are located within Sandstone 2 and the northeast TCE plume is located in Sandstone 1. The stratigraphy of the Chatsworth formation is shown in Figure 2-2. These two sandstone units have similar lithology and turbidite origin but may have different fracture characteristics likely due to structural influences. The Former Sodium Disposal Facility (FSDF) TCE and site-derived tritium plumes extend for hundreds of feet from their input location, while the northeast TCE plume extends a few thousand feet from its likely input location.

Flow paths are complex due to the physical setting and years of groundwater extraction within the SSFL. Some flow paths near the center of the site may initially be near-vertical and some of the coreholes installed at the SSFL are likely near the center-line of plumes created from releases that occurred above these areas. Vertical coring through a near-vertical flow path and analysis of rock core samples for VOCs at roughly one-foot intervals provides unprecedented data sets for vertical characterization. This is contrasted with most all other chemical characterization sites where vertical wells are installed to characterize predominantly horizontal plumes.

In summary, advective transport in the fracture network is greatly off-set by diffusive transport into the porous bedrock matrix, thus slowing the rate of transport (and hence distance traveled, i.e. extent) by orders of magnitude compared to the mean groundwater velocity in the fractures. Sorption onto the natural organic carbon present in the bedrock further slows the rate of transport for those chemicals exhibiting such characteristics. Mixing at the intersections of fracture planes in an inter-connected fracture network causes the plumes to widen and reduce concentrations as the COPCs are transported down the flow path. The rate of transport slows as the contaminants diffuse across an ever-increasing total fracture surface area into an ever-increasing volume of bedrock as they are transported down the flow path by advection. The volume expansion provides additional surface area over which diffusion can occur. Biological and radioactive decay and abiotic reactions of some chemicals, including TCE, further attenuate solute transport. Analysis of available data, coupled with the understanding of the mass transport of solutes in the hydrogeologic environment encountered below the SSFL indicates that a few plumes extend distances up to a few thousand feet from where the contaminants entered the ground. Such a plume exists in the northeast portion of the SSFL and has been the subject of comprehensive investigations that will continue into 2008. Predominant features controlling this transport are the combination of the bulk hydraulic conductivity (K) coupled with the hydraulic gradient. At the other end of this spectrum (i.e., lower bulk K coupled with similar or lower hydraulic gradients), the lateral extent of plumes extend distances of hundreds of feet. Such plumes exist in the northwest part of the SSFL in Area IV. A TCE plume originates from the FSDF and a site-derived tritium plume is believed to originate from Building 10. Available site data and the understanding of the hydrogeologic conditions indicate that COPCs in the groundwater beneath the SSFL have migrated hundreds to a few thousand feet from where they entered the ground over the course of several decades, whereas linear groundwater velocities in the fracture network are on the order of up to thousands of feet per year (Montgomery Watson, 2000a).

Additional summary descriptions of the key factors influencing these conditions are summarized in Section 2.3.3 below. The reader is referred to the *Overview of the Site Conceptual Model for the Migration and Fate of Contaminants in Groundwater at the SSFL* (Cherry, McWhorter and Parker, 2007) for further details on these controlling conditions. Note that the number of primary elements shown below (21) is higher than the numbers that were listed in the above-referenced document (16). More elements are listed below as the groundwater team continues to refine the subtleties associated with contaminant transport and fate in the bedrock underlying the SSFL.

2.3.3 Summary of Primary Elements Describing the Nature and Extent and Transport and Fate of COPCs in Bedrock at the SSFL

The following is a list of the key elements, based on the evaluation of all the available site data, that in conjunction describe the nature and extent, and transport and fate of COPCs in the Chatsworth formation at the SSFL.

1. The Chatsworth formation underlies most of the SSFL and its matrix porosity provided by interconnected pores is large and the bulk fracture porosity is orders of magnitude smaller.

2. The rock matrix composition includes abundant reactive minerals and appreciable natural organic matter.
3. The fracture network is a systematic arrangement of bedding parallel fractures and steeply-dipping joints, with fracture network spacing and apertures spatially variable due to variability in lithology and structural characteristics.
4. Groundwater present in alluvium, weathered bedrock and unweathered bedrock and throughout forms an active hydrologic continuum in which the water in the alluvium and weathered bedrock predominantly flows into the unweathered bedrock (i.e. Chatsworth formation).
5. Groundwater recharge is a small percent of the mean annual precipitation.
6. The groundwater contains many inorganic constituents of natural origin that provide insight concerning groundwater flow and contaminant behavior.
7. The bulk hydraulic conductivity is low to moderate.
8. There is low to moderate large-scale transmissivity across and along the faults and shear zones.
9. The fracture network is generally well interconnected hydraulically, both horizontally and vertically.
10. At some depth below the SSFL, the bulk hydraulic conductivity becomes very small causing groundwater flow and contaminant migration below this depth to be insignificant.
11. Effective fracture apertures are small to moderate.
12. Much of the groundwater originating in the SSFL property discharges at springs, seeps and phreatophytes that are situated on the surrounding mountain slopes.
13. A large amount of TCE mass occurs in the vicinity of many of the former DNAPL input locations, in the form of dissolved and sorbed mass in the rock matrix.
14. The chlorinated solvent contamination was initially caused by DNAPL penetration into the subsurface and commonly below the water table. The DNAPL has since been converted to dissolved and sorbed mass that now resides in the rock matrix and contaminant migration by DNAPL flow no longer occurs.
15. Appreciable chlorinated solvent mass exists as dissolved and sorbed mass in water-saturated low permeability matrix blocks between fractures above the water table at many former DNAPL input locations where it serves as a source for solvent vapor migration to ground surface. Recharge transports dissolved mass from the unsaturated zone to the groundwater plume, but does not substantially influence plume expansion.
16. All soluble chemicals and radionuclides diffuse into, and out of, the water-saturated porous rock matrix. VOCs can diffuse into the interconnected air-filled porosity in the matrix and fracture porosity above the water table.
17. Contaminant plumes are created by advective transport of dissolved contaminants through the well-interconnected fracture network and are strongly retarded by diffusion

into and out of the rock matrix. These processes result in orderly plumes that have been, and will continue to be, monitorable.

18. Small volumetric groundwater flow results from the low groundwater recharge, which severely restricts contaminant flux.
19. The contaminant plume fronts are now migrating very slowly, at velocities much smaller than the generally rapid mean groundwater velocity in the fracture networks so that the plume front positions are nearly stationary.
20. Strong contaminant retardation occurs across the site although there is substantial spatial variability in the fracture network characteristics due to variable lithology and structural influences.
21. All of the contaminant plumes are being naturally attenuated due to a number of processes including degradation, dispersion and diffusion.

3.0 INTERIM MEASURES FOR PLUME FRONT CONTAINMENT

Section 3.1 provides background information, much of which is new and previously unpublished, important to the evaluation and selection of plumes and technologies for implementation as interim measures to achieve plume front containment. Section 3.2 describes the screening of plumes and technologies to identify potential candidates for plume front containment interim measures implementation. The plume front containment interim measures recommended for implementation are described in Section 3.3, and an implementation plan for each interim measure recommendation is presented in Section 3.4. The proposed schedule for implementation of the recommended plume front containment interim measures is presented in Section 3.5, and a brief summary is presented in Section 3.6.

3.1 BACKGROUND INFORMATION

There are a number of recently completed or ongoing studies providing data that are relevant to the evaluation of interim measures for plume front containment. These interim measures technologies are being evaluated in addition to the specific DTSC requirement to initiate groundwater extraction at the "solvent plume offsite to the northeast of the site…and…in the southernmost groundwater extraction (WS-9A) at the buffer zone." (DTSC, 2008). A plume extent analysis, a summary of studied mechanisms contributing to plume front containment, and the recent results of ongoing degradation studies are discussed below.

3.1.1 Plume Extent Analysis

A work plan was submitted to and approved by the DTSC in 2000 (Montgomery Watson, 2000b), which included the temporary cessation of groundwater extraction from wells at the SSFL to facilitate the performance of Chatsworth Formation Operable Unit (CFOU) groundwater studies absent the influence of pumping. The work plan also specified monitoring wells that would be sampled and analyzed more frequently to provide a means of determining if plumes were beginning to migrate in the absence of groundwater pumping. An analysis of plume extents was performed in August, 2006 in which groundwater data collected from 62 groundwater extraction or monitoring wells during 2000 through first-quarter 2006 were evaluated to assess whether COPC concentration trends were evident that might indicate expansion of plume extent following the cessation of groundwater pumping. This analysis included data from the wells specified in the work plan, as well as from a number of additional wells that were chosen based on their proximity to the plumes and added to the analysis for completeness. The complete analysis is presented in Appendix C.

The primary conclusion of this analysis was that based on the data evaluated there had been no discernable extension of groundwater plumes during the six-year study period. Without exception, the 29 plume boundary monitoring wells in the study exhibited no appreciable concentration changes or no detections throughout the evaluation period. These data indicate that the plume front positions as monitored by the wells around their periphery have been nearly stationary during the recovery period. Statistical analysis of groundwater elevation and TCE concentration trends show similar results as presented in Appendix D.

3.1.2 Studied Mechanisms Contributing to Plume Front Containment

A detailed discussion of the current understanding of the nature and extent, and transport and fate of COPCs in SSFL groundwater was presented in Section 2 of this work plan. The information presented there is briefly summarized below using TCE as the basis for discussion for reasons described previously in Section 2.3.1.

The Chatsworth formation is a fractured and porous sedimentary formation in which groundwater primarily moves through a system of interconnected fractures. The fractures bound matrix blocks that have a much smaller ability to transmit water and have porosities greatly exceeding the porosity provided by the fracture network. TCE DNAPL entered the Chatsworth formation through the fracture system and rapidly began to dissolve into contiguous water, creating a concentration gradient of dissolved TCE that provided the driving force for the diffusion of the TCE into the water contained within the porous matrix blocks. Naturally-occurring organic carbon provided considerable surface area for adsorption of TCE to the matrix, further driving the dissolution of TCE DNAPL and the diffusion of TCE into the matrix. Consequently, virtually no TCE DNAPL remains in the system and nearly all of the TCE mass now resides in either the sorbed phase within the matrix or in the dissolved phase in the relatively stagnant matrix porewater. Another consequence of the diffusion of TCE into the matrix porewater is that the migration of the dissolved TCE plume fronts is greatly slowed compared to the groundwater velocities in the fractures. Thus, the TCE mass has remained relatively close to the locations where the TCE entered the system. Other dissolved COPCs are subject to the same diffusion processes, hence their migration is also greatly slowed. For some contaminants such as TCE, the attenuation of plume advancement is further enhanced by degradation. For the current conditions at the SSFL, the strong plume front retardation due to the combined effects of diffusion-driven contaminant mass transfer from the fractures into the rock matrix, sorption, dispersion and degradation has resulted in plume fronts that are now nearly stationary.

These mechanisms have been the subject of considerable study at the SSFL since about 1997 as summarized in the Site-wide Groundwater Characterization Work Plan (MWH, 2008), and as evidenced by the document list provided in Section 7.0 of the SCM overview (Cherry, McWhorter and Parker, 2007). The attenuating effects of these processes will be further studied with the installation of a transect of coreholes near the front of the Northeast Area plume under the DTSC-approved Phase 2 SCM work plan (MWH, 2007a) in early 2008. The degradation mechanisms active at the SSFL continue to be studied as further described below.

3.1.3 Degradation Studies

Previous field and laboratory studies reported that a combination of biotic and abiotic processes have contributed to the complete dechlorination of some of the initial TCE mass in the Chatsworth formation (Pierce, 2005 and Freedman & Darlington, 2006, Darlington et al, 2008). Degradation of TCE to cis-1,2-dichlorothene (cDCE) is mediated biotically through reductive dechlorination. TCE, cDCE and vinyl chloride were also shown to degrade abiotically to non-strippable residue (NSR; a composition of multiple soluble organic acids) and carbon dioxide (CO_2). The detection of acetylene in samples from monitoring wells provides field evidence for abiotic degradation of TCE, cDCE and vinyl chloride.

Subsequent laboratory microcosm studies led by Dr. Freedman at Clemson University confirmed the biotic degradation of TCE to cDCE in SSFL sandstone, and that cDCE is abiotically transformed to NSR and ultimately to CO_2. Recent studies show that CO_2 formation occurs via NSR, directly from cDCE (Darlington, 2008). The abiotic transformation of TCE to NSR and

CO_2 was also confirmed. Although vinyl chloride was not a significant intermediate compound in the microcosms, results from ^{14}C-labeled vinyl chloride microcosms confirmed the potential for NSR and CO_2 formation from this compound as well as from TCE and cDCE. Glycolate, formate and acetate were identified as the primary components of the NSR from the microcosms. The thermodynamics for transformation of TCE and cDCE to these organic acids were evaluated and found to be favorable. The catalyst for the transformation of these chlorinated ethenes to CO_2 is believed to be associated with iron oxides present within the bedrock (Darlington, 2008).

Additional experiments were performed with the objective of determining the rate of abiotic transformation of cDCE in SSFL sandstone and identifying the transformation products formed. The preliminary conclusions of these studies indicate that abiotic transformation of cDCE to vinyl chloride, acetylene, ethene and ethane is evident in SSFL sandstone and the abiotic transformation of cDCE to NSR and CO_2 was further confirmed. The primary components of the NSR were confirmed to be glycolate, formate and acetate, which are readily further transformed to CO_2 biotically or abiotically. A first-order rate for the abiotic transformation of cDCE by SSFL sandstone was measured and converted to a surface-area normalized rate that was found to be comparable to similarly normalized abiotic transformation rates in the literature.

Finally, an additional study was performed aimed at identifying the TCE to cDCE dehalogen (i.e., the microorganism responsible for the biotic transformation of TCE to cDCE in SSFL sandstone). This experiment has identified the likely organism responsible for dechlorinating TCE to cDCE (Darlington, 2008).

These studies have demonstrated that some of the halogenated ethene mass in groundwater at the SSFL is being completely dechlorinated to harmless end products at measurable rates via a combination of biotic and abiotic transformation processes. In particular, at the plume fronts the contaminant concentrations are low and there is a large volume and surface area (approximately one square meter per gram) of sandstone/minerals that creates a reactive zone for the transformation of contaminants. The mineral reactivity of the sandstone matrix provides a natural barrier that, coupled with the effects of matrix diffusion, adsorption and dispersion, causes the plume fronts at the SSFL to be nearly stationary. The collective containment effects of matrix diffusion, sorption, dispersion and transformation will be referred to as Natural Reactivity Plume Front Containment throughout the remainder of this work plan.

A comprehensive search and review of the literature on degradation of other chemicals present in the SSFL groundwater is being performed as described in the DTSC-approved SCM Phase 3 Work Plan (MWH, 2007b). A specialized groundwater field sampling and analysis program aimed at measuring low concentrations of dissolved gases potentially present as transformation products in SSFL groundwater is also being performed under that work plan.

3.2 EVALUATION OF PLUMES AND TECHNOLOGIES FOR PLUME FRONT CONTAINMENT INTERIM MEASURES

The groundwater plumes were evaluated based on a number of criteria to assess the need for interim measures, and over a dozen technologies were screened to evaluate their potential applicability as interim measures for plume front containment in the fractured porous media of the Chatsworth formation at the SSFL. These evaluations, and the selection of plumes and technologies for plume front containment interim measures implementation, are discussed below.

3.2.1 Screening of Plumes for Interim Measures Applicability

The groundwater plumes were screened to evaluate the need for plume front containment interim measures as presented in Table 3-1. Analysis of the available data, including the new data and ongoing studies described above in Section 3.1 support the concept that the plume fronts are nearly stationary. As such, though the evaluation considered the proximity of a plume to the property boundary and the plume extent, nearly-stationary plume fronts located within the property boundary were, with one exception, not considered to be candidates for interim measures. The only plume extending off site is the Northeast plume (Plume 1 on Figure 2-1). Despite the mounting evidence for nearly-stationary plume fronts, the potential continued expansion of this off-site plume front has more serious implications than the potential further expansion of a plume within the property boundary. As such, the off-site portion of the Northeast Plume was identified as a candidate for interim measures.

The exception noted above involves a third evaluation criteria that was considered. The occurrence of seeps and springs at and around the SSFL permit the possibility that impacted groundwater could be discharged via a seep or spring to the ground surface (Figure 3-1). Though the proximity of plume extents to identified seeps and springs varies, nearly stationary plume fronts without a seep or spring within or immediate adjacent to the plume boundary were not considered candidates for interim measures. The noted exception is at the southern boundary of the Coca/Delta/STL-IV Plume (Plume 9 on Figure 2-1). VOCs (primarily TCE and cDCE) have been detected in samples from springs FDP-890 and FDP-881 when the water table in this area is sufficiently high. This area has been the subject of an ongoing interim measure involving the pumping of groundwater from extraction well WS-9A to lower the local water table and maintain these springs in a dewatered state. This location was also identified as a candidate for interim measures.

Additionally, both locations were specified for interim measures in DTSC's May 16, 2008 letter.

3.2.2 Screening of Technologies for Plume Front Containment Interim Measures Applicability

A summary of the screening of technologies potentially applicable for plume front containment interim measures is presented in Table 3-2. The primary basis for the development of Table 3-2 is provided in *Contaminants in the Subsurface – Source Zone Assessment and Remediation*, a report published in book form by the National Research Council (NRC) of the National Academies (NRC, 2005). The NRC was organized by the National Academy of Sciences in 1916 and is administered jointly by the Academy, and the National Academy of Engineering and the Institute of Medicine, both of which were also established by the National Academy of Sciences. The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. The Academy has a mandate requiring it to advise the federal government on scientific and technical matters upon the authority of the charter granted to it by the Congress in 1863.

The report was developed by the NRC Committee on Source Removal of Contaminants in the Subsurface, which analyzed the results of source remediation activities completed at dozens of U.S. Army and other facilities. The committee heard presentations and reviewed extensive reports for 11 U.S. Army sites, and reviewed five additional sites discussed in a

U.S. Environmental Protection Agency (EPA) expert panel report (EPA, 2003). These sites were contaminated with either chemical explosives or chlorinated solvents, and they spanned a range of hydrogeologic conditions. The committee also reviewed numerous source remediation activities at non-Army sites, including nearly 100 technology-specific case studies. The data from these sites and case studies formed the basis for development of the NRC report and for the DNAPL source remediation technology comparison table contained therein (NRC, 2005).

The entries in the NRC technology summary table for what is classified there as a Type V media setting (fractured media with high matrix porosity, e.g., SSFL-type hydrogeologic conditions) were replicated in Table 3-2, and edited for consistency with the application of those technologies to plume front containment based on the information available for such application of those technologies and on professional judgment. The information in Table 3-2 was further augmented with information regarding remediation in fractured rock settings from presentations and proceedings of the *"2007 EPA/National Groundwater Resource Association Fractured Rock Conference: State of the Science and Measuring Success in Remediation"* in Portland, Maine (EPA/NGWA, 2007), and with information about technologies specific to DNAPL and chlorinated solvent remediation from presentations and proceedings of the California Groundwater Resources Association *"DNAPL 2: Source Zone Characterization and Remediation"* conference in Long Beach, California (CGRA, 2007).

The following publications were also used in developing the technology screening summary:

- *Conceptual analysis of zero-valent iron fracture reactive barriers for remediating a trichloroethylene plume in a chalk aquifer*, Water Resources Research. Vol. 43. March, 2007.
- *Technology Status Report: Hydraulic, Pneumatic and Blast-Enhanced Fracturing for Environmental Applications,* National Defense Center for Environmental Excellence, March 29, 2000.
- *Blast Fracturing: Installation and Evaluation of a Fractured Bedrock Zone Within Granitic Bedrock at Edwards AFB,* Mark Henkes, Sarah Grossi Ph.D., and Doug Britton Ph.D., September, 2007.
- *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents*, United States Department of Defense. August 2004.
- *In-Situ Chemical Oxidation*, United States Environmental Protection Agency Engineering Issue. Scott G. Huling and Bruce E. Pivetz, EPA/600/R-06/072, August, 2006.

- *The DNAPL Remediation Challenge: Is There a Case for Source Depletion?* United States Environmental Protection Agency, EPA/600/R-03/143, December, 2003.
- *Dense Non-Aqueous Phase Liquids (DNAPLS): Review of Emerging Characterization and Remediation Technologies*. Interstate Technology Regulatory Cooperation. June, 2000.
- *Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones.* Interstate Technology Regulatory Cooperation. June, 2000.

The screening prioritized technologies potentially applicable to containing plume fronts extending over large areas and to depths of hundreds of feet in fractured media with high matrix porosity. These criteria eliminated many of the technologies from consideration either because of physical limitations or energy requirements at the required depth and scale. Several technologies would require pilot testing to evaluate feasibility and site-specific design parameters. These technologies and others that would require more than one year to implement were also eliminated from consideration for interim measures.

Groundwater extraction and monitored natural reactivity plume front containment were identified as technologies potentially applicable as plume front containment interim measures that could be implemented and functional within one year. Additionally, groundwater extraction was specified as a requirement for the Northeast area (Plume 1) and in the southwest area (WS-9A, Plume 9) in DTSC's May 16, 2004 letter.

3.3 RECOMMENDATIONS FOR PLUME FRONT CONTAINMENT INTERIM MEASURES IMPLEMENTATION

Based on the screening of plumes and technologies as described above in Section 3.2, three specific plume front containment interim measures are being proposed for implementation. Each of these recommendations is discussed below.

3.3.1 Plume 9 Spring Dewatering

As noted previously in Section 3.2.1, the dewatering of springs FDP-890 and FDP-881 located at the southern boundary of the Coca/Delta/STL-IV Plume (Plume 9) via pumping at extraction well WS-9A has been the subject of an ongoing interim measure since December, 2006. Features are shown in Figure 3-2. It is recommended that pumping groundwater from WS-9A to maintain these springs in a dewatered state continue as an interim measure. However, changes to the existing approach to pumping, water conveyance, and treatment will be required in the near future as a result of pending changes to the on-site groundwater treatment systems and associated operating permits. These changes, as well as specific performance criteria for this recommended interim measure, are discussed further in the implementation plan presented in Section 3.4 below.

3.3.2 Northeast Plume 1 Off-site Plume Front Containment

The off-site extent of the Northeast Plume (Plume 1) was identified as a candidate for interim measures. Consistent with the requirement contained in DTSC's May 16, 2008 letter groundwater extraction will be implemented in this area even though it is possible that ongoing studies being performed in that area under DTSC-approved work plans may be compromised, most notably the installation of a transect of coreholes through the off-site portion of the Northeast Plume. The purpose of the transect is to further evaluate the magnitude of contaminant attenuation resulting from matrix diffusion, sorption, dispersion and degradation (MWH, 2007a). Monitored natural reactivity plume front containment is also being recommended as an interim measure at this location. The details of these interim measures are discussed further in the implementation plan presented in Section 3.4 below.

3.4 PLUME FRONT CONTAINMENT INTERIM MEASURES IMPLEMENTATION PLANS

An implementation plan is presented below for each of the plume front interim measures being proposed.

3.4.1 Plume 9 Spring Dewatering Implementation

This ongoing interim measure that was initiated in December, 2006 has consisted of pumping groundwater from extraction well WS-9A at a rate sufficient to lower the water table such that VOC-impacted groundwater from Plume 9 does not discharge to the ground surface at springs FDP-890 and FDP-881. The groundwater pumped from WS-9A has been conveyed via pipeline to the Delta treatment system where it has been treated and discharged. However, a new central treatment system is being constructed, and the Delta treatment system will be permanently decommissioned following the commissioning and effective operation of the new treatment system (expected to be operational by late-2008).

As a result, a new pipeline will be constructed to convey the pumped groundwater from WS-9A to the central treatment system. Groundwater will be pumped from WS-9A at a frequency and rate sufficient to maintain springs FDP-890 and FDP-881 in a dewatered state. These two springs will be inspected weekly to ensure that they are not discharging groundwater. These weekly inspections will be documented and reported in the quarterly and annual groundwater monitoring reports submitted to DTSC.

3.4.2 Off-site Northeast Plume Front Implementation

Groundwater extraction will be implemented within this plume as required by DTSC (2008). Groundwater extraction is being proposed from well RD-84, which is the well located furthest to the north in this area and positioned within the site boundary. Target extraction rates from this well are projected to range from a low of 150 gallons per day (gpd) to a high of 4,500 gpd. Groundwater will also be extracted from two additional up-gradient locations, RD-72 and corehole C-1. Locations of these proposed extraction wells are shown in Figure 3-3. Groundwater extraction from corehole C-1, RD-72 and RD-84 should be initiated sequentially in this order to ensure that the transport of high concentration zones of contaminated groundwater is not enhanced from the source area near corehole C-1 toward the plume front. C-1 should be pumped at the highest flow rate, with an intermediate pumping rate at RD-72 and a lower pumping rate at RD-84. Target extraction rates from corehole C-1 and RD-72 are estimated to range from a low of 15,000 gpd to a high of 45,000 gpd and from 750 gpd to 7,500 gpd, respectively. Collectively, extraction rates from all three wells within the northeast area will range from 15,900 gpd to 57,000 gpd.

Natural containment of the off-site portion of the northeast plume (Plume 1) will be monitored through the analysis of continuing routine quarterly groundwater monitoring data. To augment the routine quarterly sampling data in this area, additional samples will be collected quarterly for one year and annually thereafter from the sampling intervals of the Westbay multilevel systems being installed in coreholes C-16 and C-17 and analyzed for VOCs. These two coreholes are located near the plume front and provide an opportunity to collect discrete-depth groundwater data throughout the vertical profile at a plume front that can be evaluated for trends over time (Figure 3-2). The wells proposed for inclusion in the natural containment analysis are shown in Figure 3-3 and, in addition to the C-16 and C-17 Westbay multilevel systems, include:

- RD-32
- RD-36A,B,C,D
- RD-37
- RD-38A,B
- RD-39A,B
- RD-53
- RD-66
- RD-71
- RD-84 (C-9)
- OS-24

The evaluation will be performed in the same style as the plume extent analysis described in Section 3.1.1 and presented in Appendix C, but will be completed using the quarterly TCE and cDCE concentration data rather than annual maximum concentrations in order to provide greater resolution over shorter time scales. The concentration and groundwater elevation data will be presented on summary well data sheets (please see Appendix C for examples) that facilitate the identification of trends and potential relationships between them. Trend identification will be based on the statistical methods described in Appendix D.

This evaluation will be completed quarterly and will be submitted to DTSC in the quarterly groundwater monitoring reports. The evaluation of data through a given quarter will be presented in the report for the following quarter; for example, the evaluation of data through the first quarter will be presented in the second quarter report. These evaluations will include a discussion of the observed trends and their implications for the plume front position.

These two groundwater interim measures will be used to evaluate plume front containment in this area. If site data indicate further off-site transport of contaminants, additional groundwater extraction wells may be added down the flow path from RD-84.

3.5 IMPLEMENTATION SCHEDULE FOR PROPOSED PLUME FRONT CONTAINMENT INTERIM MEASURES

Implementation activities for source area groundwater extraction will commence within 30 days of DTSC's approval of this IM work plan. Initial activities will include: design of the conveyance pipeline distribution, electrical feeds, extraction well control systems, and upgrades to the groundwater treatment system; supplier contracting; equipment procurement for pipelines, pumps and controls; permitting; construction; and start-up testing. Work has been initiated to modify the configuration of the previously-designed groundwater treatment plant as of the date of this work plan. Modifications to the treatment plant unit processes and equipment sizes are required to accommodate the type and concentrations of chemicals that are estimated to be within the extracted groundwater. These modifications may also trigger additional permitting constraints and the re-submittal of applications. As such, it is expected that the new groundwater treatment plant, which incorporates the new IM extraction wells, will not be operational until the first quarter of 2009 assuming permitting is complete within 2 months of submittal. The tasks and preliminary milestones for implementing the plume front interim measures are noted below.

Task	Preliminary Milestone Target
Plume 9 Spring Dewatering	
Conveyance of extracted groundwater from WS-9A to new central treatment system via pipeline, and weekly inspection of springs FDP-890 and FDP-881	Begin upon commissioning and effective operation of new central treatment system (expected in early-2009)
Document weekly inspection of springs FDP-890 and FDP-881 and submit field inspection reports to DTSC	Include weekly inspection reports in quarterly groundwater monitoring reports
Northeast Plume Front Containment	
Procure pumps, provide power, construct conveyance piping and tie to new treatment system	Initiate upon approval of work plan. Commission wells sequentially with C-1, RD-72 and RD-84, starting extraction from C-1 at target extraction rate for 30 days after new treatment system is fully operational. Initiate extraction from RD-72 30 days after C-1 operational. Initiated extraction from RD-84 30 days after RD-72 operational.
Collect groundwater samples from all sampling intervals of Westbay multilevel systems at C-16 and C-17 quarterly for one year and collect samples annually thereafter	Begin upon completion of Westbay system installation and development
Evaluate natural containment of off-site Northeast plume quarterly and submit findings to DTSC	First evaluation to be submitted in the quarterly groundwater monitoring report for the quarter following receipt of DTSC approval of this work

Task	Preliminary Milestone Target
	plan; subsequent quarterly evaluations to be submitted in the quarterly groundwater monitoring reports

3.6 ANNUAL REPORT AND PERFORMANCE EVALUATION

Results of the groundwater interim measures will be reported to DTSC annually to coincide with submittal of the groundwater monitoring reports. The reports will describe operations of extraction and treatments systems, volume of water extracted and treated, and influent and effluent concentrations of COPCs.

The groundwater extraction interim measure for the northeast area will continue until the time that the plume retardation processes are verified through the acquisition of additional field data and if monitoring data indicate that the natural containment interim measure is effective. Upon completing the northeast transect, an evaluation will be performed in the context of contaminant attenuation regarding the need for continuing groundwater extraction interim measures. This is expected to occur during the second half of 2009.

3.7 SUMMARY

In support of evaluating potential interim measures for plume front containment as required by DTSC, some relevant and previously unpublished background information was presented. In particular, an evaluation of plume extents based on six years of site data after initiating the shutdown of SSFL groundwater extraction wells suggested that the plume front positions as monitored by the wells around their peripheries have been nearly stationary during the recovery period. A summary of the studied mechanisms contributing to the nearly stationary plume front positions, including matrix diffusion, sorption, dispersion and degradation was also presented. A combination of field and laboratory degradation studies have demonstrated that some of the halogenated ethene mass in groundwater at the SSFL is being completely dechlorinated to harmless end products at measurable rates via a combination of biotic and abiotic transformation processes. It is expected that the abiotic transformation reactions are catalyzed by iron oxide minerals in the SSFL sandstone. The term “natural reactivity plume front containment” has been defined to represent the collective effects of matrix diffusion, sorption, dispersion and degradation.

TCE was used as the basis for discussion in much of the information described above. In the context of potential for off-site migration, TCE is the worst-case COPC because it penetrated much deeper into the Chatsworth formation due to its initial migration as a DNAPL, because a much larger TCE mass was released to the subsurface at many more locations throughout the SSFL, because of its occurrence and concentration in groundwater, and because of its chemical characteristics. Though some COPCs may be unaffected by sorption or degradation, all solutes (i.e., all dissolved-phase COPCs) are subject to the processes of dispersion and matrix diffusion.

Plumes were screened to evaluate the need for plume front containment interim measures, resulting in the identification of the off-site portion of the Northeast Plume, and the southern boundary of the Coca/Delta/STL-IV Plume as candidates. A technology screening was completed that identified pump and treat (hydraulic containment), and monitored natural reactivity plume front containment as technologies potentially applicable as plume front containment interim measures that could be implemented and functional within one year in accordance with DTSC's requirement.

Three interim measures recommendations are proposed as a result of these evaluations and as specified by DTSC (2008). First, the ongoing interim measure of pumping groundwater from well WS-9A to dewater springs FDP-890 and FDP-881 near the southern boundary of the Coca/Delta/STL-IV plume be continued, with pipeline modifications to be made to convey the pumped groundwater to the new central SSFL groundwater treatment system upon its commissioning and effective operation (expected in early-2009). The other two interim measures include groundwater extraction from three wells, coupled with monitored natural reactivity plume front containment, for the off-site portion of the Northeast plume. This interim measure should meet DTSC's requirement and provide an opportunity for closer study and monitoring of this plume front and for an evaluation of potential responses if further off-site plume expansion is indicated by site data.

4.0 INTERIM MEASURES FOR SOURCE AREA REMEDIATION

Section 4.1 provides background information important to the understanding of source area conditions at the SSFL. Section 4.2 presents an analysis of the effects of source area remediation on the plumes at the SSFL, specifically considering the SSFL source area conditions described in Section 4.1. Section 4.3 presents a technology evaluation summary. Section 4.4 presents a discussion of recommendations for source area remediation interim measures, and Section 4.5 describes a source area remediation interim measures implementation plan and schedule. Finally, a brief summary is presented in Section 4.6.

4.1 SOURCE AREA DEFINITION

As described in detail in Section 2, the available site data indicate that the reportedly large volume of TCE DNAPL that entered the subsurface at the various input locations at the SSFL can be reasonably accounted for by the total dissolved and sorbed mass now found in the rock matrix at and near the input locations, and that there is now virtually no DNAPL in the system. This realization is critical to source area remediation considerations because in much of the literature available on the remediation of DNAPL source zones, the source zone is defined as the region containing DNAPL and the remediation objective is to remove as much DNAPL from the source zone as possible. At the SSFL virtually no DNAPL remains in the system, and what remains is sorbed and dissolved phase TCE mass that resides primarily within the porous matrix blocks.

A more thorough source area definition is provided by the NRC (NRC, 2005):

> *"A source zone is a saturated or unsaturated subsurface zone containing hazardous substances, pollutants or contaminants that acts as a reservoir that sustains a contaminant plume in groundwater, surface water, or air, or acts as a source for direct exposure. This volume is or has been in contact with separate phase contaminant (NAPL or solid). Source zone mass can include sorbed and aqueous-phase contaminants as well as contamination that exists as a solid or NAPL."*

This definition allows that a DNAPL source zone may not necessarily still contain DNAPL. Furthermore, from a practical standpoint, at the SSFL it is often not possible to know whether or not a particular region or volume was or was not in contact with DNAPL at one time. As such, one definition of a source area at the SSFL could be considered simply as the region containing the highest current dissolved concentrations. However, DTSC's attachment to its May 16, 2008 letter defines source zones as "any monitoring wells where the reported concentrations of TCE have been 1,000 micrograms per liter (µg/L) or higher."

4.2 ANALYSIS OF SOURCE AREA REMEDIATION EFFECTS ON PLUMES

The transport of soluble COPCs in the fractured porous media of the Chatsworth formation is dominated by the transfer of contaminant mass from the groundwater flowing through the fracture network into the nearly stagnant groundwater that is resident in the porous rock matrix by molecular diffusion. This transfer of mass into the rock matrix effectively slows the rate at which contaminants are transported in groundwater flowing through the fracture network (by orders of magnitude relative to the average linear groundwater velocity). This phenomenon is reflected in the conditions at the SSFL where plumes have migrated hundreds to a few thousands of feet from the contaminant input locations over the course of several decades, whereas linear groundwater velocities in the fracture network are on the order of up to thousands of feet per year (Montgomery Watson, 2000a).

Molecular diffusion, like Darcy's law, is a gradient flux law that was first described by Fick in 1852. Stephen Foster (1975) was the first to apply the concept of molecular diffusion to groundwater flow and solute transport in a fractured porous media. In this case, the concept was applied to the diffusion of atmospheric tritium into the fractured Chalk formation in England. Freeze and Cherry (1979) extended the concept of retardation of a solute plume front due to matrix diffusion. Additional work done by members of the SSFL Groundwater Advisory Panel extended the concept of matrix diffusion to the disappearance of immiscible phase liquids in fractured geologic media (Parker, et al, 1994), and others have considered the effects of diffusion-limited mass transfer on contaminant mass removal from fractured porous media (Mutch, et. al, 1993; Freeze and McWhorter, 1997; and Wilson, 1997). Specific details as to the effects of matrix diffusion on the transport of TCE in the Chatsworth formation were published in the April 2000 Technical Memorandum (Montgomery Watson, 2000a), and a general conceptual model for source zones and plumes that considers chlorinated solvent DNAPL behavior in fractured porous media as well as the formation and evolution of contaminant plumes from the source zone was presented by Parker (2007). Others have published additional information regarding the retardation of organic compounds (both sorbing and conservative, i.e., non-sorbing) in fractured chalk (Roehl, et al, 2002). Hence, the science supporting the effect of matrix diffusion on both reactive and non-reactive compounds is well established.

Two-dimensional (2-D) steady-state flow and transient transport discrete-fracture network simulations were performed by Steven Chapman, a research associate at the University of Waterloo, working under the supervision of Drs. Parker and Cherry, to evaluate the effect of matrix diffusion on the attenuation of TCE and other COPCs in the Chatsworth formation groundwater (Montgomery Watson, 2000a and MWH, 2003a and 2003b). Additional simulations have been performed to provide insight into the potential effects of source area remediation on contaminant plumes in a SSFL-type hydrogeologic setting. The results of these simulations were first presented to DTSC by the SSFL Groundwater Advisory Panel in June 2001 and are described in further detail below (Cherry, Parker and McWhorter, 2001).

4.2.1 Description of Source Area Remediation Simulations

Insight into the potential effectiveness of source area remediation was developed by running stylistic simulations using a two-dimensional numerical model (FRACTRAN), developed at the University of Waterloo (Sudicky and McLaren, 1992). The model allows the simulation of steady state flow and transient contaminant transport in discretely fractured porous media and includes rigorous analysis of flow and transport both in the fractures and in the matrix, including the effects of matrix diffusion. Numerical simulations of TCE and perchlorate transport using this same model were previously reported (Montgomery Watson, 2000a and MWH, 2003a and 2003b) and demonstrated the strong retardation effect that matrix diffusion has on the transport of both sorbing and conservative (non-sorbing) solutes in hydrogeologic conditions similar to the SSFL. Additional details on the FRACTRAN model and its application to the SSFL site can be found in these documents. The purpose of the source area remediation simulations presented in this section of the IM work plan is to provide insight into the potential effects of source area remediation on the evolution and extent of a TCE plume in fractured porous sandstone, with assignment of fracture and matrix parameters generally consistent with the ranges measured in the Chatsworth formation during various SSFL investigations. These simulations provide a basis for comparing the relative plume extent over time when source area remediation is performed relative to a condition where source areas are left in a natural state.

Model properties and input parameters for this stylistic assessment were as follows:

- 2-D vertical cross-section with a length of 300 meters (m)and height of 60 m (Figure 4-1)
- Orthogonal fracture network with variable fracture apertures with a mean of 70 microns (μm), and a range from about 15 to over 300 μm
- Matrix porosity ϕ_m = 13 percent
- Bulk fracture porosity, horizontal, $\phi_{fh} = 5.6 \times 10^{-5}$
- Bulk fracture porosity, vertical, $\phi_{fv} = 1.7 \times 10^{-5}$
- Hydraulic gradient, horizontal = 1 percent
- Hydraulic gradient, vertical (downward) = 0.5 percent
- Bulk hydraulic conductivity, horizontal, $K_{bh} = 1.8 \times 10^{-5}$ centimeters per second (cm/sec)
- Bulk hydraulic conductivity, vertical, $K_{bv} = 4.4 \times 10^{-6}$ cm/sec (anisotropy ratio = 4.2)
- Average linear groundwater velocity, horizontal = 1030 meters per year (m/yr)
- Average linear groundwater velocity, vertical = 400 m/yr

The contaminant properties and source parameters used in the simulations were based on TCE as the solute. The free-solution diffusion coefficient for TCE (D_o) was $1.0\text{x}10^{-9}$ m^2/sec (calculated for 25^{o}C), and the matrix retardation factor (R_m) was 3.0. A tortuosity (τ) of 0.10, based on laboratory diffusion tests on SSFL sandstone samples (Golder, 1997), was applied to the free-solution diffusion coefficient to estimate the effective diffusion coefficient (D_e) for TCE in the sandstone matrix that was used in these simulations.

The source conditions for TCE are shown in Figure 4-1. The TCE source was placed along the left model boundary, extending over a 15 m vertical interval, and was assumed to be constant over a 10-year time period, after which time the source term was set to zero. The vertical extent and source period assumed for TCE recognize that it was released as DNAPL, and therefore would have migrated downward in the fractures before becoming immobile, where it would have persisted (for 10 years in this simulation) as the DNAPL mass was gradually depleted and ultimately disappeared due to dissolution in groundwater flowing in fractures and diffusion into the sandstone matrix. One simulation was run to completion (200 years) under these conditions, while in the parallel simulation all of the TCE mass in the source area was removed at 40 years (Figure 4-1). This source removal in the simulation represents the equivalent of a 100 percent effective source area remediation being completed 40 years after the DNAPL entered the system. Also note that in this simulation the source area removed at 40 years no longer contains TCE DNAPL, only sorbed and dissolved phase TCE mass; this approach and nomenclature are consistent with the source area definition provided in Section 4.1 and the conditions at the SSFL.

4.2.2 Transport Simulation Results

The resultant plumes for these two parallel simulations are presented in Figures 4-2 and 4-3 at simulation times of 100 and 200 years. In both cases, concentrations are expressed relative to the source concentration (C/C_o). Fractures are not superimposed on the contour plots for easier viewing of the concentration contours. The plume contours at $C/C_o=10^{-4}$ represent a four order-of-magnitude decline from the source concentration. For TCE this represents a concentration of about 100 μg/L, since TCE solubility is about 1,000,000 μg/L. This concentration is above the MCL for TCE, however the model provides exact ‘point’ concentrations within the fractures, whereas in the field such concentrations would be diluted during sampling over larger vertical intervals such that concentrations would likely be close to or below the MCL. As indicated in the contour plots, the $C/C_o=10^{-5}$ contour levels, which are approaching the lower limit of model stability, are not much further downgradient than the 10^{-4} level TCE concentration contours.

The plumes for the two parallel simulations are compared side-by-side in Figure 4-4 at 100 and 200 years after the point of initial release. This comparison shows indistinguishable plume front migration rates for the “source area removed” and “source area left in natural state” cases, and there is no discernable difference in the overall extents of the plumes at either time step. These results indicate that the 100 percent effective source area remediation (i.e., 100 percent of the TCE mass is removed from the source area) had no discernable effect on the plume front migration rate, the overall extent of the plume, or the plume longevity over the timeframe of interest.

4.3 SCREENING OF TECHNOLOGIES FOR SOURCE AREA REMEDIATION INTERIM MEASURES

A summary of the technologies evaluated for potential applicability as source area remediation interim measures is shown in Table 4-1. This summary includes the technology of groundwater extraction as specified by DTSC in its May 16, 2008 letter. Again, the primary basis for the development of this table was the NRC document referenced in Section 3.2.2 above (NRC, 2005). In this case, the entries in the NRC DNAPL source remediation technologies comparison table for Type V (fractured media with high matrix porosity, e.g. conditions similar to the SSFL) are directly applicable and were not altered in Table 4-1 other than to augment the descriptive details provided with additional information from other sources; these additional sources were listed in Section 3.2.2 above. A number of additional technologies were assessed and added to the table based on information from these additional sources, the results of SSFL studies described previously in this work plan, and professional judgment.

As noted previously in Section 3.2.2, few of the objectives in Table 4-1 have been measured in the field for the technologies evaluated. Most of the technologies are not applicable in, are negatively impacted by, or have not been adequately demonstrated in fractured porous media (NRC, 2005). Furthermore, almost all of the source remediation technologies evaluated require systematic field-scale testing to adequately understand their technical performance. the available data are inadequate to determine how effective most technologies will be in any but the simpler hydrogeologic settings (NRC, 2005).

Pump and treat (hydraulic containment) was identified as a potentially applicable technology for source area remediation that could be implemented as an interim measure within one year. Additionally, this technology has been specified for implementation in DTSC's May 16, 2008 letter. However, it should be clarified that groundwater extraction is limited to source zone containment rather than remediation. In most cases, pump and treat will not be effective for source zone remediation due to the limited solubilities of most COPCs (e.g., TCE), and due to limitations in mass transfer to the aqueous phase (NRC, 1994, 1999, 2005; EPA, 1996;

Illangasekare and Reible, 2001). In fractured porous media such as the Chatsworth formation at the SSFL, these hindrances can be extreme because of the mass transfer limitations of reverse diffusion from dissolved and sorbed mass in water within the matrix blocks to the water flowing in the fractures (Mutch, et. al, 1993; Freeze and McWhorter, 1997; and Wilson, 1997).

A number of conclusions can be reached based on the evaluations presented and discussed above. First, none of the technologies evaluated have been adequately demonstrated in the hydrogeologic conditions and at the depths that would be required to allow their implementation as interim measures for source zone remediation at the SSFL within one year. Groundwater extraction at source areas will be implemented as required, but the restoration of these areas using pump and treat is ineffective for the reasons described above.

Second, the available data from field studies do not demonstrate what effect source remediation is likely to have on water quality (NRC, 2005). Thus, computer simulations using site-specific hydrogeologic characterization data are the most sophisticated tools available to assess the likely effects of source area remediation. The source area remediation simulations that were performed using FRACTRAN as presented in Section 4.2 above suggest that even 100 percent removal of (or, equivalently, 100 percent containment of) the contaminants from a source area at this time in a SSFL-type hydrogeologic setting would likely have no discernable effect on the overall extent or longevity of the plume over the timeframe of interest.

In summary, the technologies available do not offer a reasonable likelihood of success for the remediation of source areas in the hydrogeologic conditions and at the depths at which contaminants are present at the SSFL. Additionally, considerable new information has been presented in this work plan showing that it is not clear that the remediation of SSFL source areas is justifiable as an interim measure. The sophisticated FRACTRAN computer simulations that were performed suggest that in a SSFL-type hydrogeologic setting, even the complete removal of the contaminants from a source area will have no discernable effect on the plume longevity, plume front migration rate or on the overall plume extent over the timeframe of interest. Furthermore, considerable site data indicate that the plume fronts at the SSFL are nearly stationary, including the analysis that was completed based on six years of groundwater sampling and analysis data as presented in Section 3.2 of this work plan and the statistical concentration trend analysis described in Appendix D of this work plan.

4.4 PROPOSED SOURCE AREA REMEDIATION INTERIM MEASURES

As requested by DTSC in the April 24, 2008 attachment to the May 16, 2008 letter, the SSFL will initiate groundwater extraction at “any monitoring wells where the reported concentrations of TCE have been 1,000 µg/L or higher and/or any monitoring wells where TCE concentrations and water levels are trending higher since shut-down of groundwater extraction wells.” An analysis of wells that meet the criteria specified above is presented in Appendix D. This appendix also contains an evaluation of groundwater extraction for plume fronts that was discussed in Section 3.3 of this work plan.

Based on the analysis presented in Appendix D that is intended to meet the specifications of DTSC as noted above, groundwater extraction is being proposed from the following ten locations: HAR-7, HAR-18, RD-1, RD-4, RD-41B, RD-46A, RD-49A, RS-54, WS-9 and HAR-20. It is worthy to note that one of the locations proposed for groundwater extraction for plume front containment, WS-9A also meets the definition of a source zone well, as TCE concentrations in samples collected from this location exceeds 1,000 µg/L. The locations of the proposed extraction wells are shown in Figure 4-6. Table 4-2 provides a summary that identifies the source area where groundwater extraction will occur, along with the details of the proposed extraction location and target extraction rates. Groundwater will be extracted from wells using dedicated pumping systems.

Target extraction rates were established to fulfill the objective of groundwater extraction as specified by DTSC in its April 24, 2008 memorandum, which states a “two-fold” objective that includes “prevent contaminated vadose zone from becoming saturated and provide capture of contaminated groundwater moving through source zones.” The collective extraction rate for the 12 proposed locations in source zones ranges from a low of about 19,000 gpd to a high of 158,000 gpd, with the targeted rate being about 72,000 gpd. This extraction rate is nearly twice that of the estimated groundwater recharge rate above the 528 acres of impacted groundwater as noted in Section 2.1. The estimated average recharge through the areas of impacted groundwater associated with the SSFL is about 40,000 gpd based on recharge being 1 inch per year (6 percent of the average annual precipitation).

4.5 SOURCE AREA GROUNDWATER EXTRACTION IMPLEMENTATION PLAN

Implementation activities for source area groundwater extraction will commence within 30 days of DTSC's approval of this IM work plan. Initial activities will include: design of the conveyance pipeline distribution, electrical feeds, extraction well control systems, and upgrades to the groundwater treatment system; supplier contracting; equipment procurement for pipelines, pumps and controls; permitting; construction; and start-up testing. Work has been initiated to modify the configuration of the previously-designed groundwater treatment plant as of the date of this work plan. Modifications to the treatment plant unit processes and equipment sizes are required to accommodate the type and concentrations of chemicals that are estimated to be within the extracted groundwater. These modifications may also trigger additional permitting constraints and the re-submittal of applications. As such, it is expected that the new groundwater treatment plant, which incorporates the new IM extraction wells, will not be operational until the first quarter of 2009 assuming permitting is complete within 2 months of submittal.

Once operational, groundwater extraction wells will be brought on line over a period of 90 days leading to a fully operational target date in late-May or early-June of 2009. Extracted groundwater will be conveyed to the groundwater treatment plant via double-wall piping where appropriate. Operations and performance reporting will be provided in the quarterly and annual groundwater monitoring and sampling reports that are submitted for the SSFL.

It is worthy to note that there is an opportunity to explore the magnitude and distribution of hydraulic connections at the SSFL through the proper sequencing of starting the extraction wells and the concomitant monitoring of hydraulic responses in adjacent wells. However, such actions will likely lead to a longer period for the extraction network to become fully operational. SSFL site investigators believe that there is sufficient understanding of the hydraulic connectivity at the site that such an effort is not mandatory. However, this may provide an opportunity for other investigators to clarify the magnitude and distribution of hydraulic responses where such clarity is required (e.g., across/along faults or deformation bands).

4.6 ANNUAL REPORT AND PERFORMANCE EVALUATION

Results of the groundwater interim measures will be reported to DTSC annually to coincide with submittal of the groundwater monitoring reports. The reports will describe operations of extraction and treatments systems, volume of water extracted and treated, and influent and effluent concentrations of COPCs.

Source area interim measures will continue until the time that the plume retardation processes are verified through the acquisition of additional field data. Upon completion of the northeast transect, an evaluation will be performed in the context of contaminant attenuation regarding the need for continuing groundwater extraction interim measures. This is expected to occur during the second half of 2009.

4.7 SUMMARY

Source area interim measures will be implemented as required by DTSC in its April 24 , 2008 memorandum. The interim measure proposed includes extracting groundwater from 10 locations that meet DTSC's specified criteria of either containing concentrations greater than 1,000 µg/L and/or having increasing TCE concentrations and groundwater levels since the shut-down of groundwater extraction wells in late 2000. Extraction will occur via the installation and operation of dedicated submersible pumps. Extracted groundwater will be conveyed via double-walled piping (where appropriate) to a new groundwater treatment plant that is undergoing design modifications and should be constructed by late 2008. Extraction from source area wells is expected to be fully operational in late March or early April of 2009.

5.0 LONG-TERM TECHNOLOGY EVALUATION

The following sections describe the long-term study of potential groundwater remediation technologies required in DTSC's November 19, 2007 letter (Appendix A). This study will build upon the technology screenings presented in Sections 3.2.2 and 4.3 of this work plan. It is anticipated that any pilot studies conducted under this evaluation will be applicable to future corrective measures studies.

5.1 GROUNDWATER REMEDIATION TECHNOLOGY EVALUATION

An evaluation of groundwater remediation technologies and their potential applicability at the SSFL will be performed (Task 1). This evaluation will build upon the technology screenings presented in Sections 3.2.2 and 4.3 of this work plan, but without the constraint of implementability within 12 months. Important terms (e.g., source area) will be clearly defined consistent with the current state of the science and applicable regulatory guidance. The COPCs that will be considered in the technology evaluation are listed in Appendix B. The technologies to be evaluated will include, at a minimum:

- Hydraulic containment (pump and treat)
- Physical containment
- Surfactant/co-solvent flushing
- Steam injection
- Conductive, electrical resistance, and microwave heating
- In-situ chemical oxidation
- Nanoscale zero-valent iron reduction technology
- Permeable reactive barriers
- Blast-fracture-enhanced permeability technology
- Enhanced biodegradation
- Air sparging/vapor extraction

The evaluation will focus on technology performance at other sites with similar hydrogeologic conditions and COPCs, and the possible application of those technologies at the SSFL. Regulatory guidance documents and technology information sources expected to be used in the course of this evaluation will include, at a minimum:

- Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action (EPA, 2004),
- RCRA Corrective Action Environmental Indicators (EPA, 1999),
- Environmental Protection Indicators for California (CalEPA, 2002),
- CalEPA strategic vision document (CalEPA, 2000),
- RCRA Corrective Action Interim Measures guidance document (DOE, 1993),
- Post-Closure Permit Attachment E – Scope of Work for a Corrective Measures Study (DTSC, 1995),
- The DNAPL Remediation Challenge: Is there a case for source depletion? (EPA, 2003), and
- Contaminants in the Subsurface, Source Zone Assessment and Remediation (NRC, 2005).

Literature searches that will be performed during the course of this evaluation will include, at a minimum:

- U.S. EPA Technology Innovation Office's (TIO) CLU-IN database,
- Fractured rock conference proceedings, and
- Other technical publications with applicability to hydrogeologic conditions similar to the SSFL.

It is also anticipated that the 3-D groundwater flow model (AquaResource Inc./MWH, 2007), as well as a number of 1-D discrete fracture or 2-D discrete fracture network transport models (e.g., CRAFLUSH and FRACTRAN, respectively), will be used to help evaluate potential groundwater remediation technologies at the SSFL. The evaluation will culminate in the submittal of a report to DTSC presenting the evaluation data and criteria, and identifying candidate technologies for pilot or treatability studies, or that are applicable and would not require additional studies in order for them to be implemented at SSFL. The expected Task 1 duration is 180 days.

5.2 PILOT TESTING AND REPORT

Following the completion, submittal and DTSC approval of the IM technology evaluation report, pilot or treatability studies will be designed and performed as required by DTSC based on the recommendations in the technology evaluation report. This task will be implemented in a series of steps, the first being the submittal of a pilot test design document to DTSC (Task 2a). This document will detail the proposed implementation of the required pilot tests, including locations, materials, equipment, required permits, methodologies, anticipated durations and the types and frequencies of data to be collected to gauge the performance of each technology to be tested and an overall schedule. Numerical models will likely be useful tools in helping to evaluate appropriate pilot test locations, conditions, durations, and in establishing monitoring and performance criteria. The expected duration of this task (Task 2a) is 120 days.

Upon DTSC's approval of the pilot test design document, the pilot tests described therein will be implemented in accordance with the design document specifications. Collected data will be analyzed throughout the course of each pilot test to evaluate progress and to determine if field modifications to the test design may be necessary to achieve the specific goals of that pilot test. DTSC would be notified prior to the implementation of any such changes to an ongoing pilot test.

At the conclusion of the pilot tests, a report will be prepared and submitted to DTSC presenting the results of the pilot tests and discussing the implications for the potential application of those technologies for groundwater remediation at SSFL (Task 2b). The actual duration of this task (Task 2b) will depend on the required duration of the pilot test field activities, but it is anticipated to be about 18 months.

5.3 IMPLEMENTATION SCHEDULE

The major milestones to be achieved in the course of performing the long-term technology evaluation tasks described are identified below with estimated time frames for completion. There is considerable uncertainty in the time frames for Tasks 2a and 2b as they may depend strongly on the number and types of pilot or treatability studies to be performed. As such, this milestone schedule is meant to serve as an initial guide presenting preliminary target durations for the identified elements of the long-term groundwater remediation technology evaluation. The durations specified below are in calendar days.

Milestone	**Preliminary Completion Target**
Submit Groundwater Interim Measures Work Plan to DTSC	July 14, 2008
Task 1 – Submit Groundwater Remediation Technology Evaluation Report to DTSC	180 days from DTSC approval of Interim Measures Work Plan
Task 2a - Submit Pilot Test Design Report to DTSC	120 days from DTSC approval of Technology Evaluation Report
Task 2b - Complete pilot tests and submit Pilot Test Report to DTSC	18 months from DTSC approval of Pilot Test Design Report

6.0 GROUNDWATER INTERIM MEASURES WORK PLAN SUMMARY

The primary objective of this groundwater interim measures work plan is to comply with the requirements of DTSC as specified in their May 16, 2008 letter. DTSC's requirements for interim measures were specified in an April 24, 2008 internal memorandum that was attached to the May 16, 2008. These requirements included:

- "Groundwater extraction should be initiated at all wells identified in the source areas and at plume fronts where the contaminants may be advancing. Groundwater pumping at these locations will be focused having limited reach and will not affect ongoing investigative activities."
- "Groundwater extraction should be initiated at all groundwater monitoring wells within source zones, defined as any monitoring wells where the reported concentrations of TCE have been 1,000 µg/L or higher and/or any monitoring wells where TCE concentrations and water levels are trending higher since shut-down of groundwater extraction wells."
- The April 24, 2008 memorandum also requires initiating groundwater extraction at the "solvent plume offsite to the northeast of the site…and…in the southernmost groundwater extraction (WS-9A) at the buffer zone."

This work plan proposes to comply with these specifications by extracting groundwater from a total of 14 locations throughout the SSFL. Information on the proposed interim measures extraction wells is provided in Table 6-1. Groundwater extraction will be initiated in the northeast area of the SSFL in two wells and one corehole at the locations shown in Figure 6-1 to influence the plume front that extends off-site at this location. Groundwater extraction will continue as previously proposed at WS-9A to control the plume front in the southwestern portion of the site where impacted groundwater periodically emerges at two springs (see Figure 6-1). Groundwater extraction will be initiated at 10 other locations at or near source areas where either the concentrations of TCE are greater than 1,000 µg/L or where TCE concentrations and water levels have been trending higher since late in 2000, which corresponds to the initial shut-down of groundwater extraction wells (locations shown in Figure 6-1). Volumetric flow rates from the 14 locations proposed for groundwater extraction are targeted for about 77,000 gpd, but may vary from a low of about 20,200 gpd to a high of about 173,000 gpd. Groundwater extraction will occur through the installation and operation of dedicated pumping systems that will discharge the groundwater via double-walled piping as appropriate to a new groundwater treatment plant that is being re-designed to accommodate the flow rates and concentrations of chemicals from these 14 locations. The extraction network is projected to be fully operational by late-May or early-June 2009. Operations and performance reporting will be provided in the quarterly and annual groundwater monitoring and sampling reports that are submitted for the SSFL.

It should be noted that the initiation of groundwater extraction from wells broadly distributed throughout the SSFL provides an opportunity to explore the magnitude and distribution of hydraulic connections across/along stratigraphic and/or structural features. Such an exploration has not been incorporated into the implementation schedule since it would take an appreciably longer time for the full extraction network to become operational. However, should DTSC warrant that such explorations of the hydraulic connections would yield valuable characterization information, then the schedule for sequencing the start-up of the extraction wells can be adjusted accordingly. Groundwater extraction interim measures will continue until the time that the plume retardation processes are verified through the acquisition of additional field data. Upon completion of the northeast transect, an evaluation will be performed in the context of contaminant attenuation regarding the need for continuing groundwater extraction interim measures. This is expected to occur during the second half of 2009. The groundwater extraction interim measure at the WS-9A area will continue into the future to prevent the emergence of springs within the drainage just south of this extraction well.

A secondary objective of this work plan is to document the analysis that was performed in response to DTSC’s November 19, 2007 letter on interim measures. The November 19, 2007 DTSC letter required an evaluation of technologies potentially applicable and implementable within one year as interim measures to:

- Achieve source zone remediation and plume front containment,
- Describe the resultant recommendations for interim measures implementation, and
- Present a schedule for implementation of the recommended interim measures.

The specific issues that DTSC’s November 19, 2007 letter required to be addressed included:

1. Descriptions of all contaminant plumes and source areas (including maps, figures, and narratives),
2. Proposals for IMs at the groundwater plumes and source areas to achieve source zone remediation and plume front containment,
3. A discussion of technologies evaluated and figures to support the technology or technologies selected,
4. Implementation plan for proven remedial approaches such as pump and treat where contamination migration potential is high,
5. IMs that can be operational and functional within one year,
6. A project schedule for implementation of the IMs including descriptions of tasks and deliverables expected.

In fulfillment of requirement 1, Section 2 of this work plan provided detailed narrative on the occurrence and distribution of TCE and other COPCs in groundwater beneath the SSFL, including reference to maps, figures and tables providing locations and descriptions of all contaminant plumes and available information on associated source areas.

In fulfillment of requirements 2 through 6, monitored natural reactivity plume front containment is also being proposed for the off-site portion of the northeast plume and the 16 other areas of impacted groundwater within the SSFL. Implementation plans and schedules for the recommended interim measures were also provided, including task descriptions and expected deliverables. Performance reporting will be provided in the quarterly and annual groundwater monitoring and sampling reports that are submitted for the SSFL.

This work plan also includes a description and schedule for the implementation of the longer-term study of potential groundwater remediation technologies.

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TABLES

Table 2-1
Information on Areas of Impacted Groundwater at the SSFL

Number	Administrative Area	Location Name	Primary Contaminants of Concern	Input Location Known?	Areal Extent of Impacted Groundwater (in Acres, Including Comments	Complexity of Physical Setting (Remoteness & Terrain)	Relative Proximity to Receptors	Within Area of Historic Groundwater Pumping?
1	I	Northeast	VOCs, 1,4-dioxane, NDMA, 1,2,3-TCP and perchlorate	At least 4 input locations: Former B-1 test stand located to the north of Woolsey Canyon Fault; IEL facility located near the IEL fault and adjacent to Corehole C-1; APTF, located north of the intersection of Happy Valley Fault and Shear zone; Vicinity of Happy Valley	124.0 Length of plume in northeast running parallel to Shear Zone (~4,500 feet).	Relatively flat topography over the majority of the plume area, with steep scarp at northeastern extent.	Plume extends off-site	All wells to the west of the Shear Zone have been influenced by pumping from wells WS-5 and/or WS-6. North of Woolsey Canyon Fault, OS-24 was pumped from a short time in the 1980s. South of the Happy Valley Fault RD-1 has been a pumping well. Portions of the plume may have also been influenced from groundwater extraction at the water supply wells (WS-5, WS-6 and WS-12).
2	I	Happy Valley	Perchlorate	Building 372 Sump area & other areas down drainage (prior to interim measure)	3.1 Primarily low concentration, near-surface groundwater plume along drainage likely from surface water infiltration	Based on previous work already completed to install wells and implement interim measure, infrastructure in place	Shallow groundwater plume without adjacent receptors	None.
3	I	Bowl	VOCs, NDMA & 1,4-dioxane	Bowl Test Stand, two to three distinct locations possible.	4.7 Dissolved concentrations in RD-2 and rock core results from C-4 that indicate max depth of contamination about 400 ft	Rising topography to north, east & south	Local area and relatively distant from receptors	Yes, RD-2 has been used as an extraction well.
4	I	CTL-III	VOCs, 1,4-dioxane & 1, 2, 3-TCP	Small waste pond near RD-46 cluster. Other additional sources located to the north based on soil vapor results.	30.9 Relatively shallow impact (RD-46B ND) and limited lateral extent	Topographic setting relatively gentle for SSFL	Local area and relatively distant from receptors	Yes, ES-1 and ES-3 has been used as extraction well.
5	I (NASA)	LOX	VOCs, 1,4-dioxane	Former LOX facility source area is known based on soil vapor results.	5.0 Plume relatively limited in lateral extent, however results of sampling WS-12 indicate vertical impacts to ~1500 feet	Topographic setting at/near LOX relatively gentle, however, topography to west along drainage becomes steep with limited access	Dissolved concentrations that produce vapor flux at the ground surface	WS-4A and WS-12 located upgradient and downgradient of the LOX plume, respectively have historically been used for groundwater extraction.
6	II	RD-9/ELV	VOCs	At corehole C-7, former pond location south of corehole. Also at ELV and Building 203. Uncertain near RD-9.	9.6 Plume extending toward North fault and additional likely source at ELV based on soil vapor sampling results	Presence of more difficult topography north of North fault and suspected source	Area at ELV relatively close to property boundary in north	Yes, RD-9 has been used as an extraction well.

Table 2-1
Information on Areas of Impacted Groundwater at the SSFL

Number	Administrative Area	Location Name	Primary Contaminants of Concern	Input Location Known?	Areal Extent of Impacted Groundwater (in Acres, Including Comments	Complexity of Physical Setting (Remoteness & Terrain)	Relative Proximity to Receptors	Within Area of Historic Groundwater Pumping?
7	II	Building 204	VOCs including 1,2,3-TCP	Unknown, soil vapor sample results ND.	8.4 Lateral extent of plume and elevated concentrations at RD-60	Presence of steep topography north of North fault	Presence of springs off-site to the north. Wells to north ND however.	None.
8	II	Alpha/Bravo	VOCs, 1,4-dioxane & NDMA.	Alpha & Bravo Test Stands	70.0 Lateral and vertical extent of impacted area appreciable (RD-49C impacted)	Steep topography to south, and east, and ridge to north	Area distant from receptors	Yes, wells RD-4, WS-6 and WS-9 have been pumped; WS-6 was pumped at a rate of 100 to 160 gpm until spring of 2001
9	II & III	Coca/ Delta/ STL-IV	VOCs, 1,4-dioxane & NDMA.	A number of sources are responsible for this plume including the test stands and corresponding collection ponds. Two former surface impoundments are also located at STL-IV.	104.0 Appreciable lateral and vertical impacts as rock core results from C-6 show TCE at ~1 milligram per liter to 1000 feet	Complex topographic setting around Coca, Delta and STL-IV	Dissolved concentrations produce vapor flux at the ground surface.	Yes, HAR-7, WS-9A and other shallow wells have been used for extraction.
10	III	Compound A	VOCs, perchlorate	Not yet evaluated	2.5 Near-surface groundwater plume with appreciable lateral extent	Topographic setting relatively gentle for SSFL	Relatively low concentrations and position in interior of site	Yes, ES-24 and ES-14 have been used for extraction.
11	III	ECL	VOCs, 1,2,3-TCP	Not yet evaluated	2.3 Near-surface groundwater plume with appreciable lateral extent	Topographic setting relatively gentle for SSFL	Relatively low concentrations and position in interior of site	None.
12	III	EEL	VOCs	Not yet evaluated	8.7 Near-surface groundwater plume with appreciable lateral extent	Topographic setting relatively gentle for SSFL	Relatively low concentrations and position in interior of site	Yes, ES-30 has been used as extraction well.
13	IV	RMHF	VOCs. Tritium (below drinking water standard).	Unknown. Limited soil vapor sampling results ND.	1.8 Llimited lateral and vertical extent	Complex topographic setting , with ridge to the north	Relatively low concentrations and limited extent of plume	Yes, RD-63 has been used as extraction well.
14	IV	Building 10 Leach Field	Tritium, VOCs	Source assessment currently in progress.	2.0 Limited lateral extent	Complex topographic setting toward north and northwest	Presence of springs off-site to the northwest	None.

Table 2-1
Information on Areas of Impacted Groundwater at the SSFL

Number	Administrative Area	Location Name	Primary Contaminants of Concern	Input Location Known?	Areal Extent of Impacted Groundwater (in Acres, Including Comments	Complexity of Physical Setting (Remoteness & Terrain)	Relative Proximity to Receptors	Within Area of Historic Groundwater Pumping?
15	IV	Hazardous Materials Storage Area	VOCs	Currently not defined. Soil vapor sampling results all ND.	3.7 Shallow groundwater plume with appreciable lateral extent	Topographic setting relatively gentle for SSFL	Relatively low concentrations and position in interior of site	None.
16	IV	Building 56 Area	VOCs	Unknown. Soil vapor sampling results all ND.	2.3 Limited lateral extent	Presence of more difficult topography to the north	Relatively low concentrations and limited extent of plume	Yes, RS-16 and wells east of Bldg 056(RD-24,RD-25 and RD-28) has been used as extraction wells primarily to reduce the seepage into the basement of Bldg 059.
17	IV	FSDF	VOCs and perchlorate	Former ponds located near RD-54 well cluster	18.6 Appreciable lateral extent and limited vertical extent	Presence of difficult topography to the north	Dissolved concentrations that produce vapor flux at the ground surface.	Yes, RS-54 and RD-21
18	IV	Leach field (B363 & B373)	VOCs	Currently not defined. Soil vapor sampling results all ND.	8.0 near-surface groundwater plume with appreciable lateral extent	Topographic setting relatively gentle for SSFL	Relatively low concentrations and area is positioned in interior of site	None.

EEL - Engineering Effects Laboratory
STL-IV - Systems Test Laboratory IV
ELV- Expendable Launch Vehicle
FSDF - Former Sodium Disposal Facility
LOX - Liquid oxygen
RMHF - Radioactive Materials Handling Facility
CTL III - Components Test Laboratory III
IEL - Instrument and Equipment Laboratory
VOCs - volatile organic compounds
NDMA - n-nitrosodimethylamine
ECL - Engineering Chemistry Laboratory
TCP- trichloropropane

Total Acreage 533.6

Notes:
1. Evaluation of contaminant mix does not include metals.

Table 3-1
Plume Screening for Plume Front Containment Interim Measure Candidates

Plume No.	Proximity to Property Boundary Less than 1500 feet	Plume Extent	Relative Proximity to Seeps/Springs	Candidate for Interim Measure
1	**Y (plume off site)**	Relatively large plume extending off-site to the northeast.	Relatively distant.	**Y**
2	N	Primarily low concentration, shallow groundwater plume.	Located in the interior of site, far from springs.	N
3	N	Local area plume with vertical extent of about 400 feet.	Located in the interior of site, far from springs.	N
4	N	Local area plume, with relatively shallow impact, and limited lateral extent.	Located in the interior of site, far from springs.	N
5	Y	Plume has relatively limited lateral extent but sampling at WS-12 indicates vertical impacts to about 1,500 feet.	Springs off-site to Northwest.	N
6	Y	Local Area plume extends toward north fault.	Springs off-site to North.	N
7	Y	Local Area plume extends toward north fault.	Springs off-site to North; however, wells to the North ND.	N
8	N	Appreciable lateral and vertical extent.	Located in the interior of site, far from springs.	N
9	N	Appreciable lateral and vertical extent.	**Southernmost boundary of plume discharges VOC-impacted groundwater to springs FDP-890 and FDP-881.**	**Y**
10	N	Shallow groundwater plume with appreciable lateral extent.	Located in the interior of site, far from springs.	N
11	N	Shallow groundwater plume with appreciable lateral extent.	Located in the interior of site, far from springs.	N
12	N	Shallow groundwater plume with appreciable lateral extent.	Located in the interior of site, far from springs.	N
13	Y	Limited lateral and vertical extent of plume.	Springs off-site to Northwest.	N
14	Y	Limited lateral extent.	Springs off-site to Northwest.	N
15	N	Shallow groundwater plume with appreciable lateral extent.	Relatively distant.	N
16	Y	Limited lateral extent.	Springs off-site to North.	N
17	Y	Plume has appreciable lateral extent, but limited vertical extent.	Springs off-site to North.	N
18	N	Shallow groundwater plume with appreciable lateral extent.	Located in the interior of site, far from springs.	N

Table 3-2
Evaluation of Technologies for Potential Applicability as Plume Front Containment Interim Measures

			Likely Effectiveness									
Technology	**Mechanisms**	**Applicable Contaminant Types**	**Mass Removal**	**Local Aqueous Concentration Reduction**	**Mass Flux Reduction**	**Reduction of Source Migration Potential**	**Technology Limitations**	**Pilot Test Required**	**Typical Time to Implement**	**Assessment of Potential Technical Applicability to Plume Front Containment**	**Potentially Implementable as Short Term IM**
Excavation	Extraction	All Compounds	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Excavating bedrock is very difficult. Physical access beneath foundations and buildings restricts excavation. Excavation below water table is very difficult due to influx of groundwater. Deep excavations require benching/shoring. High cost for disposal of large excavation volumes.	No	<12 months	Not applicable in bedrock or to plume front containment.	No
Physical Containment	Isolation	All Compounds	Not Applicable	Not Applicable	Low - High	Low - High	Areal extent and depth of source areas essential to containment. Detailed aquitard topography must be known for vertical barrier installation. Usually used in sources <200 feet deep. Difficult to install barriers in bedrock. High cost associated with deep installations.	No	<12 months	Source are depths >200 feet and downward gradients nullify applicability of this technology.	No
Hydraulic Containment (Pump-and-Treat)	Isolation, extraction	All organics, higher solubility contaminants	Low	Low	Low	Low	Limited effectiveness for source zone remediation because of limited solubilities of most COCs and limitations in mass transfer of contaminants from the rock matrix to the aqueous phase in the fracture system. Highly heterogeneous systems have limited effective containment due to lack of hydraulic connectivity for lower permeability zones. Disposal and/or treatment of large amounts of extracted groundwater required.	No	<12 months	Technology can provide a measure of hydraulic control and additional assurance of plume front containment.	Yes
Multiphase Extraction	Extraction, volatilization	Organics with low to moderate viscosity	Low	Low	Low	Low	Severe flow channeling along high permeability fractures limits effectiveness. Highly heterogeneous soils experience channeling. Low permeability leads to high air entry pressures and difficulty dewatering soils. Multiphase extraction designed for removal of NAPL and contaminant concentrations approaching saturation.	Yes	>12 months	Not applicable to dissolved phase contaminant removal.	No
Surfactant/Cosolvent Flushing	Solubilization, mobilization, extraction	All Organics	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not applicable to dissolved phase contamination. Limited experience in fractured media. Flow bypassing can occur after areas are cleaned up creating preferrential pathways. Good sweeping effficiency required (making sure injected solution flows uniformly through the media). High heterogeneity decreases sweeping efficiency.	Yes	>12 months	Not applicable to dissolved phase contamination.	No
Chemical Oxidation	Transformation	Halogenated ethenes and ethanes, VOCs, SVOCs, BTEX, PAHs	Low - Medium	Low - Medium	Low - Medium	Low	Poor delivery of oxidant, low injection rates in low - moderately permeable media. Diffusion-limited mass transfer rates of oxidants into clay and rock matrices limits effectiveness (permanganate a possible exception). High natural oxidant demand (due to high carbon content in soil) will limit efficacy. Potential for mobilization of redox sensitive and exchangeable sorbed metal ions. Formation of colloidal materials as a result of chemical oxidation can lead to reduction in soil permeability.	Yes	>12 months	Limited success has been demonstrated with permanganate in fractured rock setting. Field scale studies have shown that fracture plugging can occur with coincident increase in downgradient mass flux. Limited experience in fractured media. Technology application will require pilot testing.	No
Permeable Reaction Barrier - Soil Mixing Chemical Reduction w/ Zero Valent Iron	Transformation	Chlorinated and flourinated compounds	Not Applicable	Not Applicable	Not Applicable	Not Applicable	The source has to be defined, and located in a soil that is amenable to mixing. Soil mixing is more difficult with depth (35 meters is generally the maximum depth). Cannot be combined with other technologies due to loss of permeability after mixing with clay.	Yes	>12 months	Developing technology with extremely limited use to date. Technology is not applicable to contaminants in bedrock.	No
Permeable Reaction Barrier - Nanoscale Zero-Valent Iron Reduction in Fractured Rock	Transformation/Isolation	Chlorinated and flourinated compounds	Low - Medium	Low - Medium	Medium	Medium	Flow pattern in fracture network altered after injection, causing flow bypass of iron filled fractures. If a high degree of Fe^{o} is required, fracture enlarement will be required.	Yes	>12 months	Nanoscale SVI FRB can be placed downgradient from plume to limit mass flux and plume front mobility. Nanoscale particles increase reactivity and decrease size leading to decreased required concentrations for contaminant destruction, and less fracture clogging. Limited field scale studies in bedrock. Modeling and field studies conducted using a fractured chalk bedrock aquifer. Technology is applicable to plume front containment. Pilot testing required.	No

Table 3-2
Evaluation of Technologies for Potential Applicability as Plume Front Containment Interim Measures

Technology	Mechanisms	Applicable Contaminant Types	Likely Effectiveness: Mass Removal	Local Aqueous Concentration Reduction	Mass Flux Reduction	Reduction of Source Migration Potential	Technology Limitations	Pilot Test Required	Typical Time to Implement	Assessment of Potential Technical Applicability to Plume Front Containment	Potentially Implementable as Short Term IM
Blast Fracture-Enhanced Permeability	Mobilization	All compounds, depends on coupled technolgoy	Low-Medium	Low-Medium	Low	Low	Blast fracturing requires paring with additional techologies for mass removal/destruction. Blast Fracturing can lead to increased heterogenous permeability decreaing effectiveness of coupled technologies. Large plume extents increase cost signifcantly. Technology destabilizes the soil foundation beneath structures.	Yes	>12 months	Paring with additional technologies required, increases implementation time. Can be effective at plume boundary treatment if coupled with appropriate technologies. Pilot testing required.	No
Steam Flushing	Volatilization, condensation front mobilization, hydraulic displacement, extraction	Volatile organic compounds and the more volatile end of semi-volatile organic compounds	Low	Low	Low	Low	Less permeable and more heterogeneous media make steam flushing less effective. More effective for separate phase NAPLs than dissolved phase contaminants. Sites with substantial contrasts in permeabilities between soil layers can experience significant channelling of steam along the high permeability layers, bypassing contaminants trapped in low permeability layers.	Yes	>12 months	Not applicable to contaminant concentrations associated with plume boundaries.	No
Conductive Heating (in situ thermal desorption)	Thermal conduction, volatilization, transformation, extraction	All organics and some metals	Medium	Medium	Medium	Medium	Close well spacing required to treat low concentration and low volatility contaminants. Water recharge is a concern in saturated zone.	Yes	>12 months	Most applications to date have been in vadose zone, no experience in saturated fractured media. High energy required for heating translates into high cost. Not efficient for plume front containment. Pilot test required.	No
Electrical Resistance Heating (ERH)	Volatilization, extraction	Compounds with boiling points less than that of water	Low - Medium	Low - Medium	Low - Medium	Low - Medium	As soils dry out due to conversion of liquid water to steam, the electrical conductivity decreases. Subsurface temperatures are limited to 100^{o}C, depending on depth. This limits organics oxidation and pyrolysis. Electrode overheating can be an issue. ERH is not expected to be particularly effective in fracture rock due to low conductivity of low-porosity rocks and difficulty in maintaining control of fluid migration.	Yes	>12 months	Technology may not be as effective as conductive heating due to electrical conductivity of rock matrix. Not efficient for minimization of plume front migration. Pilot test required.	No
Radio Frequency Heating	Volatilization	Halogenated and non-halogenated solvents, straight chain and polycyclic aromatic hydrocarbons	Low	Low	Low	Low	Requires additional extraction technology like SVE for volatilized contaminant collection. Can be difficult to evenly heat heterogeneous soils. Large plume extent requires extensive Radio Frequency treatment well networks.	Yes	>12 months	Technology has not been field demonstrated in fractured rock setting. Large plume extents make technology cost inefficient. Vapor extraction technologies required are not predicted to be effective. Pilot testing required.	No
Air Sparging/Soil Vapor Extraction	Volatilization, extraction, biotransformation	Organic compounds such organic solvents and gasoline aromatics	Low	Low	Low	Low	Air flow is irregular in shape and is sensitive to very subtle changes in soil structure. Heterogeneous soils may ave either a positive or a negative effect on air distribution, and can significantly hinder contaminant transport and the effective zone of influence. Preferential pathways and short circuiting of air flow can develop. Aerobic degradation is not a significant removal process for chlorinated solvents	Yes	>12 months	Not effective in low permeability media such as bedrock.	No

Table 3-2
Evaluation of Technologies for Potential Applicability as Plume Front Containment Interim Measures

Technology	Mechanisms	Applicable Contaminant Types	Likely Effectiveness: Mass Removal	Local Aqueous Concentration Reduction	Mass Flux Reduction	Reduction of Source Migration Potential	Technology Limitations	Pilot Test Required	Typical Time to Implement	Assessment of Potential Technical Applicability to Plume Front Containment	Potentially Implementable as Short Term IM
Enhanced Bioremediation	Transformation	Most volatile, semivolatile, and nonvolatile organics, some metals, some inorganic ions,	Low-Medium	Medium	Medium	Low	Proper contact between contaminant, microorganism, and any other required reactant is necessary before bioremediation can occur. Heterogeneity can limit transport of contaminants and reactants to microbes. Delivery of substrate to stimulate microbes can be difficult in highly heterogeneous media or in fractured bedrock.	Yes	>12 months	Success has been demonstrated in fractured rock media. Technology has ability to be applied to plume boundaries. Pilot testing will be required. Pilot tests for this technology may last significantly longer than other technologies.	No
Monitored Natural Reactivity Plume Front Containment	Transformation	Halogenated ethenes and ethanes.	Low	Low	Medium	Medium	Recent technology proven in laboratory studies that requires field verification. Not effective at source zone remediation.	No	<12 months	Effective at mass flux reduction and containment of plume front migration. No pilot test required. Sampling and monitoring plan required.	Yes

<u>Acronyms</u>
NA - Not Applicable
COC - Contaminant of Concern
NAPL - Non-Aqueous Phase Liquid (Dense and Light)
PRB - Permeable Reactive Barrier
FRB - Fractured Reactive Barrier
ZVI - Zero Valent Iron

<u>Assumptions</u>
1. Source zone - areas of impacted groundwater where contaminant concentrations are highest.
2. Subsurface media is fractured bedrock with medium to high porosity.
3. Technologies for interim measures must be implementable and functional within 12 months.

Table 4-1
Evaluation of Technologies for Potential Applicability as Source Area Remediation Interim Measures

			Likely Effectiveness								
Technology	**Mechanisms**	**Applicable Contaminant Types**	**Mass Removal**	**Local Aqueous Concentration Reduction**	**Mass Flux Reduction**	**Reduction of Source Migration Potential**	**Technology Limitations**	**Pilot Test Required**	**Typical Time to Implement**	**Assessment of Potential Technical Applicability to Source Area Remediation**	**Potentially Implementable as Short Term IM**
Excavation	Extraction	All Compounds	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Excavating bedrock is very difficult. Physical access beneath foundations and buildings restricts excavation. Excavation below water table is very difficult due to influx of groundwater. Deep excavations require benching/shoring. High cost for disposal of large excavation volumes.	No	<12 months	Not applicable in bedrock.	No
Physical Containment	Isolation	All Compounds	Not Applicable	Not Applicable	Low - High	Low - High	Areal extent and depth of source areas essential to containment. Detailed aquitard topography must be known for vertical barrier installation. Usually used in sources <200 feet deep. Difficult to install barriers in bedrock. High cost associated with deep installations.	No	<12 months	Source are depths >200 feet and downward gradients nullify applicability of this technology.	No
Hydraulic Containment (Pump-and-Treat)	Isolation, extraction	All organics, higher solubility contaminants	Low	Low	Low	Low	Limited effectiveness for source zone remediation because of limited solubilities of most COCs and limitations in mass transfer of contaminants from the rock matrix to the aqueous phase in the fracture system. Highly heterogeneous systems have limited effective containment due to lack of hydraulic connectivity for lower permeability zones. Disposal and/or treatment of large amounts of extracted groundwater required.	No	<12 months	Technology provides mass removal, but is diffusion mass transer limited. Technology can provide a measure of hydraulic control, limiting mass flux from the source zone.	Yes
Multiphase Extraction	Extraction, volatilization	Organics with low to moderate viscosity	Low	Low	Low	Low	Severe flow channeling along high permeability fractures limits effectiveness. Highly heterogeneous soils experience channeling. Low permeability leads to high air entry pressures and difficulty dewatering soils. Multiphase extraction designed for removal of NAPL and contaminant concentrations approaching saturation.	Yes	>12 months	Not applicable to dissolved phase contaminant removal.	No
Surfactant/Cosolvent Flushing	Solubilization, mobilization, extraction	All Organics	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not applicable to dissolved phase contamination. Limited experience in fractured media. Flow bypassing can occur after areas are cleaned up creating preferrential pathways. Good sweeping effficiency required (making sure injected solution flows uniformly through the media). High heterogeneity decreases sweeping efficiency.	Yes	>12 months	Not applicable to dissolved phase contamination.	No
Chemical Oxidation	Transformation	Halogenated ethenes and ethanes, VOCs, SVOCs, BTEX, PAHs	Low - Medium	Low - Medium	Low - Medium	Low	Poor delivery of oxidant, low injection rates in low - moderately permeable media. Diffusion-limited mass transfer rates of oxidants into clay and rock matrices limits effectiveness (permanganate a possible exception). High natural oxidant demand (due to high carbon content in soil) will limit efficacy. Potential for mobilization of redox sensitive and exchangeable sorbed metal ions. Formation of colloidal materials as a result of chemical oxidation can lead to reduction in soil permeability.	Yes	>12 months	Significant mass reduction possible in source areas. Aqueous phase reduction can promote mass transfer from sorbed or NAPL phase, reducing source mass in otherwise inaccessible areas. Limited success has been demonstrated with permanganate in fractured rock setting. Limited experience in fractured media. Technology application will require pilot testing.	No
Permeable Reaction Barrier - Soil Mixing Chemical Reduction w/ Zero Valent Iron	Transformation	Chlorinated and flourinated compounds	Not Applicable	Not Applicable	Not Applicable	Not Applicable	The source has to be defined, and located in a soil that is amenable to mixing. Soil mixing is more difficult with depth (35 meters is generally the maximum depth). Cannot be combined with other technologies due to loss of permeability after mixing with clay.	Yes	>12 months	Developing technology with extremely limited use to date. Technology is not applicable in bedrock.	No
Permeable Reaction Barrier - Nanoscale Zero-Valent Iron Reduction in Fractured Rock	Transformation/Isolation	Chlorinated and flourinated compounds	Low - Medium	Low - Medium	Medium	Medium	Flow pattern in fracture network altered after injection, causing flow bypass of iron filled fractures. If a high degree of Fe^0 is required, fracture enlargement will be required.	Yes	>12 months	Limited field scale studies in bedrock. Not applicable to stable source zone areas. Pilot testing required.	No

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Table 4-1
Evaluation of Technologies for Potential Applicability as Source Area Remediation Interim Measures

			Likely Effectiveness								
Technology	**Mechanisms**	**Applicable Contaminant Types**	**Mass Removal**	**Local Aqueous Concentration Reduction**	**Mass Flux Reduction**	**Reduction of Source Migration Potential**	**Technology Limitations**	**Pilot Test Required**	**Typical Time to Implement**	**Assessment of Potential Technical Applicability to Source Area Remediation**	**Potentially Implementable as Short Term IM**
Blast Fracture-Enhanced Permeability	Mobilization	All compounds, depends on coupled technolgoy	Low-Medium	Low-Medium	Low	Low	Blast fracturing requires pairing with additional techologies for mass removal/destruction. Blast fracturing can lead to increased heterogenous permeability and flow channelling, decreaing effectiveness of coupled technologies. Large plume extents increase cost signifcantly. Technology destabilizes the soil foundation beneath structures.	Yes	>12 months	Pilot testing required. Pairing with additional technologies required, increases implementation time. Multiple source areas and large plume extents limit economic feasability.	No
Steam Flushing	Volatilization, condensation front mobilization, hydraulic displacement, extraction	Volatile organic compounds and the more volatile end of semi-volatile organic compounds	Low	Low	Low	Low	Less permeable and more heterogeneous media make steam flushing less effective. More effective for separate phase NAPLs than dissolved phase contaminants. Sites with substantial contrasts in permeabilities between soil layers can experience significant channelling of steam along the high permeability layers, bypassing contaminants trapped in low permeability layers.	Yes	>12 months	Possibly applicable to source zones with concentrations near saturation or with residual DNAPL pockets. Not applicable to most source zones at the SSFL. Pilot testing required.	No
Conductive Heating (in situ thermal desorption)	Thermal conduction, volatilization, transformation, extraction	All organics and some metals	Medium	Medium	Medium	Medium	Close well spacing required to treat low concentration and low volatility contaminants. Water recharge is a concern in saturated zone. Not effective at treating dissolved phase contamination.	Yes	>12 months	Most applications to date have been in vadose zone, no experience in saturated fractured media. Not applicable to dissolved phase contamination in source zones. High energy required for heating translates into high cost. Pilot test required.	No
Electrical Resistance Heating (ERH)	Volatilization	Compounds with boiling points less than that of water	Low - Medium	Low - Medium	Low - Medium	Low - Medium	As soils dry out due to conversion of liquid water to steam, the electrical conductivity decreases. Subsurface temperatures are limited to 100^{o}C, depending on depth. This limits organics oxidation and pyrolysis. Electrode overheating can be an issue. ERH is not expected to be particularly effective in fracture rock due to low conductivity of low-porosity rocks and difficulty in maintaining control of fluid migration.	Yes	>12 months	Technology may not be as effective as conductive heating due to electrical conductivity of rock matrix. Pilot test required.	No
Radio Frequency Heating	Volatilization	Halogenated and non-halogenated solvents, straight chain and polycyclic aromatic hydrocarbons	Low	Low	Low	Low	Requires additional extraction technology like SVE for volatilized contaminant collection. Can be difficult to evenly heat heterogeneous soils. Large plume extent requires extensive Radio Frequency treatment well networks.	Yes	>12 months	Technology has not been field demonstrated in fractured rock setting. Large plume extents make technology cost inefficient. Vapor extraction technologies required are not predicted to be effective. Pilot testing required.	No
Air Sparging/Soil Vapor Extraction	Volatilization, extraction, biotransformation	Organic compounds such organic solvents and gasoline aromatics	Low	Low	Low	Low	Air flow is irregular in shape and is sensitive to very subtle changes in soil structure. Heterogeneous soils may ave either a positive or a negative effect on air distribution, and can significantly hinder contaminant transport and the effective zone of influence. Preferential pathways and short circuiting of air flow can develop. Aerobic degradation is not a significant removal process for chlorinated solvents	Yes	>12 months	Not effective in low permeability media such as bedrock. Pilot testing required.	No

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Table 4-1
Evaluation of Technologies for Potential Applicability as Source Area Remediation Interim Measures

Technology	Mechanisms	Applicable Contaminant Types	Likely Effectiveness: Mass Removal	Likely Effectiveness: Local Aqueous Concentration Reduction	Likely Effectiveness: Mass Flux Reduction	Likely Effectiveness: Reduction of Source Migration Potential	Technology Limitations	Pilot Test Required	Typical Time to Implement	Assessment of Potential Technical Applicability to Source Area Remediation	Potentially Implementable as Short Term IM
Enhanced Bioremediation	Transformation	Most volatile, semivolatile, and nonvolatile organics, some metals, some inorganic ions,	Low-Medium	Medium	Medium	Low	Proper contact between contaminant, microorganism, and any other required reactant is necessary before bioremediation can occur. Heterogeneity can limit transport of contaminants and reactants to microbes. Delivery of substrate to stimulate microbes can be difficult in highly heterogeneous media or in fractured bedrock.	Yes	>12 months	There is evidence that reductive dechlorinating microbial communities may be capable of surviving and flourishing under source zone conditions. As chlorinated ethenes become more reduced, their solubility increases, increasing bio accessibility. No depth limitations. Success has been demonstrated in fractured rock media. Technology has ability to be applied to source zones. Pilot testing will be required. Pilot tests for this technology may last significantly longer than other technologies.	No
Monitored Natural Reactivity Plume Front Containment	Transformation	Halogenated ethenes and ethanes.	Low	Low	Medium	Medium	Technology demonstrated in field and laboratory studies at SSFL with additional field and laboratory studies pending that require field verification. Not effective at source zone remediation.	No	<12 months	High concentrations associated with source areas limit natural capacity of bedrock matrix to react with contaminants. Not applicable to source areas.	No

Acronyms
NA - Not Applicable
COC - Contaminant of Concern
NAPL - Non-Aqueous Phase Liquid (Dense and Light)
PRB - Permeable Reactive Barrier
FRB - Fractured Reactive Barrier
ZVI - Zero Valent Iron

Assumptions
1. Source zone - areas of impacted groundwater where contaminant concentrations are highest.
2. Subsurface media is fractured bedrock with medium to high porosity.
3. Technologies for interim measures must be implementable and functional within 12 months.

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Table 4-2
Summary of Proposed Interim Measures Extraction Wells at Source Areas
Santa Susana Field Laboratory

Well Identifier	Interim Measure Pumping Objective	Source/Area of Impacted Groundwater Being Extracted	Ground Elev (ft msl)	Well Completion Details	Depth to Groundwater (ft btc)					Extraction Rates (GPD)		
					Q1 2007	Q2 2007	Q3 2007	Q4 2007	Q1 2008	Min	Target	Max
HAR-07	Source Zone Mass Removal from Wells with [TCE] >1,000 ug/L	Delta	1728.38	open 8" hole 30 - 100 ft.	67.38	74.10	76.47	78.19	46.84	150	300	750
HAR-18		STL-IV	1749.41	open 8" hole 30 - 80 ft.	19.57	19.51	22.19	24.61	26.97	150	1500	7500
RD-1		Canyon	1935.89	open 8.625" hole 26 - 506 ft.	200.10	199.61	200.50	202.81	202.10	150	1500	7500
RD-4		Bravo	1883.85	open 8.625" hole 27 - 496 ft.	293.94	292.43	290.73	290.21	289.03	1500	15000	30000
RD-41B		Coca/Delta	1774.71	open 5.875" hole 340 - 390 ft.	113.61	120.71	123.98	123.36	121.60	150	1500	4500
RD-46A		CTL-III	1806.13	open 6.25" hole 29.5 - 140 ft.	70.55	71.98	74.42	76.58	77.81	150	1500	7500
RD-49A		Alfa	1867.25	open 6.25" hole 18 - 50 ft.	20.87	23.00	25.12	26.36	13.42	150	1500	7500
RS-54		FSDF	1846.66	open 5.875" hole 7 - 38 ft.	22.34	23.76	dry	29.51	32.19	150	750	1500
WS-9		Bravo	1883.99	open 15" hole 17 - 690 ft. open 10" hole 690 - 1800 ft.	292.89	291.38	289.81	289.39	288.19	1500	15000	30000
HAR-20	Stop Increasing TCE and GW Elevation Trend	Alfa/Bravo	1830.47	open 8" hole 30 - 230 ft.	189.60	189.19	188.63	188.38	188.06	150	1500	4500
								Total-GPD		4,200	40,050	101,250
								Total-GPM		3	28	70

Notes:
ft msl - feet above mean sea level
ft btc - feet below top of casing
GPD - gallons per day
GPM - gallons per minute
ug/L - micrograms per liter
ft - feet
TCE - trichloroethene
" - inches

STL-IV Systems Test Laboratory IV
IEL - Instrument and Equipment Laboratory
CTL-III Components Test Laboratory III
FSDF Former Sodium Disposal Facility
GW Groundwater
FDP field data point

Two other wells proposed for interim measures extraction at plume fronts, WS-9A and C-1, also contain concentrations of TCE above 1,000 ug/L and therefore meet the definition of source zone wells as identified by DTSC in its April 24, 2008 internal memorandum.

Table 6-1
Summary of Proposed Interim Measures Extraction Wells
Santa Susana Field Laboratory

Well Identifier	Interim Measure Pumping Objective	Source/Area of Impacted Groundwater Being Extracted	Ground Elev (ft msl)	Well Completion Details	Depth to Groundwater (ft btc)					Extraction Rates (GPD)		
					Q1 2007	Q2 2007	Q3 2007	Q4 2007	Q1 2008	Min	Target	Max
WS-9A	Dewater FDP-890/ -881	Delta/STL-IV	1647.61	8.25" casing screened 20 - 539 ft.	33.44	63.73	44.43	35.70	13.45	150	3000	15000
C-1	Northeast plume front	IEL	1916.1	open 5" hole 48.6 - 600 ft.	approx. 95 ft (pump and packer in corehole)					15000	30000	45000
RD-72			1907.25	open 6.5" hole 27 - 182 ft.	approx. 90 ft (FLUTe multilevel in well)					750	3000	7500
RD-84			1907.82	open 4" hole 40 - 171 ft.	133.93	134.89	136.34	137.16	138.00	150	750	4500
HAR-07	Source Zone Mass Removal from Wells with [TCE] >1,000 ug/L	Delta	1728.38	open 8" hole 30 - 100 ft.	67.38	74.10	76.47	78.19	46.84	150	300	750
HAR-18		STL-IV	1749.41	open 8" hole 30 - 80 ft.	19.57	19.51	22.19	24.61	26.97	150	1500	7500
RD-1		Canyon	1935.89	open 8.625" hole 26 - 506 ft.	200.10	199.61	200.50	202.81	202.10	150	1500	7500
RD-4		Bravo	1883.85	open 8.625" hole 27 - 496 ft.	293.94	292.43	290.73	290.21	289.03	1500	15000	30000
RD-41B		Coca/Delta	1774.71	open 5.875" hole 340 - 390 ft.	113.61	120.71	123.98	123.36	121.60	150	1500	4500
RD-46A		CTL-III	1806.13	open 6.25" hole 29.5 - 140 ft.	70.55	71.98	74.42	76.58	77.81	150	1500	7500
RD-49A		Alfa	1867.25	open 6.25" hole 18 - 50 ft.	20.87	23.00	25.12	26.36	13.42	150	1500	7500
RS-54		FSDF	1846.66	open 5.875" hole 7 - 38 ft.	22.34	23.76	dry	29.51	32.19	150	750	1500
WS-9		Bravo	1883.99	open 15" hole 17 - 690 ft. open 10" hole 690 - 1800 ft.	292.89	291.38	289.81	289.39	288.19	1500	15000	30000
HAR-20	Stop Increasing TCE and GW Elevation Trend	Alfa/Bravo	1830.47	open 8" hole 30 - 230 ft.	189.60	189.19	188.63	188.38	188.06	150	1500	4500
								Total-GPD		20,250	76,800	173,250
								Total-GPM		14	53	120

Notes:
ft msl - feet above mean sea level
ft btc - feet below top of casing
GPD - gallons per day
GPM - gallons per minute
ug/L - micrograms per liter
ft - feet
TCE - trichloroethene
" - inches

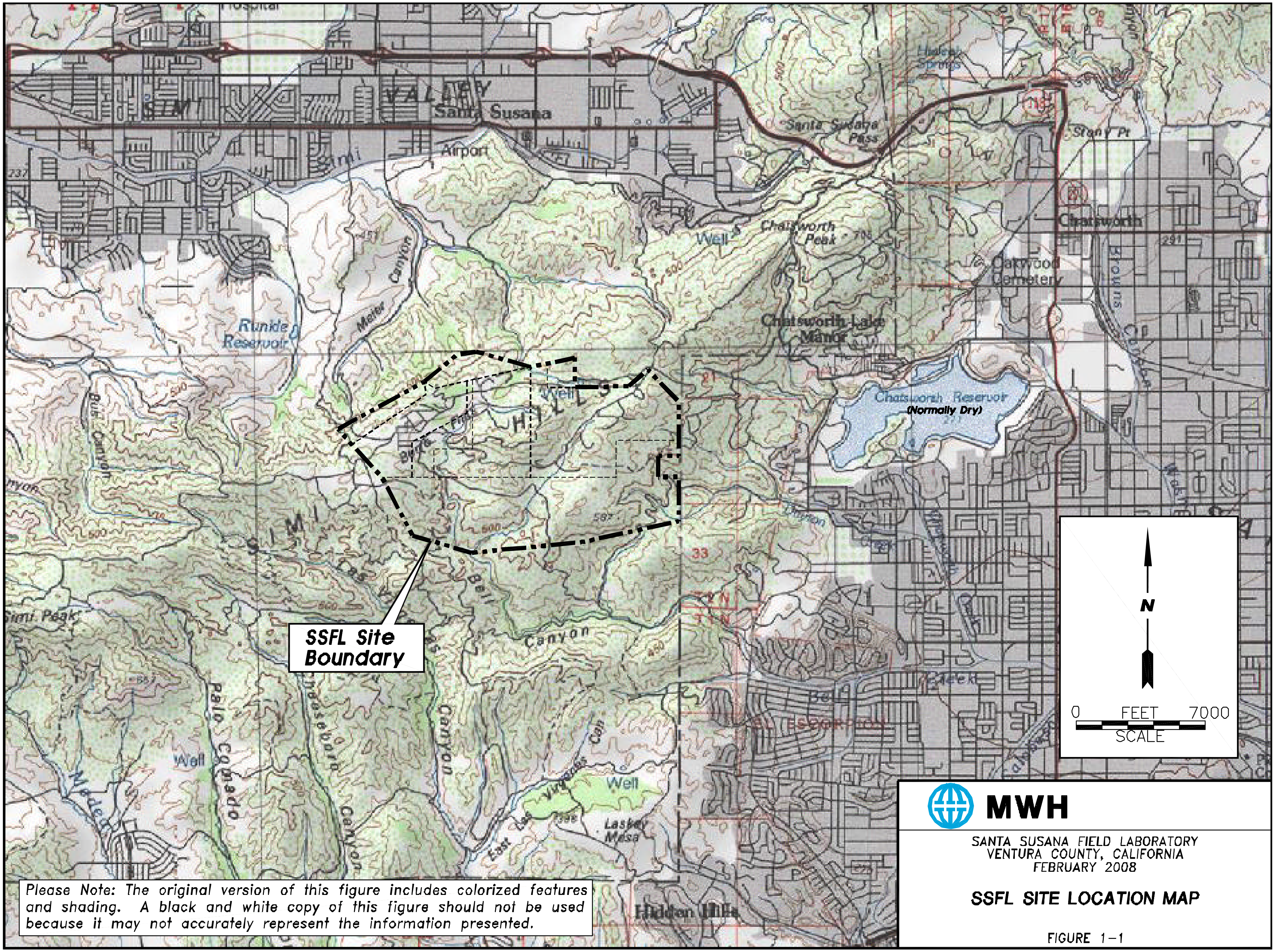
STL-IV Systems Test Laboratory IV
IEL - Instrument and Equipment Laboratory
CTL-III Components Test Laboratory III
FSDF Former Sodium Disposal Facility
GW Groundwater
FDP field data point

WS-9A and C-1 also contain concentrations of TCE above 1,000 ug/L and therefore meet the definition of source zone wells as identified by DTSC in its April 24, 2008 internal memorandum

FIGURES

FILE: INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\SITE WIDE WOEKPLAN\SITE LOCATION 9 07

JOB No.



Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

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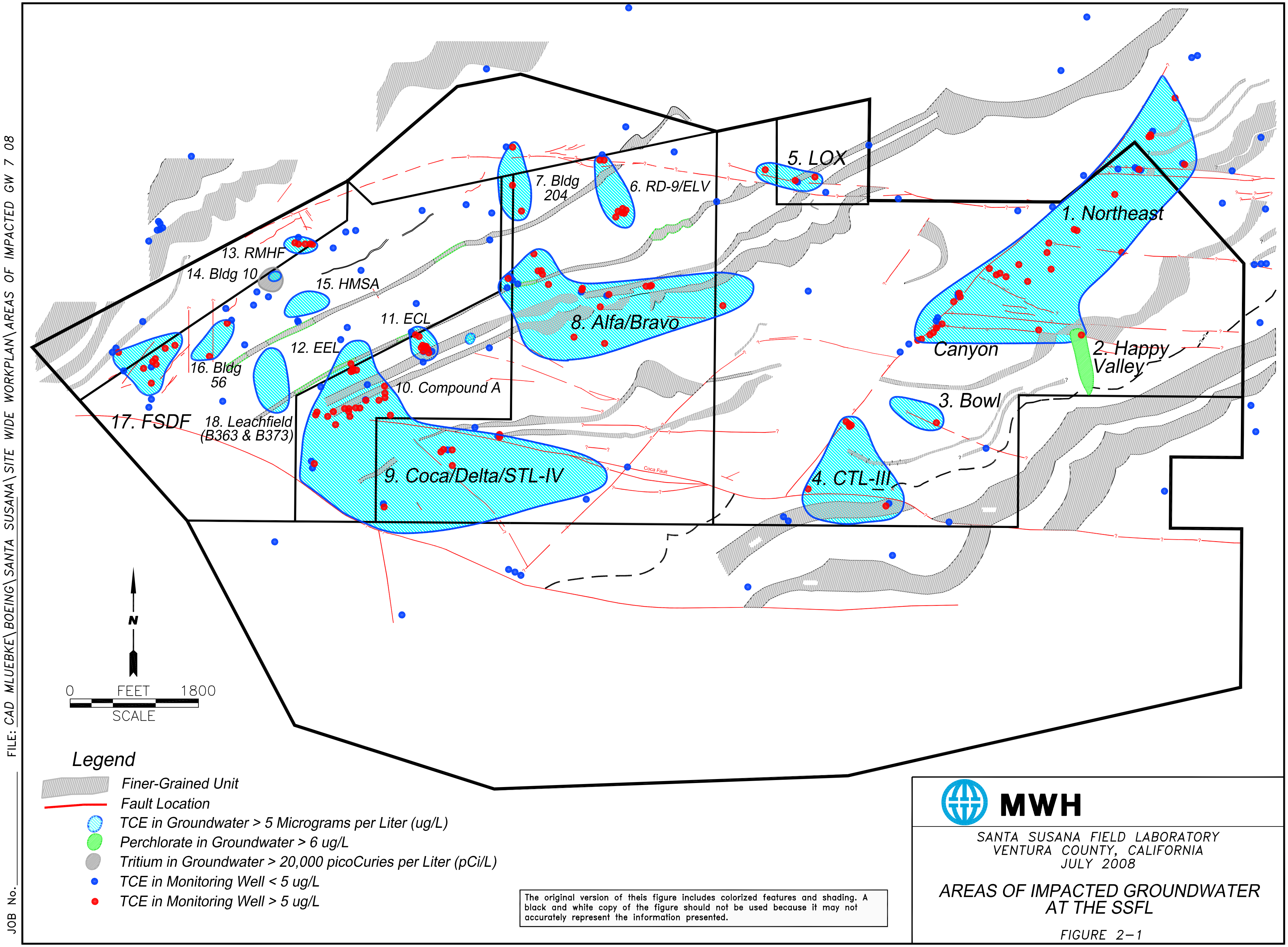
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

SSFL SITE LOCATION MAP

FIGURE 1–1



13. RMHF
14. Bldg 10
15. HMSA
11. ECL
12. EEL
16. Bldg 56
17. FSDF
18. Leachfield (B363 & B373)
10. Compound A
9. Coca/Delta/STL-IV
7. Bldg 204
6. RD-9/ELV
8. Alfa/Bravo
5. LOX
1. Northeast
Canyon
2. Happy Valley
3. Bowl
4. CTL-III
Coca Fault
N
0 FEET 1800
SCALE
FILE: CAD MLUEBKE\BOEING\SANTA SUSANA\SITE WIDE WORKPLAN\AREAS OF IMPACTED GW 7 08
JOB No.
Legend
Finer-Grained Unit
Fault Location
TCE in Groundwater > 5 Micrograms per Liter (ug/L)
Perchlorate in Groundwater > 6 ug/L
Tritium in Groundwater > 20,000 picoCuries per Liter (pCi/L)
TCE in Monitoring Well < 5 ug/L
TCE in Monitoring Well > 5 ug/L
The original version of theis figure includes colorized features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.
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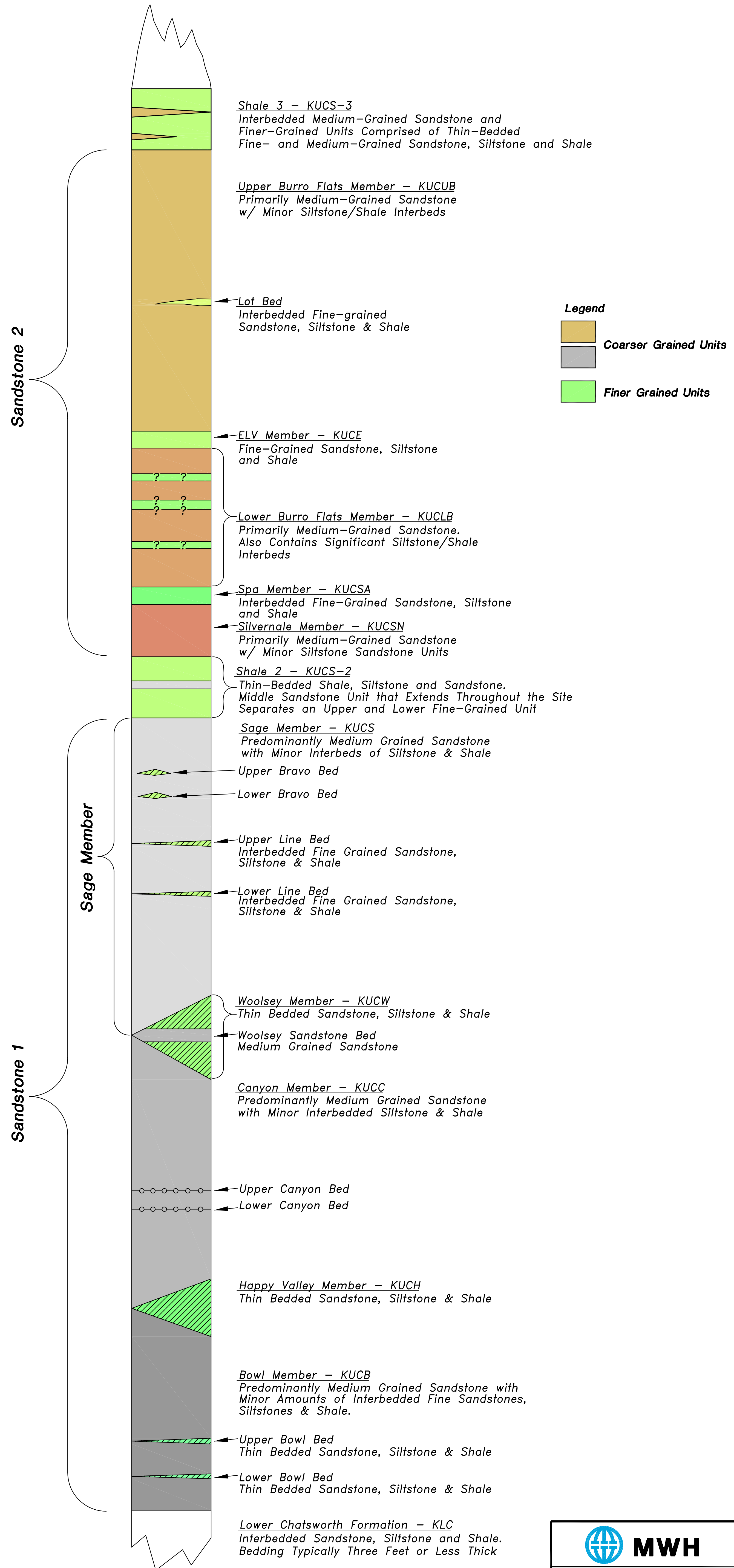
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
JULY 2008
AREAS OF IMPACTED GROUNDWATER AT THE SSFL
FIGURE 2-1



Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

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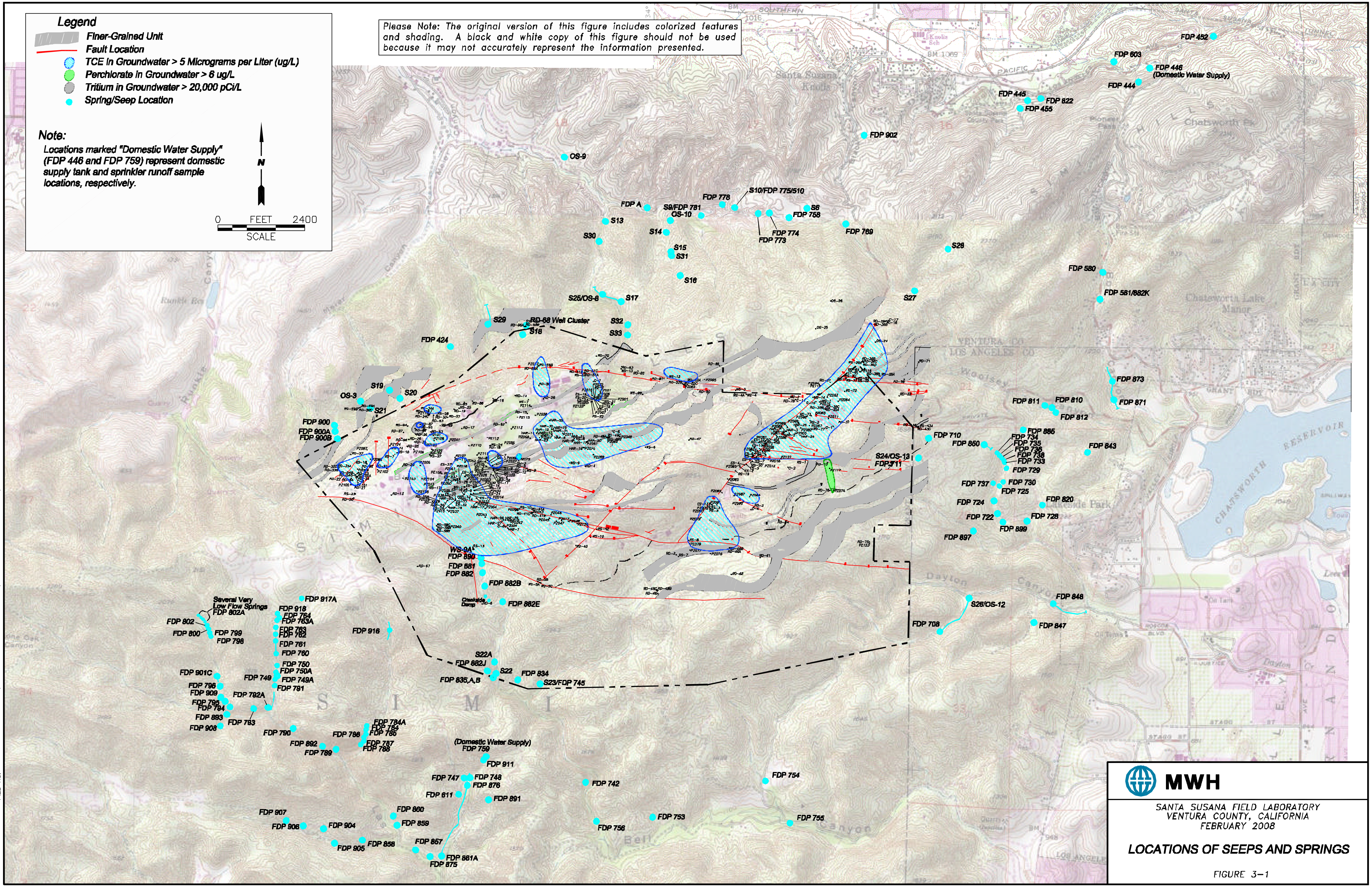
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

STRATIGRAPHIC COLUMN OF THE CHATSWORTH FORMATION

FIGURE 2–2

JOB No. — FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\SITE WIDE WORKPLAN\STRAT COLUMN 1 08



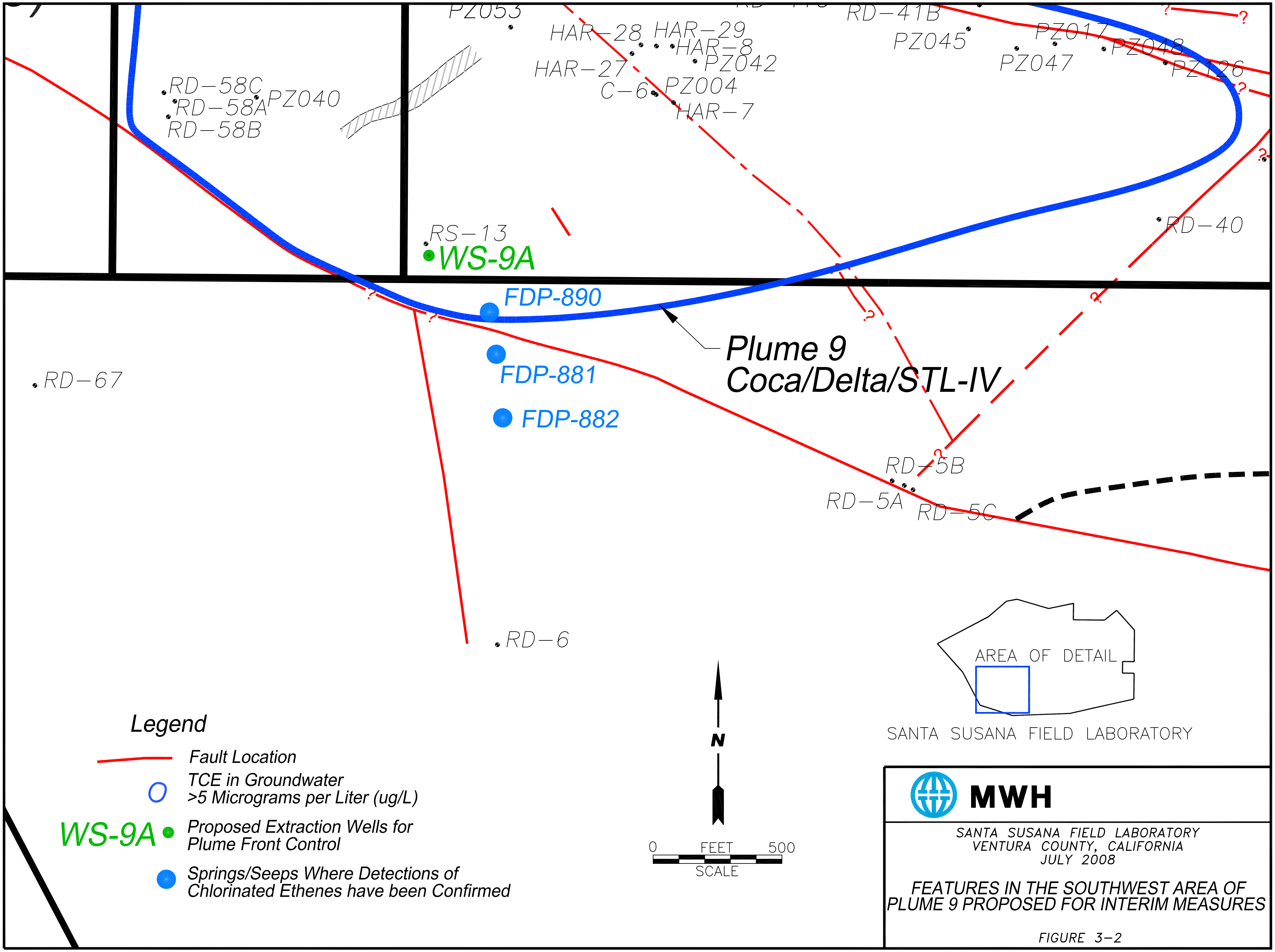
CAD: MLUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\SSFL WELL NETWORK OVER TIME 1 9 08

FILE No. ___

JOB No. ___

CAD MLUEBKE\BOEING\SANTA SUSANA\SITE WIDE WORKPLAN\PLUMES AND WELLS 7 08

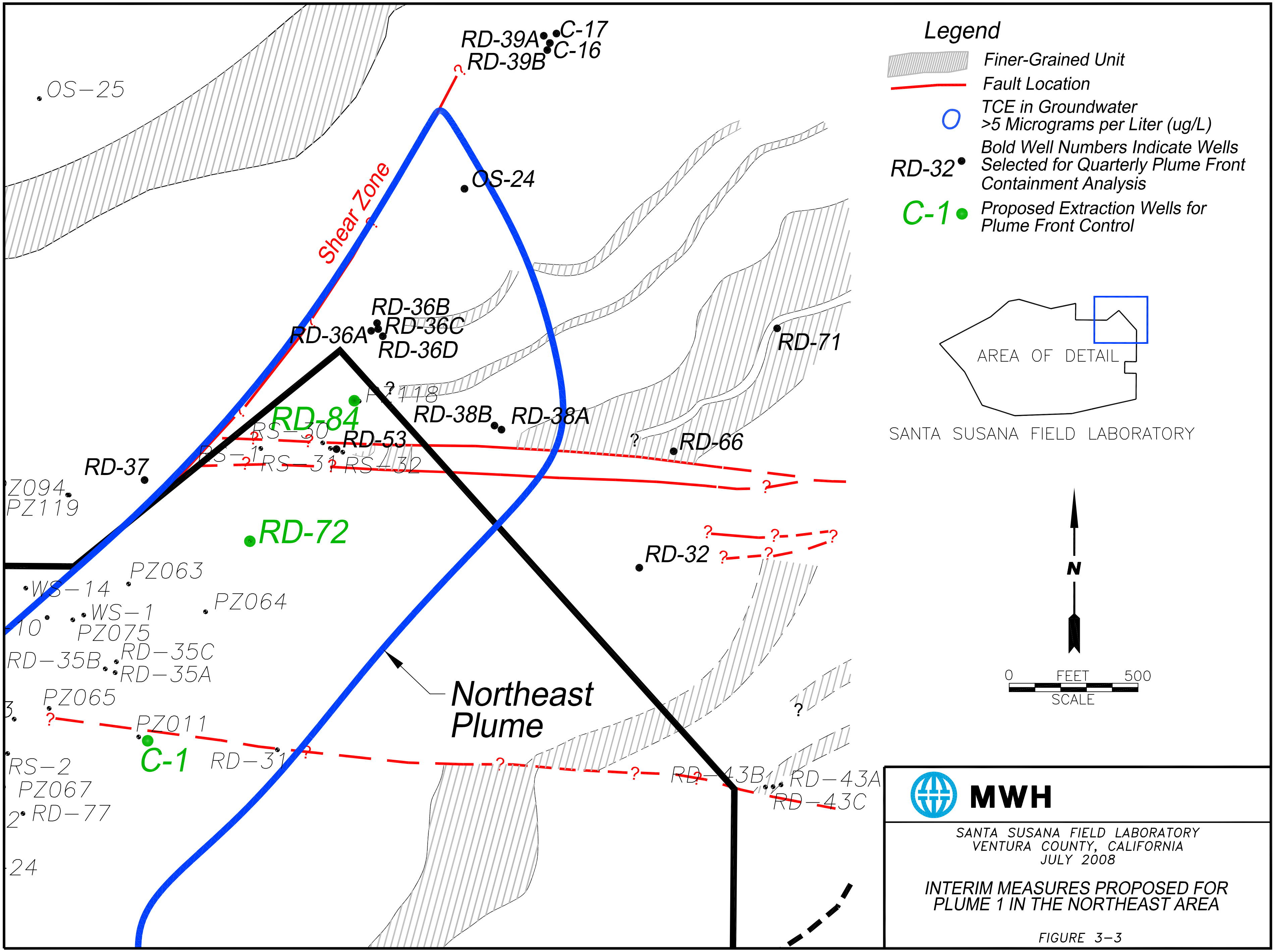
FILE No.



SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
JULY 2008

FEATURES IN THE SOUTHWEST AREA OF PLUME 9 PROPOSED FOR INTERIM MEASURES

FIGURE 3-2



MWH

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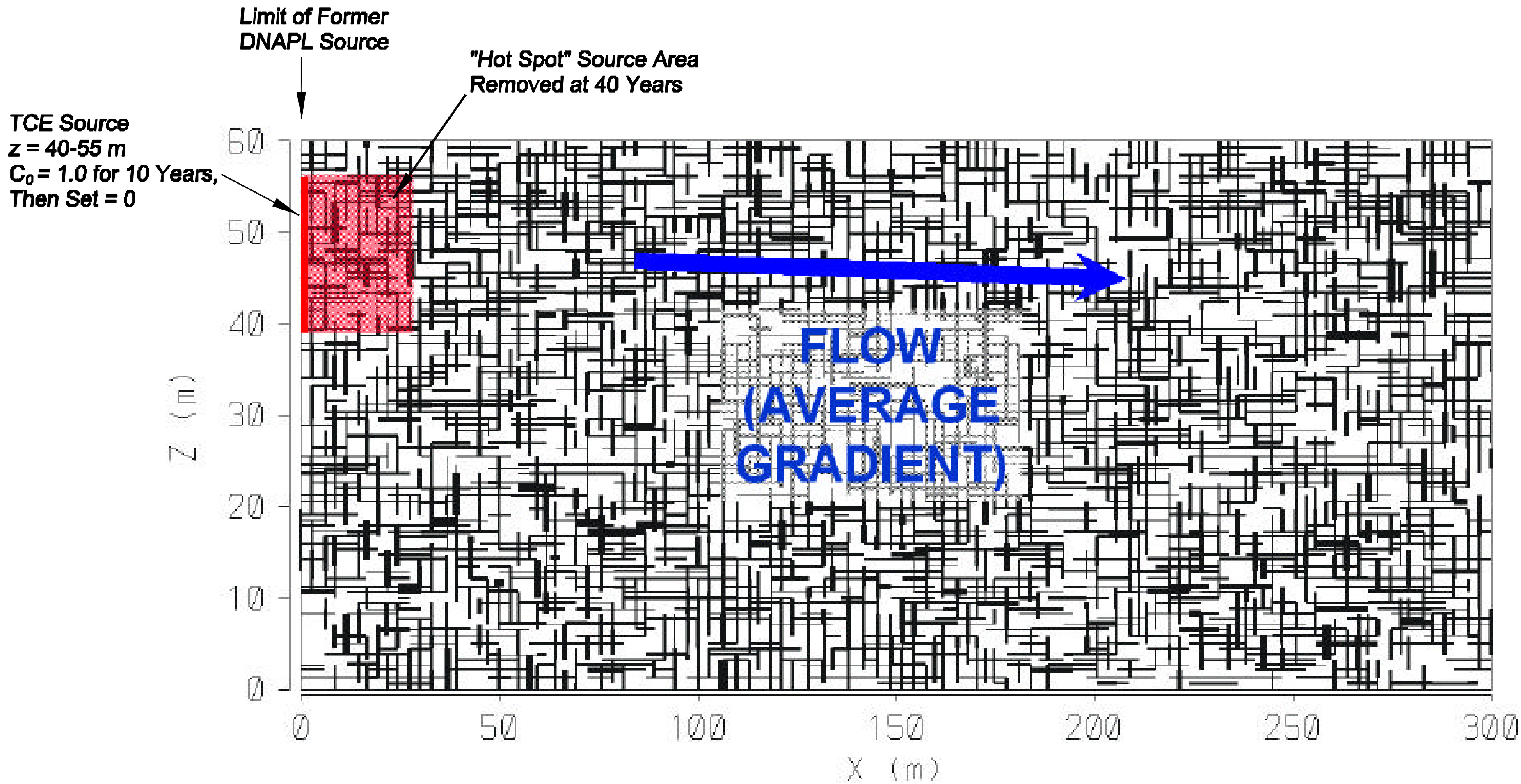
VENTURA COUNTY, CALIFORNIA
JULY 2008

INTERIM MEASURES PROPOSED FOR PLUME 1 IN THE NORTHEAST AREA

FIGURE 3-3



Fracture Apertures are Proportional to the Plotted Line Thickness

FILE: CAD MLUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\PPT GRAPHS 1 08

JOB No.

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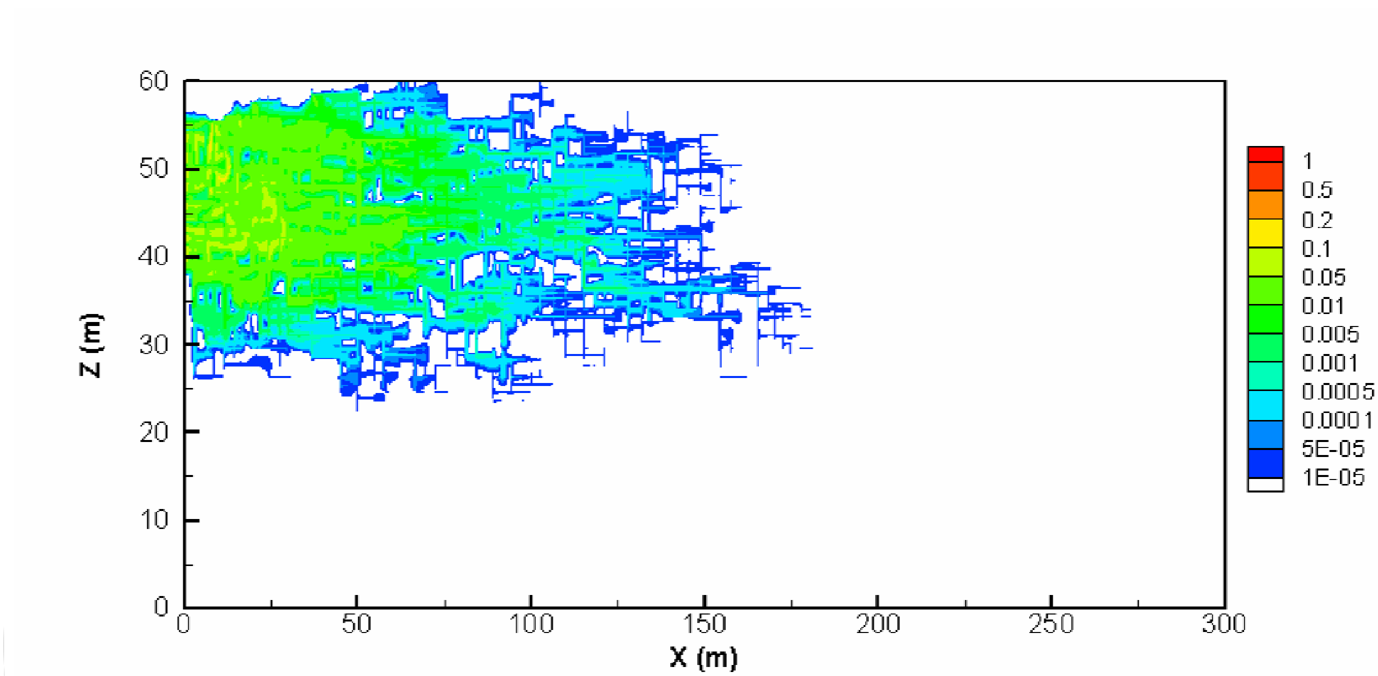
FEBRUARY 2008

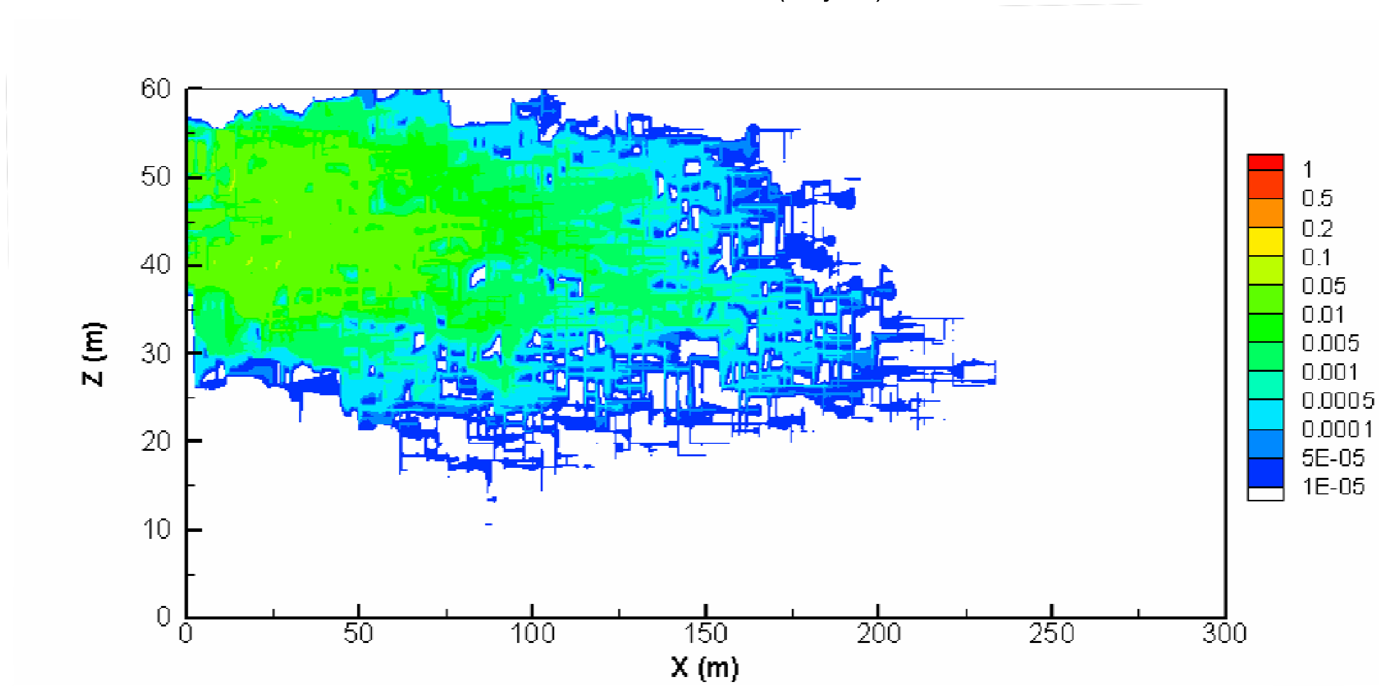
FRACTURE NETWORK VERTICAL CROSS SECTION WITH SCHEMATIC OF SOURCE REMOVAL

FIGURE 4-1

Plume at 100 Years
No Source Remediation; Finite (10 year) Source



Plume at 200 Years
No Source Remediation; Finite (10 year) Source



FILE: CAD MLUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\PPT GRAPHS 1 08

JOB No.

TCE Concentration Contours at 100 and 200 Years

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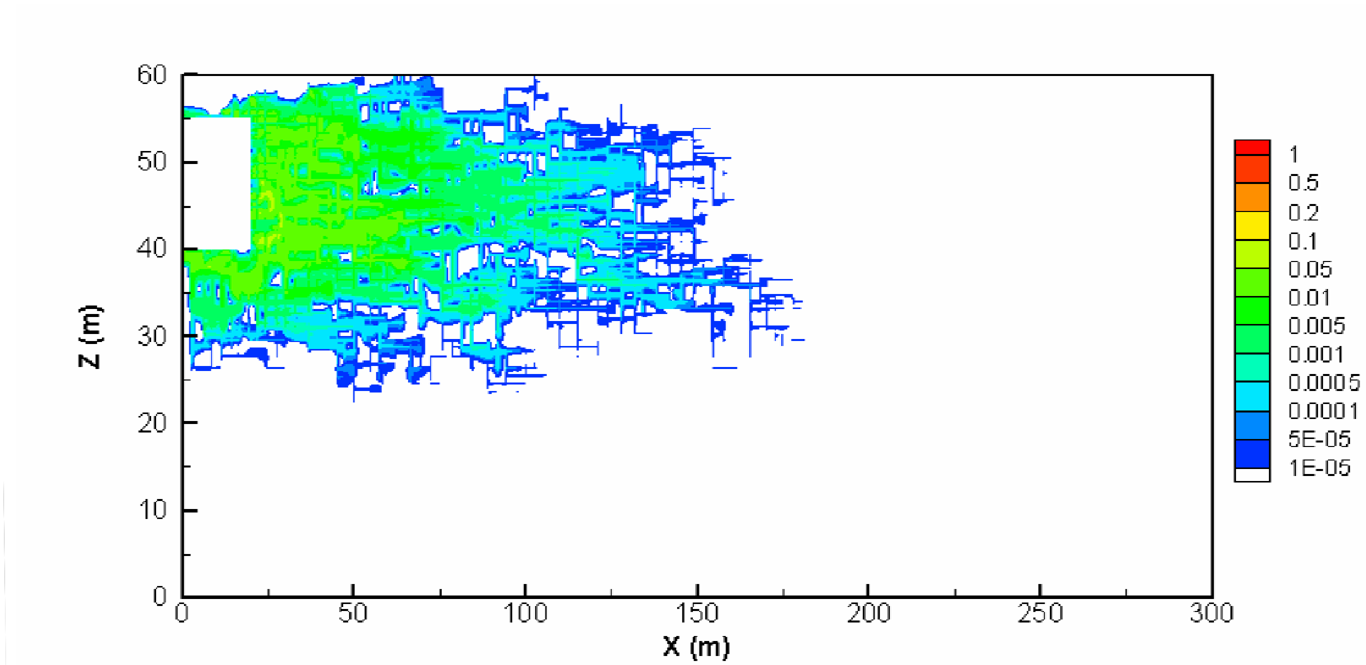
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

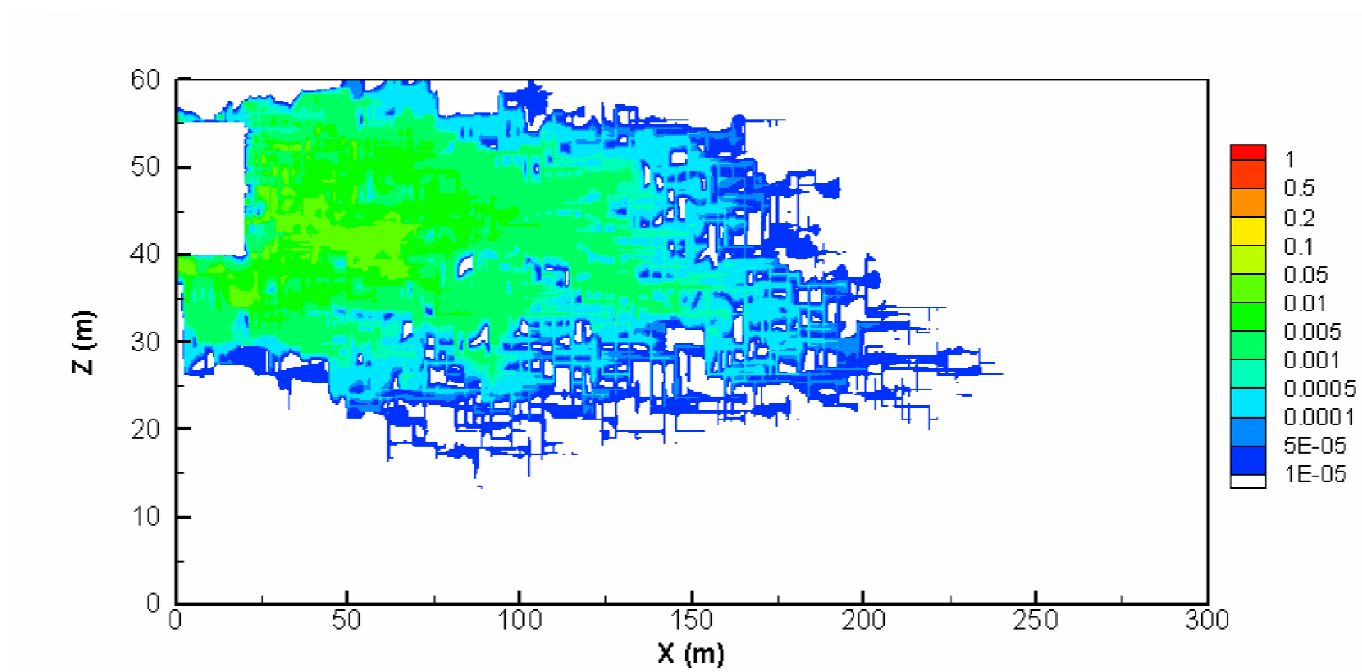
TRANSPORT SIMULATION RESULTS:
PLUME WITH NO SOURCE AREA REMEDIATION

FIGURE 4-2

Plume at 100 Years
Source Area Removed at 40 Years



Plume at 200 Years
Source Area Removed at 40 Years



TCE Concentration Contours at 100 and 200 Years

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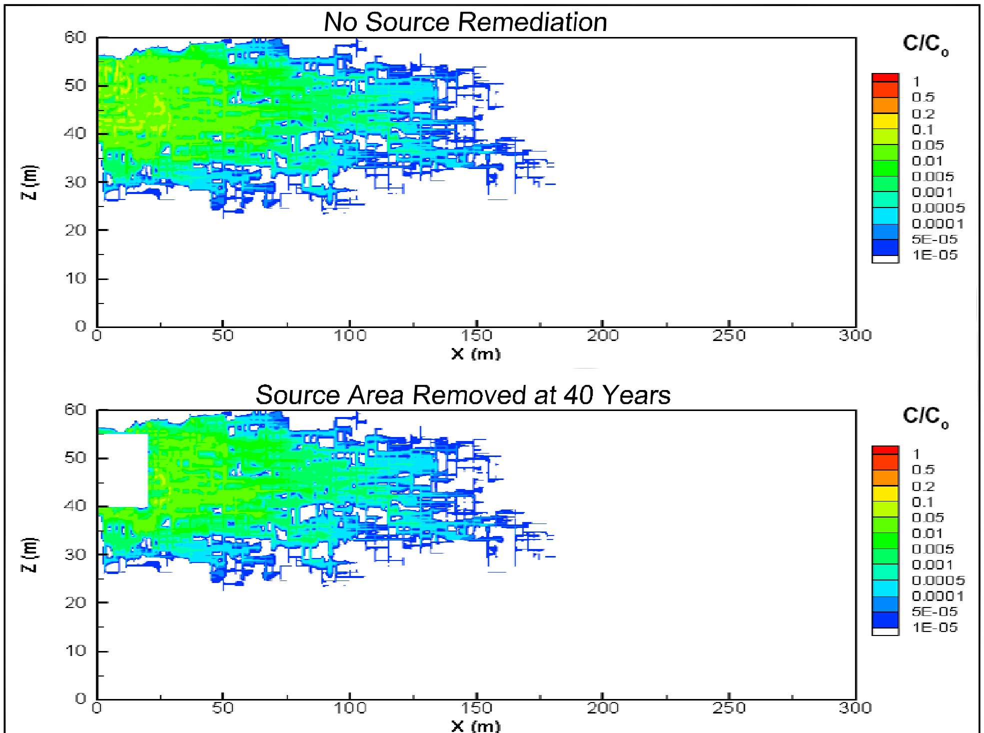
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

TRANSPORT SIMULATION RESULTS:
PLUME WITH SOURCE AREA REMOVED
AT 40 YEARS

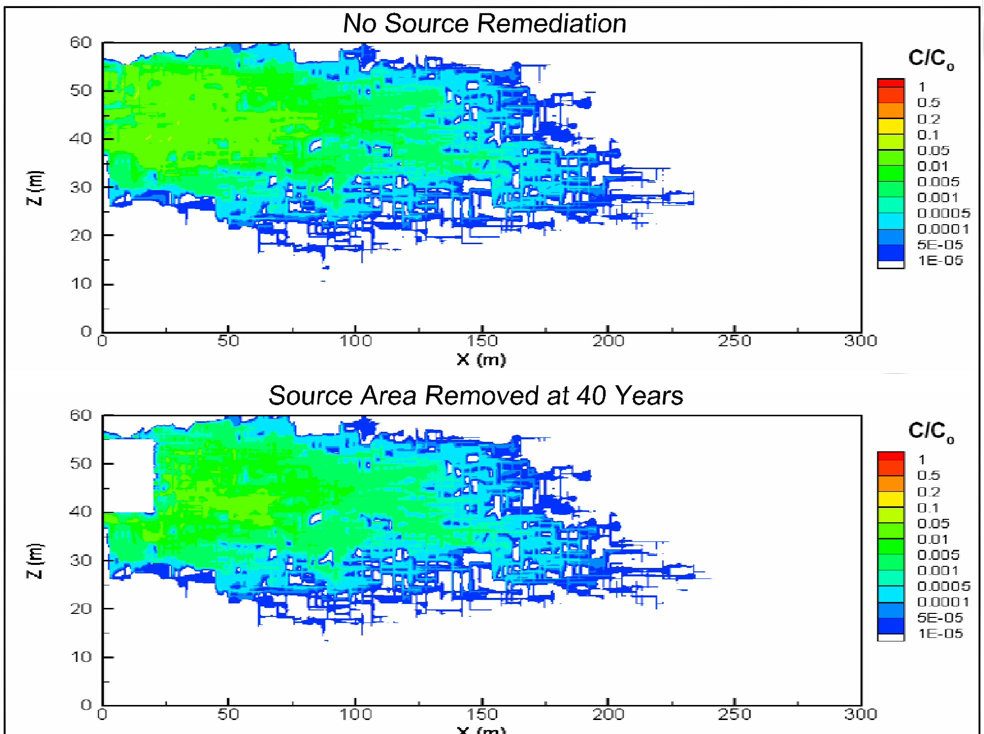
FIGURE 4-3

FILE: CAD MLUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\PPT GRAPHS 1 08

JOB No.



Comparison of Plumes at 100 Years



Comparison of Plumes at 200 Years

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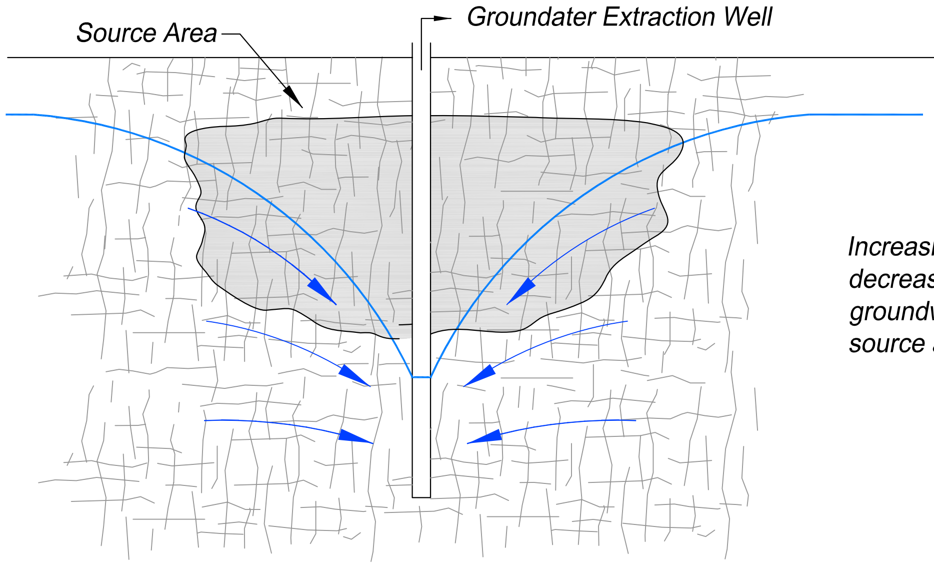
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

TRANSPORT SIMULATION RESULTS:
PLUME COMPARISON

FIGURE 4-4

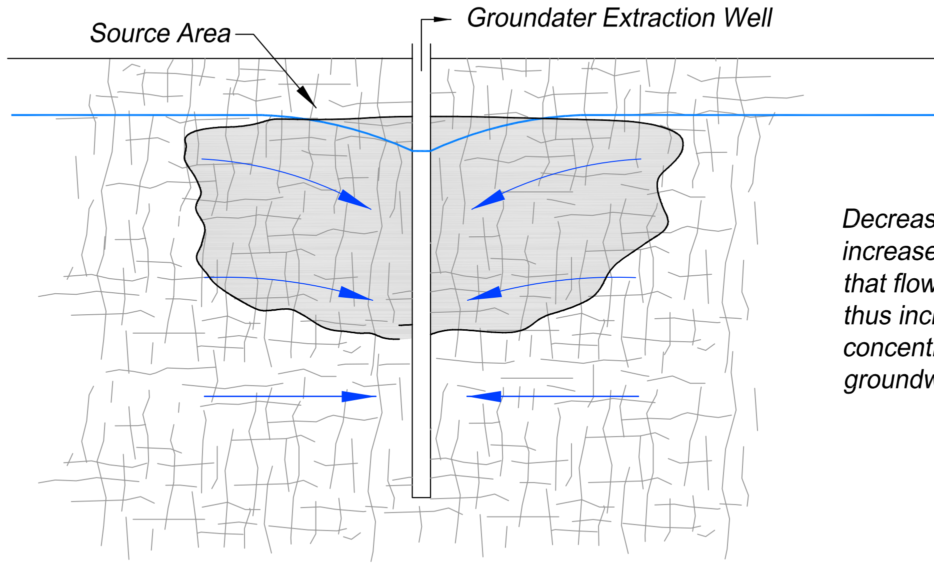
FILE: CAD MLUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\PPT GRAPHS 1 08

JOB No.



Higher Extraction Rate Increases Drawdown

Increasing the drawdown can decrease the amount of groundwater that flows through the source area to the extraction well.



Lower Extraction Rate Decreases Drawdown

Decreasing the drawdown can increase the amount of groundwater that flows through the source area, thus increasing the contaminant concentrations in the extracted groundwater.

Source Area - the region of a plume with the highest current aqueous phase concentrations.

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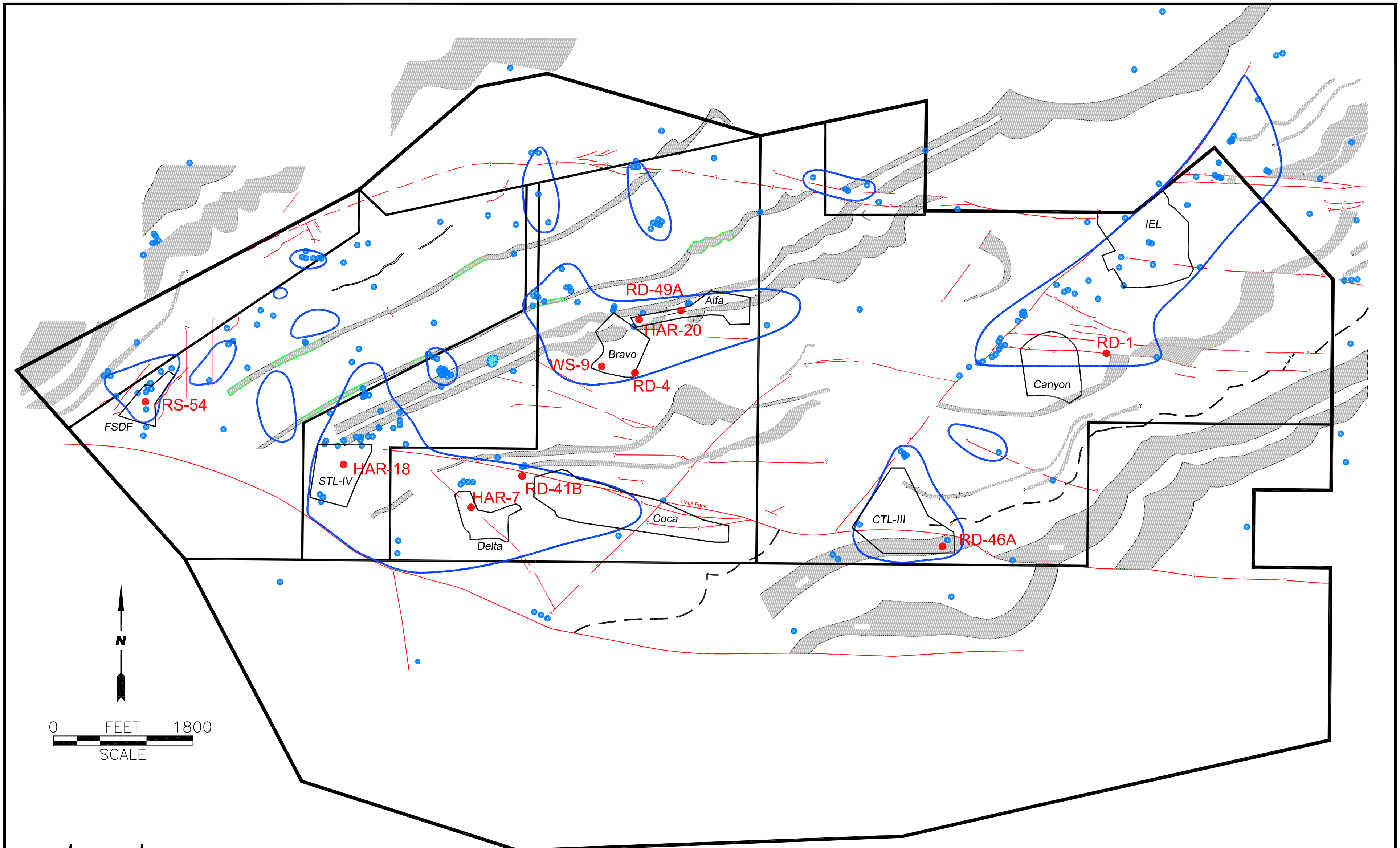
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

SCHEMATIC: EFFECTS OF DRAWDOWN FROM PUMPING IN SOURCE AREAS

FIGURE 4–5

FILE: CADM\LUEBKE\BOEING SANTA SUSANA\SITE WIDE WORKPLAN\EFFECTS OF DRAWDOWN

JOB No. ________



Legend

- Finer-Grained Unit
- Fault Location
- TCE in Groundwater >5 Micrograms per Liter (ug/L)
- Monitoring Well
- Extraction Wells Proposed in Source Areas
- RFI Site Boundary

The original version of theis figure includes colorized features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.

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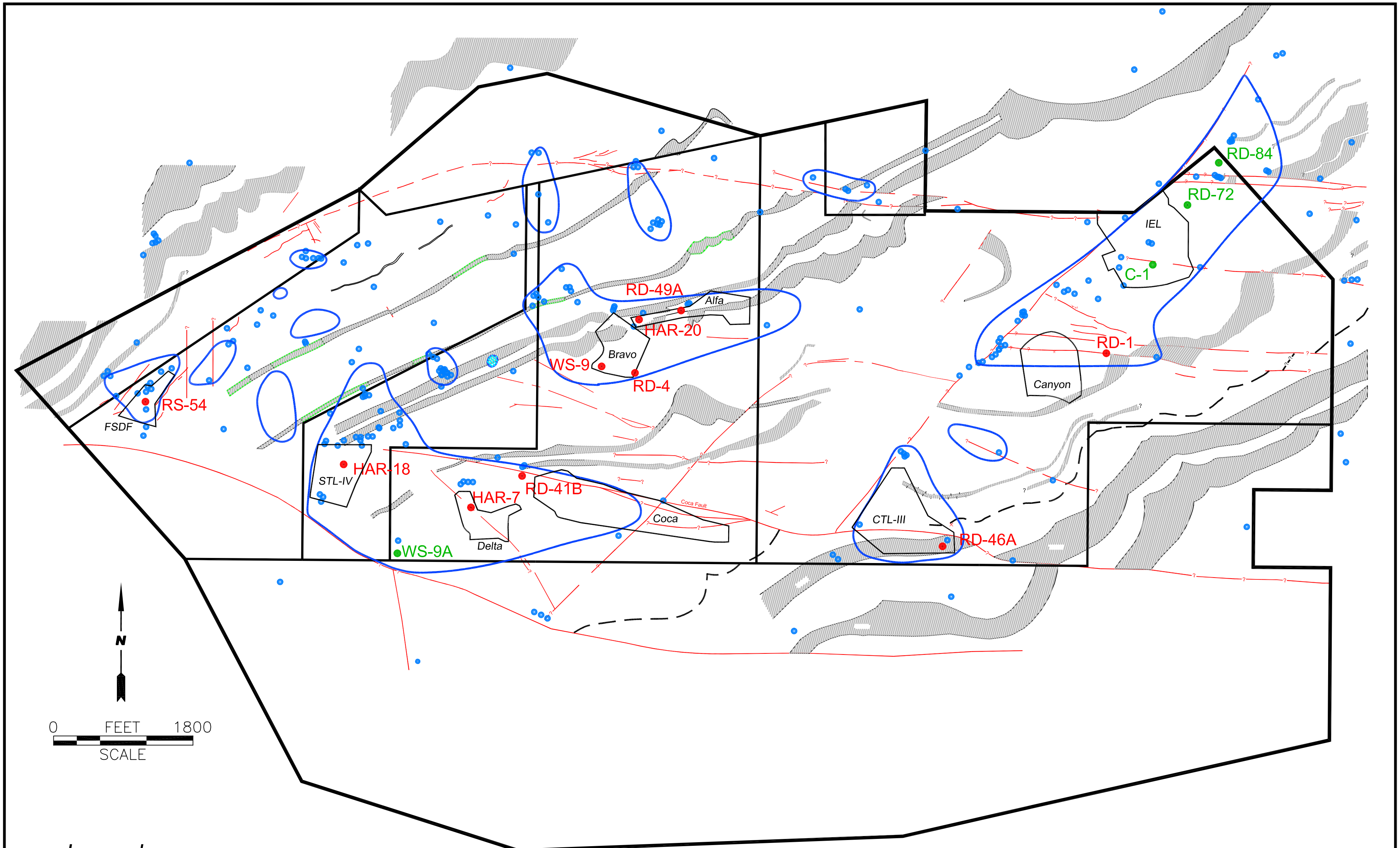
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
JULY 2008

INTERIM MEASURES EXTRACTION WELLS FOR SOURCE AREAS

FIGURE 4–6

CAD MLUEBKE\BOEING\SANTA SUSANA SITE WIDE WORKPLAN\INTERIM MEASURES 7 08

FILE No.



Legend

- Finer-Grained Unit
- Fault Location
- TCE in Groundwater >5 Micrograms per Liter (ug/L)
- Monitoring Well
- Extraction Wells Proposed in Source Areas
- Extraction Wells Proposed for Plume Front Control
- RFI Site Boundary

The original version of theis figure includes colorized features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.

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SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
JULY 2008

SUMMARY OF PROPOSED
GROUNDWATER INTERIM MEASURES

FIGURE 6–1

FILE No. CAD MLUEBKE\BOEING\SANTA SUSANA SITE WIDE WORKPLAN\PROPOSED GW EXTRACTION WELLS 6 17 08

PLATES


C
C'
Bowl Test Area
Upper Bowl Bed
Bowl Member
Lower Bowl Bed
Lower Chatsworth
Elevation (Feet Mean Sea Level)
H
H'
Silvernale Member
Lower Burro Flats Member
Upper Burro Flats Member
Sandstone 1
Shale 2
SPA Member
ELV Member
B
B'
Happy Valley Area
Middle Sage Member
Lower Line Bed
Lower Sage Member
Canyon Member
Bowl Member
Lower Chatsworth Formation
Shear Zone
Woolsey Member 1
A
A'
Building 359
Upper Sage Member
Middle Sage Member
Lower Sage Member
Upper Line Bed
Lower Line Bed
Woolsey Member
Projected Top of Happy Valley Member
North Edge of Happy Valley Fault Zone
North Edge Woolsey Canyon Fault Zone
South Edge Woolsey Canyon Fault Zone
I
I'
FSDF
Shale 3
Legend
Potentiometric Surface Elevation (August 2007)
TCE Concentration (ug/L) from August 2007 Unless Indicated Otherwise
Distribution of TCE in Near-Surface Groundwater (Concentrations ›1,000 ug/L)
Distribution of TCE in Near-Surface Groundwater (Concentrations ›100 ug/L)
Distribution of TCE in Near-Surface Groundwater (Concentrations ›5 ug/L)
Monitoring Well with FLUTe System
Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.
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SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008
GEOLOGIC CROSS SECTIONS (1 of 2)
PLATE 2-1

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

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SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
FEBRUARY 2008

GEOLOGIC CROSS SECTIONS (2 of 2)

PLATE 2-2

APPENDICES

APPENDIX A

Department of Toxic Substances Control

Linda S. Adams
Secretary for
Environmental Protection

Maureen F. Gorsen, Director
8800 Cal Center
Sacramento, California 95826-3200

Arnold Schwarzenegger
Governor

April 18, 2007

Mr. Dave Dassler
Environmental Remediation
The Boeing Company
6633 Canoga Avenue
PO Box 7922
Canoga Park, CA 91309-7922

REQUIREMENT TO SUBMIT GROUNDWATER INTERIM MEASURES WORKPLAN AND REINITIATE CERTAIN EXTRACTION WELLS, SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY

Dear Mr. Dassler:

As part of the processing of the postclosure permit renewals for Areas I and III, and Area II at the Santa Susana Field Laboratory (SSFL), the Boeing Company (Boeing) submitted a Groundwater Interim Measures Work Plan (work plan) with the permit renewal applications. This letter highlights the necessary revisions to the work plan, establishes the due date for the revised work plan and confirms that DTSC is requiring reinitiation of treatment of water extracted from wells RD-2 and WS-9A.

Boeing is hereby directed to submit a revised groundwater interim measures work plan, separate from the postclosure plans, within one hundred and twenty (120) days of the date of this letter. The work plan shall establish a schedule for implementation of the interim measures within ninety (90) days after approval by DTSC.

The revised work plan shall address remediation of, at a minimum, chlorinated solvents and other contaminants at the test stands and other significant input locations. Contaminants of interest include but are not necessarily limited to, N-Nitrosodimethylamine (NDMA), 1, 4-dioxane, and perchlorate. Prior to submission of the work plan and within 30 days from the date of this letter, Boeing shall submit to DTSC a detailed list of all known contaminants and a discussion of the rationale for proposed inclusion in or omission from the suggested work plan list of contaminants. The interim measures shall include, but not be limited to, focused groundwater extraction or other active remedial technologies applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source area(s).

This also confirms that DTSC is requiring groundwater extraction to be reinitiated at wells RD-2 (WS-5 Treatment System) and WS-9A (Delta Treatment System) immediately. During the week of March 26, 2007, Boeing reported to DTSC that the Delta air stripping system has been operating and treating water from WS-9A since late December 2006. For RD-2, Boeing reported that repairs have been underway on the pipeline and electrical wiring and that Boeing believes treatment of water can be fully reinitiated during the week of April 16, 2007.

To verify the above information, please send me a letter by April 25, 2007, that confirms that both wells and associated treatment systems are operational and that reports the dates that each began operating. Please ensure that the letter is signed pursuant to California Code of Regulations, title 22, section 66260.11(a) and (b) and includes the certification required by section 66270.11(d).

If you have any questions, please contact me at (916) 255-3574.

Sincerely,

James M. Pappas

James M. Pappas, P.E., Chief
Northern California Permitting and Corrective Action Branch

cc: Mr. Arthur J. Lenox
Environmental Remediation
The Boeing Company
Santa Susana Field Laboratory
5800 Woolsey Canyon Road
Canoga Park, CA 91304-1148

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Project Director
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P. O. Box 806
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Governor

November 19, 2007

Mr. Dave Dassler
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PO Box 7922
Canoga Park, California 91309-7922

REQUIREMENT TO SUBMIT REVISED GROUNDWATER INTERIM MEASURES WORKPLAN, SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY

Dear Mr. Dassler:

The Department of Toxic Substances Control (DTSC) has reviewed the Work Plan for Groundwater Interim Measures (Work Plan), at the Santa Susana Field Laboratory (SSFL), submitted by The Boeing Company (Boeing) on August 16, 2007. The Work Plan was submitted pursuant to DTSC's letter of April 18, 2007 and the Consent Order for Corrective Action (Order) of August 16, 2007.

In the Order and letter, Boeing was directed to address interim measures (IMs) for focused groundwater extraction or other remedial technologies applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source zone area(s). The submitted Work Plan laid out a reasonable approach and outline for long term research of groundwater remedies applicable at the SSFL Site and should facilitate a future Corrective Measures Study (CMS).

However, the Work Plan does not address solutions that can be implemented quickly to remediate source zone areas and achieve plume front containment. We believe that there are short term actions that should be taken to prevent ground water contaminants from infiltrating deeper or migrating further.

Paragraph 3.3.1. of the Order specifies that IMs shall be used to control or abate immediate threats to human health and/or the environment, and/or to minimize the spread of contaminants while long term-corrective action alternatives are being evaluated. Pursuant to the Order, paragraph 3.3.4., DTSC identifies an immediate or potential threat to human health or the environment from contaminants at source zone areas and from contaminant migration in ground water plumes at SSFL.

Boeing must propose and detail IMs that can be taken quickly at the site in addition to the proposed long term study of potential groundwater remediation technologies. The objective of a short term IM implementation should be the achievement of source zone remediation and plume front containment through technologies that can be operational and functional in twelve months or less.

The following are specific issues associated with the Work Plan that, at a minimum, need to be addressed in a revised IM Work Plan:

- Descriptions of all contaminant plumes and source areas (maps, figures, narratives)
- Proposals for IMs at groundwater plumes and source areas to achieve source zone remediation and plume front containment
- A discussion of technologies evaluated and figures to support the technology or technologies selected
- Implementation plan for proven remedial approaches such as pump and treat where contamination migration potential is high
- IMs that can be operational and functional within one year
- A project schedule for implementation of the IMs including descriptions of tasks and deliverables expected

Within 60 days of the date of this letter, Boeing is required to submit a revised IM work plan addressing the issues cited in this letter. The technology must meet the objectives of the IMs, which are source zone remediation and plume front containment. Failure to comply with these requirements could result in a finding of noncompliance with the Order.

If you have any questions, please contact me at (916) 255-3574.

Sincerely,

James M. Pappas

James M. Pappas, P.E., Chief
Northern California Permitting and Corrective Action Branch

cc: See next page.

cc: Mr. Arthur Lenox
Environmental Remediation
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Santa Susana Field Laboratory
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Public Participation Supervisor
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Department of Toxic Substances Control
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#107365

Department of Toxic Substances Control

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May 16, 2008

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GROUNDWATER INTERIM MEASURES WORKPLAN, SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY, DATED FEBRUARY 2008

Dear Mr. Dassler:

The Department of Toxic Substances Control (DTSC) has reviewed the revised Groundwater Interim Measures Work Plan for the Santa Susana Field Laboratory dated February 2008 (Revised Work Plan), submitted by The Boeing Company (Boeing) on January 31, 2008. The Revised Work Plan was submitted pursuant to DTSC's letter of November 19, 2007.

The Revised Work Plan is the second revision to a Ground Water Interim Measures Work Plan that was initially submitted in 2004 as part of the RCRA Permit renewal. The first revision was submitted on August 16, 2007 by Boeing pursuant to DTSC's letter of April 18, 2007.

The DTSC Geological Services Unit (GSU) reviewed the February 2008 Revised Work Plan and its analysis, conclusions, and recommendations are provided in the attached memo dated April 24, 2008. Please incorporate the GSU recommendations into your submittal of the new Draft Ground Water Interim Measures Work Plan.

In correspondence to Boeing, DTSC has consistently required an Interim Measures Work plan that included active source zone and plume front containment. Specifically:

- The April 18, 2007 letter stated, and it was repeated in the August 16, 2007 Consent Order for Corrective Action (Consent Order), that "The interim measures shall include, but not be limited to, focused groundwater extraction or other active remedial technologies applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source area(s)."

- The Consent Order states that "Interim measures shall be used whenever necessary and appropriate or when directed by DTSC to control or abate immediate threats to human health and/or the environment, and to prevent and/or minimize the spread of contaminants which long-term corrective action alternatives are being evaluated."

- The November 19, 2007 letter states that, "In the [Consent] Order and [April 18, 2007] letter, Boeing was directed to address interim measures (IMs) for focused groundwater extraction or other remedial technologies applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source zone area(s)."

DTSC does not concur with Boeing's argument which discounts the need for groundwater IMs based on the site conceptual model. As stated in the attached memo, although DTSC acknowledges Boeing's site conceptual model which recognizes the potential effects of matrix diffusion and natural degradation on advancement of contaminant plumes, the degree to which these processes are operating has not been adequately established. DTSC does not accept the argument that there is not a need for comprehensive and active groundwater IMs. DTSC elaborated on the uncertainties associated with the site conceptual model in the attached memorandum. DTSC believes that the site conceptual model at this time is a working hypothesis which requires further evaluation and testing using site-derived data.

In summary, the Revised Work Plan only recommends action at one location (WS-9A) to dewater springs FDP-890 and FDP-881 which transmit contaminated groundwater into the Bell Canyon creek drainage. The actions presented in the Revised Work Plan are not acceptable because they are insufficient to address the potential ground water threats to public health and the environment.

DTSC hereby directs Boeing to submit, within 60 days of the date of this letter, a new Draft Ground Water Interim Measures Work Plan addressing all of the issues cited in this letter and the attached GSU memo. The Interim Measures must meet the objectives of active technologies for source zone remediation and plume front containment. As set forth in the Consent Order, Respondents are joint and severally liable for fulfilling all obligations and requirements of the Order. Failure to submit a new Draft Ground Water Interim Measures Work Plan that adequately addresses these requirements will result in a finding of noncompliance with the Consent Order and Respondents will be assessed stipulated penalties.

If you have any questions, please contact me at (916) 255-3572.

Sincerely,

James M. Pappas

James M. Pappas, P.E.
DTSC Special Projects

Attachment: DTSC Geological Services Unit Memo dated April 24, 2008

cc: Mr. Tom Gallacher
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To: Christopher Sherman, P.E.
Senior Engineer
Northern California Permitting and Corrective Action Branch
Hazardous Waste Management Program

From: Thomas M. Seckington, C.HG.
Senior Engineering Geologist
Geology, Permitting and Corrective Action Branch
Hazardous Waste Management Program

Date: April 24, 2008

Re: Santa Susana Field Laboratory

Groundwater Interim Measures Work Plan, dated February 2008

The Geological Services Unit (GSU) of the Geology and Corrective Action Brach has reviewed the Groundwater Interim Measures Work Plan (work plan) dated February 2008. This work plan is the second revision to an Interim Measures Work Plan initially submitted in 2004 as part of the RCRA Post-Closure Permit renewal. The intent of this memorandum is to provide a comprehensive discussion of the history of groundwater interim measures at the site and to provide explicit recommendations to the project management for actions that are required at the site as part of Interim Measures.

BACKGROUND

PREVIOUS GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS

Beginning in the mid-1980s, under the direction of the Regional Water Quality Control Board – Los Angeles Region (RWQCB-LAR), Boeing initiated groundwater extraction at the site to control potential offsite migration of contaminants. In 1995, the groundwater treatment systems, extraction wells, and associated conveyance piping were permitted by DTSC under the Areas 1 & 3 and Area 2 Post-Closure permits (PCPs).

There are currently eight (8) ground-water remediation systems and one (1) collection unit permittedunder the PCPs at SSFL. They are the following:

System	Status	Type of System	Period of Operation	Area	Wells
ALFA	Active	Air Stripper	1987 – Present	I	WS-6
Area I Road	Standby	Air Stripper	1987-2000	I	
Canyon	Standby	Air Stripper	1987-1998	I	
WS-5 Area	Active	UV/Peroxidation	1991-Present	I	ES-1, ES-3, ES-4, ES-5, ES-6, ES-7, ES-11, HAR-4, HAR-16, RD-1, RD-2, and WS-5
Bravo	Active	Air Stripper	1989-Present	II	RD-4, WS-9, ES-21, ES-22, and RD-9
Delta	Active	Air Stripper	1987-Present	II	HAR-7 and WS-9A
RD-9 Area	Standby	UV/Peroxidation	1990-1998	II	
STL-IV	Active	Air Stripper	1990-Present	III	ES-14, ES-17, ES-23, ES-24, ES-26, ES-27, ES-30, ES-32, HAR-17, HAR-18, ECL Sump, ECL Fr. Drn.

Three additional groundwater remediation systems have operated in Area 4. They are: the Former Sodium Disposal Facility groundwater remediation system (currently in standby); the Building 59 dewatering system (dismantled); and the Radioactive Materials Handling Facility groundwater remediation system (currently in standby).

2000 Pumping Cessation during CFOU Investigation

Extraction and treatment of groundwater were temporarily suspended at SSFL in 2000 as part of the DTSC approved field investigation to evaluate the deep Chatsworth groundwater flow at the site. The *Work Plan for Additional Field Investigations Chatsworth Formation Operable Unit* (dated October 2000) was approved by DTSC in October 2000. The scope of the investigation included drilling 11 coreholes through the vertical depth of the contamination in sources areas; analyzing the rock core for VOCs; and retrofitting the coreholes and the existing deep wells with discrete monitoring ports. A critical aspect of the field investigation was to collect discrete groundwater elevation measurements from the retrofitted wells and coreholes through the vertical depth of the dipping layered and fractured geology. The vertical groundwater elevation profiles aid in understanding the three dimensional groundwater flow in the fractured bedrock. Prior to allowing shutdown of the extraction wells, DTSC stipulated increased sampling frequency of TCE and other chemicals to monitor the stability of the plumes while the extraction wells were not operating. The approach taken is outlined in the Appendix B of the October 2000 Work plan and required that wells in the vicinity of the extraction wells be monitored monthly for constituents of concern the first 3 months following shutdown, and quarterly thereafter. If concentrations of contaminants exceed prior levels, Boeing would meet with DTSC to assess the extent of change in water quality conditions and stability of the plume and reinitiate pumping. Most of the pumping wells were shut down at the initiation of the field work in 2000.

2001 Post-Closure Permit Modification

In November 2001, the following modifications were made to groundwater treatment systems in Post-Closure Permits: the Canyon, Area 1 Road, and RD-09 treatment systems were placed on stand-by and the extraction wells for these systems were piped to the Bravo or WS-5 Treatment systems.

2001 – 2005 Emergent Chemicals

Testing for emergent chemicals such as NDMA, perchlorate, and 1,4-dioxane, became more frequent and widespread since 2000. As a result, these chemicals were detected in several extraction wells. It was determined that, in many cases, the existing treatment systems, as permitted, could not treat the influent groundwater from many of the extraction wells. Most notable is the occurrence of perchlorate in the northeast portion of the site. Perchlorate cannot be currently treated by any of the groundwater treatment systems at the site as permitted.

2005 Topanga Fires

The Topanga Fires in the late summer of 2005 impacted the majority of the site. In general, the groundwater treatment systems were not visibly damaged; however, the extensive network of double-walled piping which delivered water from the extraction wells to the treatment units was mostly destroyed.

Prior to the 2005 Topanga Fires, groundwater extraction was only conducted at well WS-9A which conveyed water to the Delta treatment system. After the fires no groundwater extraction was conducted at the site with the exception of a startup period in 2007 required by DTSC (April 18, 2007 letter).

INTERIM MEASURES WORK PLAN SUBMITTALS AND CORRESPONDENCE

November 2004 PCP Renewal / Interim Measure Work Plan

The November 2004 PCP renewal contained the "Groundwater Remediation Facilities Interim Measures Work Plan" as Attachment VIII-B. The work plan stated *"an approach for evaluating existing groundwater data and interim corrective action well performance to determine whether groundwater interim measures are appropriate at the SSFL, and if so under what conditions."* It did not propose any interim measures, only data review.

April 18, 2007 DTSC Letter

On April 18, 2007, DTSC issued a letter directing Boeing to submit a revised groundwater interim measure work plan within 120 days which would include "focused groundwater extraction or other active remedial technologies applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source area(s)." The letter also required groundwater extraction to be reinitiated at wells RD-2 and WS-9A immediately.

August 16, 2007 Revised Groundwater Interim Measures Work Plan

Boeing submitted a revised Groundwater Interim Measures Work Plan on August 16, 2007. The revised work plan proposed four tasks: (1) interim measures (IMs) technology evaluation and report; (2) IMs pilot testing and report; (3) IMs design and implementation report, and (4) IMs implementation schedule. Tasks 1 and 2 proposed in the work plan consisted of lengthy and extensive evaluation and testing of several active remediation technologies. These tasks were more akin to a corrective measures study than IMs. In fact, the proposed work plan schedule, as proposed, would have taken over 3 years to complete before IMs would be initiated. Although the proposed scope of work was described in more detail than the 2004 work plan, the proposed work was still essentially a data review that did not propose any specific interim measures.

The GSU recommended that DTSC deny approval of the submittal and request a second revised focused IMs work plan be submitted under a much abbreviated implementation schedule. Specifically, tasks requiring the evaluation of technologies, extensive pilot-study testing, and interim reports should be removed to facilitate a more timely and efficient implementation of IMs.

Specifically, the GSU concluded the following:

1. Boeing was required to evaluate several active remedial technologies when preparing the revised IMs work plan, not to incorporate the evaluation into the proposed IMs work plan scope. A second revised IMs work plan should include: a description of the selected technology(s) to be utilized to achieve the objectives of the IMs; a description of the specific plumes and locations where the technologies will be used; and an implementation schedule. The GSU concluded that the evaluation of available technologies should have been completed by the time the work plan was submitted and recommended that no additional time should be given for this task.

2. The pilot tests and subsequent evaluations proposed in Task 2 of the work plan added significant time before IMs implementation would be completed. It should be noted that the August 16, 2007 Consent Order for Corrective Action (Consent Order) states "Pilot studies shall be conducted, as required by DTSC, to assess the effectiveness of different available remedial approaches." The requirement for pilot studies was under the discretion of DTSC and was not intended to be conducted for all technologies proposed.

   The GSU acknowledges the complexities of the site conditions and anticipates the need to conduct limited scaled tests of some promising but less proven technologies at the site before large scale implementation. The GSU concluded that the IMs work plan may propose limited pilot test(s) of these less established technologies; however, DTSC should weigh the effects of lengthy testing on meeting the short term IMs objectives of source zone and plume front containment. At a minimum, the GSU recommended the use of proven remedial approaches such as pump and treat at locations where potential exposure is the greatest (i.e. the offsite solvent plume to the northeast of the property and the solvent plume at WS-9A) and in source areas where the additional contaminant mass could enter the groundwater system and/or additional groundwater resources could be impacted.

November 18, 2007 Letter

On November 18, 2007, based on the GSU evaluation of the August 2007 work plan, DTSC issued a letter to Boeing. The letter required Boeing to submit a revised Groundwater IMs work plan that proposed and detailed IMs that can be implemented in a timely fashion at the site in addition to the proposed long term study of potential groundwater remediation technologies. The following specific issues also needed to be addressed:

- Descriptions of all contaminant plumes and source areas (maps, figures, narratives);
- Proposals for IMs at groundwater plumes and source areas to achieve source zone remediation and plume front containment;
- Implementation plan for proven remedial approaches such as pump and treat where contamination migration potential is high;
- IMs that can be operational and functional within one year; and
- A project schedule for implementation of the IMs including descriptions of tasks and deliverables expected.

GROUNDWATER INTERIM MEASURES WORKPLAN DATED FEBRUARY 2008

Boeing submitted a revised work plan in February 2008 (2008 work plan). The GSU has reviewed this document. In summary, the 2008 work plan again failed to recommend any substantive IMs at the site. In fact, the 2008 work plan proposes the cessation of groundwater extraction at one of two groundwater extraction well locations (i.e. RD-2) required in the April 18, 2007 letter. The only active IM proposed at the site is groundwater extraction at WS-09A where a nearby spring had detectable concentrations of solvents.

Monitored Natural Reactivity Plume Front Containment

In lieu of any new active remediation methods, the 2008 work plan recommended "Monitored Natural Reactivity Plume Front Containment." "Monitored Natural Reactivity Plume Front Containment" is defined "to represent the collective effects of matrix diffusion, sorption, dispersion, and degradation" and appears to be analogous to "monitored natural attenuation" or MNA. MNA is an approach to clean up environmental contamination by relying on natural processes and monitoring. Natural attenuation processes include a variety of physical [such as diffusion and dispersion], chemical [sorption], or biological processes [degradation] that, under favorable conditions, act without human intervention (i.e. passive approach) to reduce the mass, toxicity, mobility, volume, or concentration of contaminants. MNA is not considered an interim measure since it is not an "action" taken to mitigate a threat or potential threat to human health and the environment. MNA may be an appropriate final cleanup option when the facility can demonstrate that this remedy is capable of achieving facility-specific groundwater cleanup levels in a reasonable cleanup timeframe and is a more effective approach than other remedial approaches. This demonstration is part of a remedial investigation study which will follow the completion of ongoing site characterization activities.

The inclusion of MNA in the 2008 work plan does not meet the requirements of previous DTSC letters and the consent order. The following are the specific citations in these letters and in the consent order:

> In the April 18, 2007 letter and repeated in the August 16, 2007 Consent Order for Corrective Action (Consent Order), *"The interim measures shall include, but not be limited to, focused groundwater extraction or other* ***active remedial technologies*** *applied at source zone(s) to eliminate and/or remediate the contaminant mass flux from the source area(s)."*
>
> In addition, the Consent Order also states *"Interim measures shall be used whenever necessary and appropriate or when directed by DTSC* ***to control or abate*** *immediate threats to human health and/or the environment, and* ***to prevent and/or minimize*** *the spread of contaminants which long-term corrective action alternatives are being evaluated."*
>
> In the November 19, 2007 letter, *"In the [Consent] Order and [April 18, 2007] letter, Boeing was directed to address interim measures (IMs) for focused groundwater extraction or other remedial technologies applied at source zone(s)* ***to eliminate and/or remediate*** *the contaminant mass flux from the source zone area(s)."*

Site Conceptual Model for Contaminant Transport

To support the proposed interim measures, a significant portion of the 2008 work plan presents Boeing's site conceptual model for contaminant transport, which basically states that the effects of matrix diffusion have a significant retardation effect on the contaminant plumes on the site. The GSU is well aware of the potential effects of matrix diffusion and natural degradation on retarding the advancement of contaminant plumes and the associated research on this topic. However, as stated previously in memoranda and during meetings with Boeing, the degree that these processes are operating at the site has not been adequately established through the collection of site data. It was therefore unexpected that Boeing would argue the site conceptual model at this juncture to discount the need for comprehensive and active IMs and to propose a final remedy selection (i.e. MNA) prior to the completion of characterization activities and the initiation of a study to evaluate cleanup alternatives.

Since the elements of the site conceptual model are presented in the work plan in support of the proposed IMs, it is necessary to discuss several uncertainties associated with the site conceptual model to point out the need for additional data collection. Section 2.3.3, "Summary of Primary Elements Describing the Nature and Extent and Transport and Fate of COPCs in Bedrock at the SSFL" of the 2008 work plan presents a list of key elements of the site conceptual model. The following is a brief discussion of selected key critical elements. Again, the purpose is not to disprove and dispute these key points but rather to point out uncertainties associated with them. A future memorandum will further address the site conceptual model and matrix diffusion in more detail.

"5. *Groundwater recharge is a small percent of the mean annual precipitation.*"
The GSU believes that the chloride concentrations used to calculate recharge were too high and not representative of the natural conditions of the site. The GSU believes that the data set used by the facility could include groundwater data influenced by site operations. This could result in an underestimation of the range of recharge expected at the site.

"8. *The bulk hydraulic conductivity is low to moderate.*"
The bulk hydraulic conductivity was initially determined for the site using assumptions of basic geometry (a hill), homogenous conditions, and depth to water. Aquifer test data and laboratory measurements of the rock core indicate a high variability of hydraulic conductivity values across the site. Although Boeing has indicated that the hydraulic conductivity values are consistent with initial bulk hydraulic conductivity calculations, additional testing is required across the site to better bracket the range of hydraulic conductivities measured at the site and to identify spatial and geologic relationships associated with the variability.

"10. *At some depth below the SSFL, the bulk hydraulic conductivity becomes very small causing groundwater flow and contaminant migration below this depth to be insignificant.*"
This conclusion has been based mostly on literature research and not site conditions. It assumes that fracture apertures decrease with depth due to the pressure of the overlying rock that is exerted on the fractures. However, this effect can be significantly reduced in tectonically active areas such as the Simi Hills and in areas where vertical fractures dominate. In addition, TDS values in the deepest wells/coreholes at the site indicate significant deep groundwater circulation.

"11. *Effective fracture apertures are small to moderate.*"
The fracture apertures are calculated using fracture frequency, bulk hydraulic conductivity, and matrix hydraulic conductivity. If bulk hydraulic conductivity values are underestimated, aperture will also be underestimated. Furthermore, USGS geophysical work conducted within several coreholes at the site report much larger apertures than is cited by Boeing. Additionally, fracture aperture data are needed to adequately

assess the nature and distribution of the fracture system.

"12. *Much of the groundwater originating in the SSFL property discharges at springs, seeps, and phreatophytes that are situated on the surrounding mountain slopes."*
This key point is mostly supported by the 3-D model and the assumptions built into it. Field mapping has identified areas where seep, springs, and phreatophytes are present but the discharge from these elements is difficult to quantify. The 3-D model is still being evaluated and source of the water from the springs and seeps is not known.

Again, the intent of this discussion was to exemplify the uncertainties that the GSU has with the site conceptual model. The GSU anticipates that additional data will be collected during site characterization activities to further assess the validity of the site conceptual model's key elements. At this time, the site conceptual model is a working hypothesis that requires further evaluation and testing using site-derived data.

Given the uncertainty, it is useful to point out that interim measures are not constrained to actual threats but also to potential threats to human health and environment. Interim measures are also a mechanism to begin source removal when the initiation of corrective action is not anticipated to occur in a timely manner (i.e. considerable site characterization is still required).

Source Zone Containment

The following was stated in Dense Chlorinated Solvents and other DNAPLs in Groundwater (Pankow and Cherry, 1996), "Although complete aquifer restoration is an elusive goal, a better prospect exists for restoring parts of aquifers by removing all or part of the plume while at the same time isolating the source zone in place. For a portion of the aquifer, contamination from the source zone must not be allowed to enter that portion..." Furthermore, according to the "*Source Zone Characterization at SSFL: Rock Core VOC Results, C1 to* C7 (Hurley, Parker, and Cherry, 2003)" "most of the VOC remains near where the TCE DNAPL entered the subsurface..." Since the source zones are limited in lateral extent, isolation of these source zones should be an objective of interim measures.

The 2008 work plan provides a description of the development of a numerical model using FRACTRAN. Two different simulations are discussed. One simulation, without the removal of the source zone (defined earlier as "the region of a plume with the highest current dissolved concentrations) and the other simulation where the "source zone" is removed after 40 years (roughly correlating to the present). The work plan description of the source conditions for TCE (at the source area) requires some clarification. Under both simulations, the TCE source was assumed to be constant for 10-years after which time the source term was set to zero. The work plan states "*the vertical extent and source period assumed for TCE recognize that it was released as DNAPL, and therefore would have migrated downward [assumed 15m in model] in the fractures before becoming immobile, where it would have persisted (for 10 years in this simulation) as the DNAPL mass was gradually depleted and ultimately disappeared due to dissolution in groundwater flowing in fractures and diffusion into the sandstone matrix.*" The 2008 work plan states "*...in this simulation the source area removed at 40 years no longer contains TCE DNAPL, only sorbed and dissolved phase TCE mass...*" The FRACTRAN computer model is intended to support the hypothesis that source removal at the site will not have any discernible impact on the overall cleanup of the groundwater.

The GSU has several concerns. First of all, "source zone" is an ambiguous and subjective term. There is no way of knowing from this description what mass and concentration were removed from the simulation as "source zone." Secondly, in the simulation, the TCE source was present for 10 years in order to simulate the dissolution of the DNAPL. Site operations, however, suggest that a continuous DNAPL source would have likely been released over a prolonged period of time. The numerical model, however, appears to simulate an instantaneous release event and the subsequent dissolution of DNAPL over 10 years. The 2008 work plan does not provide support for the 10-year period. Lastly, the FRACTRAN runs are based on conclusions regarding the nature of the fracture system at the site. Additional refinement and confirmation are needed to ensure that the simulated fracture system is representative of site conditions.

The evaluation of the groundwater data near previous pumping locations is presented in Appendix C. It reported that, in general, the wells positioned within the source area reported increasing contaminant concentrations since the cessation of pumping either at the well or at nearby well. This was attributed to the mobilization of contaminant mass within the vadose zone as the water table rises. The evaluation concluded that the "SSFL sandstone above the water table provides a relatively large capacity to store contaminant mass in the dissolved phase in the residual matrix porewater." This is supported in the profiles of TCE porewater concentrations for several coreholes drilled at the site in source areas which indicate significant TCE concentrations (in excess of 10,000 µg/L) present in the vadose zone.

Several technologies were evaluated for potential applicability as source area remediation interim measures. The evaluation was essentially a cursory literature review. Based on the evaluation, Boeing opposed several remedial technologies as ineffective and/or as not implementable in short term. The GSU recommends that further evaluation of several of these technologies be completed, including potential scaled pilot tests. Hydraulic containment, however, was identified in the work plan as implementable, although there was concern stated regarding the difficulties in design and effective implementation.

In the end, the 2008 work plan concluded "no source area remediation interim measures are recommended for implementation at the SSFL at this time." Further, the work plan stated "it is also acknowledged that there may be non-technical considerations for the implementation of source area remediation activities as an interim measures at the SSFL. Therefore, and in the interest of compliance with the requirements of the DTSC's November 19, 2007 letter, a source zone mass removal remediation study that could be implemented as an interim measure at the direction of DTSC is described below." The work plan, therefore proposed a "Source Area Mass Removal Study Interim Measures." Again, this is an interim measures not a corrective action study so the term "study" should be omitted in reference to implementation of IMs. The work plan proposed IMs at four wells: RD-04, RD-46A, RD-49, and WS-09A. The IM consisted of water being extracted during "periodic groundwater extraction events" using a vacuum truck. The work plan excludes 13 additional wells, with reported TCE concentration above 1,000 µg/L, from IMs because they are located in plumes where groundwater characterization studies are currently being or will soon be performed.

Data indicated, and the work plan concurred, that additional contaminant mass enters the groundwater as water levels rise and the overlying contaminated vadose zone becomes saturated. Until a remedy is selected to address the significant volume of contamination within the vadose zone (sources), efforts to control continuing impacts to groundwater from source areas and to minimize the extent of impacts to groundwater flowing through source areas must be implemented. Therefore, it should be clear that regardless of the vague reference to "non-technical considerations" this is reasonable technical justification for the implementation of IMs at this time.

Conclusion:

The GSU does not concur with the approach proposed in the work plan. Groundwater extraction should be initiated at all wells identified in the source areas and at plume fronts where the contaminants may be advancing. Groundwater pumping at these locations will be focused having limited reach and will not affect ongoing investigative activities.

Recommendations:

Specifically, groundwater extraction should be initiated at all groundwater monitoring wells within source zones, defined as any monitoring wells where the reported concentrations of TCE have been 1,000 µg/L or higher and/or any monitoring wells where TCE concentrations and water levels are trending higher since shut-down of groundwater extraction wells. The proposed groundwater characterization activities, cited in the work plan, and approved by DTSC should not be impacted by the minimal pumping proposed at these locations. The GSU does concur that pumping rate should be set at levels that maximize contaminant extraction but also prevents continued water level rises that would saturate potentially contaminated vadose zones. Groundwater extraction at these wells should be done through the use of dedicated groundwater extraction pumps with automatic switches controlled by water levels in the well. The extracted water should be conveyed via double-walled piping to the permitted groundwater treatment system. The use of vacuum-trucks during "periodic events" is not recommended.

The objective of the groundwater extraction is two-fold; to prevent contaminated vadose zone from becoming saturated and provide capture of contaminated groundwater moving through the source zones.

Plume Front Containment

Groundwater data indicate the advancement of a solvent plume(s) offsite to the northeast of the site and an increase in solvent concentrations in the southernmost groundwater extraction (WS-9A) at the buffer zone since the facility ceased groundwater extraction at all other extraction wells. Groundwater extraction should be initiated at each location.

Reporting

The GSU recommends that the facility submit to DTSC a work plan to conduct IMs in accordance with the comments of this memorandum within 90 days. The work plan should include a schedule where commencement of pumping activities begins within 60 days of DTSC approval.

The GSU also recommends that the facility submitted quarterly progress reports to DTSC with data on the operation and performance of the IMs.

If you have any questions, please contact me at 714 484-5424.

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CP: Completed
HS: Host Scan
HF: Host Fax
RE: Resend
MP: Multi-Poll
RM: Receive to Memory
HP: Host Print
HR: Host Receive
PD: Polled by Remote
PG: Polling a Remote
DR: Document Removed
FO: Forced Output
FM: Forward Mailbox Doc.
MB: Receive to Mailbox
PI: Power Interruption
TM: Terminated by user
WT: Waiting Transfer
WS: Waiting Send

APPENDIX B

Table 1
List of Known Chemicals in Groundwater
Santa Susana Field Laboratory

The following list is inclusive of all chemicals detected in at least a single groundwater sample collected from wells at or near the SSFL (regardless of concentration). These chemicals are not necessarily related to releases from the SSFL and include those that occur naturally and are artifacts of work performed in analytical laboratories.

1,1,1-trichloroethane
1,1,2--trichloroethane
1,2-dichloroethane
1,1-dichloroethane
chloroethane
1,4-dioxane

tetrachloroethylene
trichloroethylene
cis-1,2-dichloroethylene
trans-1,2-dichloroethylene
1,1-dichloroethylene
vinyl chloride

n-nitrosodimethylamine
1,2,3-trichloropropane
1,3-dinitrobenzene
nitrobenzene
nitrate
perchlorate
petroleum hydrocarbons (various ranges)
benzene
ethylbenzene
m-, p-, and o-xylenes
toluene
acetone
ammonia as nitrogen
fluoride

carbon tetrachloride
methylene chloride
chloroform
chloromethane

trichlorotrifluoroethane (Freon 113)
trichlorofluoromethane (Freon 11)
dichlorodifluoromethane (Freon 12)

poly-chlorinated di-benzo dioxins/furans
formaldehyde

cadmium
chromium
copper
lead
manganese
nickel
silver
thallium
zinc

APPENDIX C

EVALUATION OF MONITORING RESULTS OBTAINED DURING THE CESSATION OF GROUNDWATER EXTRACTION AT THE SSFL

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CA

August 2006

Prepared for:

The Boeing Company
National Aeronautics and Space Administration
United States Department of Energy

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FIGURES

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LIST OF ABBREVIATIONS

Boeing	The Boeing Company
Cal/EPA	California Environmental Protection Agency
cDCE	cis-1,2-dichloroethene
COC	constituent of concern
DHS	Department of Health Services
DOE	United States Department of Energy
DTSC	Department of Toxic Substances Control
FSDF	Former Sodium Disposal Facility
NASA	National Aeronautics and Space Administration
NDMA	n-nitrosodimethylamine
NL	notification limit
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SSFL	Santa Susana Field Laboratory
TCE	trichloroethene
ug/L	micrograms per liter
VOC	volatile organic compound

1.0 INTRODUCTION

This report presents an evaluation of groundwater plume stability in the Chatsworth formation operable unit[1] at the Santa Susana Field Laboratory (SSFL) using groundwater monitoring data collected since the year 2000. Environmental investigations have shown that the Chatsworth formation beneath much of the SSFL has been impacted by historical releases of various chemicals from operational activities, with trichloroethene (TCE) being the compound detected at the highest concentration and with the greatest frequency. The SSFL is jointly owned by The Boeing Company (Boeing) and the federal government (administered by the National Aeronautics and Space Administration [NASA]) and is operated by Boeing. The U.S. Department of Energy (DOE) used a portion of the SSFL. However, there are no longer any active DOE operations and its facilities are undergoing decommissioning and demolition. The SSFL is located in the southeast corner of Ventura County, 29 miles northwest of downtown Los Angeles, California. The location of the SSFL and its surrounding vicinity is shown on Figure 1.

The field investigations of the Chatsworth formation since October, 2000 have been following work plans that have been approved by the California Environmental Protection Agency (Cal EPA), Department of Toxic Substances Control (DTSC). The work plan submitted and approved in 2000 required the temporary cessation of groundwater extraction from wells at the SSFL (Montgomery Watson, 2000). The concept presented in the 2000 work plan was to cease groundwater extraction in wells located within the groundwater unit being investigated (e.g., groundwater unit 1A) and from extraction wells located within adjacent groundwater units (e.g., from groundwater units 1B and 2 when investigations are being performed in groundwater unit 1A). In the 2000 work plan, five groundwater units were identified and their locations at the SSFL are shown on Figure 2. To maintain compliance with Boeing's and NASA's Post Closure Permits (DTSC, 1995a and 1995b), the water quality monitoring program was continued in accordance with the sampling frequency and monitoring parameters in the permit. Selected

[1] The Chatsworth formation operable unit consists predominantly of fractured sandstone and includes both the unsaturated and saturated portions of the unweathered bedrock that lies beneath the SSFL.

wells were also monitored periodically for the Constituents of Concern (COCs) listed in Table 3 of the Post Closure Permits (DTSC, 1995a and 1995b) to ensure the following:

- That there would be adequate monitoring of concentration trends of TCE and other COCs dissolved in the Chatsworth formation groundwater during cessation of the groundwater extraction systems, and
- That the plumes do not migrate beyond their current limits while the extraction wells are not operating.

2.0 GROUNDWATER EXTRACTION SYSTEM SHUTDOWN AND MONITORING

There are six general locations where permitted groundwater extraction systems have operated at the SSFL and three locations where interim systems have operated. Table 1 summarizes the treatment systems, connected extraction wells, corresponding groundwater units, and the month and year when the pumps in the extraction wells were turned off. Well locations, and groundwater units as defined in 2000 are shown on Figure 3. The groundwater units, and the extents and configurations of plumes are represented somewhat differently now than in October 2000, primarily because of the improved understanding of the geology of the site gained through the characterization work performed since that time. For the purpose of this evaluation, the year 2000 plume configurations were used to provide a consistent basis for comparison of conditions before and after the cessation of groundwater pumping (Figure 3).

Table 2 has been reproduced directly from the October 2000 work plan, and lists the wells selected for monitoring by groundwater unit and source area (MWH, 2000). The wells in this table were also designated as either source area wells (wells located at or near a known or suspected TCE input location), or dissolved plume wells (wells located within or on the periphery of a plume, but not proximal to a known or suspected TCE input location).

2.1 Overview of Work Performed

The following sections discuss the sequence and timing of the shut-down of the groundwater extraction wells and are followed by a discussion of the additional groundwater sampling that was performed following extraction well shutdown. The shutdown sequence of the groundwater extraction wells is graphically depicted on Figure 4.

RD-1 in groundwater unit 1B was the first groundwater extraction well to be turned off and this occurred in August of 2000. Groundwater extraction was stopped at RD-2 in September of 2000 and in WS-5 in October of 2000. These wells were the first to be turned off because characterization activities were initiated in October of 2000 near the Canyon and Bowl test stands. Wells RD-1 and WS-5 are located within or adjacent to the Canyon Resource

Conservation and Recovery Act (RCRA) facility investigation (RFI) site, while well RD-2 is located within the Bowl RFI site. Extraction wells were shut off in adjacent groundwater unit 2 as follows: RD-4 was turned off in December 2000, followed by WS-6 in March of 2001 and WS-9 in July 2002. The pump in extraction well RD-9 in groundwater unit 3 was also turned off in December 2000.

Characterization work was initiated at the Former Sodium Disposal Facility (FSDF) investigation area in early 2002. Groundwater extraction wells in groundwater unit 3 were turned off prior to the initiation of this work. RD-21 at the FSDF was turned off in April 2000, followed by the shutdown of HAR-7 and HAR-18 in adjacent groundwater unit 4 in November 2002. Groundwater extraction was stopped at HAR-17, also located in groundwater unit 4, in February of 2003.

2.2 Water Quality Sampling

Groundwater samples were collected and analyzed for volatile organic compounds (VOCs) and COCs at an enhanced frequency for a number of groundwater monitoring wells in close accordance with the October, 2000 work plan (MWH, 2000). A summary of the samples that were collected and analyzed for VOCs is provided in Table 3, and the COC sample summary is provided in Table 4.

2.3 Discussion of Water Level Monitoring and Water Quality Sampling Results

Recovery of water levels in both extraction and monitoring wells has been monitored through the frequent collection of depth to water measurements. The changes in water levels from the time the groundwater pumps were turned off through the first quarter of 2006 are summarized on Table 5. Changes in water levels at selected wells are also presented on hydrographs that are included in Appendix A, which provides data sheets for most monitoring wells of interest. The hydrographs are only one of the elements of the monitoring well data sheets that are presented in this appendix. The monitoring well data sheets also include information on the changes in concentrations over time of halogenated ethanes, ethenes and methanes; well construction details and the stratigraphic position of each well; and a data box of other pertinent information associated with either sampling results or the operation of the well.

The change in the water table surface can also be seen by comparing the water table surface contour map from historical quarterly groundwater monitoring reports that present this information. As a means of comparison, the water table surface map from the second quarter of 2000 (i.e., prior to the shutdown of groundwater extraction wells) and from the first quarter of 2006 are provided in Appendix B.

The evaluation of the water quality sampling results associated with the shut down of the groundwater extraction systems uses TCE as the indictor chemical to assess changes in concentration over time. As noted earlier in this report, TCE is the chemical that has been found most frequently in Chatsworth formation groundwater and at the highest concentration. A detailed discussion of the cis-1,2-dichloroethene (cDCE) monitoring results is also provided, as cDCE has been determined to be a biologically-mediated transformation product of TCE in the Chatsworth formation groundwater (Pierce, 2005 and Freedman and Darlington, 2006). Results of monitoring for other COCs of interest, namely perchlorate, 1,4-dioxane, and n-nitrosodimethylamine, (NDMA) are also discussed.

TCE concentration data are summarized on Table 6. It is worthy to note that Table 6 contains an evaluation of TCE concentration changes in more wells than those listed in the 2000 work plan (i.e., those listed in Table 2). These wells were added to the analysis to better evaluate if the TCE plumes were expanding as a result of the shutdown of the extraction wells. Wells designated as source area wells in Table 2 are also identified as such in Table 6. Wells designated as dissolved plume wells in Table 2 and wells added to the analysis for completeness are identified in Table 6 as either plume interior wells (wells located within the central portion of a plume) or plume boundary wells (wells located near or beyond a plume boundary). Wells with a TCE or cDCE concentration greater than 5 ug/L prior to the cessation of pumping were designated as plume interior wells, while those with concentrations less than 5 ug/L or that had no detections prior to pumping cessation were designated as plume boundary wells. It is also important to note that these designations cannot be made based on a well's location relative to the plumes as they are represented on a two-dimensional plan view map. For example, a well that in plan view appears to be located within a source area may have an open interval that is beyond the plume boundary in vertical profile. Furthermore, the year 2000 plume contours and boundaries shown are for TCE, and may not coincide exactly with the contours and boundaries for cDCE in all cases.

The concentrations shown on Table 6 were color-coded according to a series of specified ranges to allow the reader to more readily observe trends in the TCE concentrations over time and relative to the timing of cessation of groundwater pumping from nearby extraction wells. Changes in TCE concentrations and groundwater elevations over the complete history of sampling results for selected wells are shown on the individual well data sheets provided in Appendix A. The data summarized in Table 6 are also depicted on four site maps provided as Figures 5, 7, 9 and 11.

A similar analysis was conducted for cDCE, the results of which are provided on Table 7. Changes in cDCE concentrations and groundwater elevations over the complete history of sampling results for selected wells are shown on the individual well data sheets provided in Appendix A. The data summarized in Table 7 are also depicted on four site maps provided as Figures 6, 8, 10 and 12.

Summaries of sampling and analysis results for perchlorate, 1,4-dioxane and NDMA are presented in Tables 8, 9 and 10, respectively.

A discussion of the observed changes in water levels, and in TCE and cDCE concentrations is presented below for each groundwater unit.

2.3.1 Groundwater Unit 1B

Canyon Plume
Extraction Well RD-1 and Monitoring Well RD-10

The groundwater elevation in RD-1 rose about 99 feet from the time that the pump was turned off at RD-1 in August of 2000 through the first quarter of 2006. The groundwater elevation in monitoring well RD-10 rose about 42 feet during the same period. The positions of the wells and the changes in water levels are shown on Figures 5 and 6 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

RD-1 is a source area well (Table 2), and the concentrations of both TCE and cDCE increased after pumping ceased and the water level began to recover. RD-10 is in the interior of the plume and showed no appreciable changes in either TCE or cDCE concentrations. Boundary well RD-47 exhibited no appreciable changes in TCE or cDCE concentrations, and neither TCE nor cDCE was detected in any of the other plume boundary wells as shown on Tables 6 and 7, respectively, and Figures 5 and 6, respectively.

The results of COC analyses performed on samples from RD-1 show that with only one exception, perchlorate was not detected. 1,4-dioxane was occasionally detected at concentrations below the California Department of Health Services (DHS) drinking water notification level (NL) of 3 micrograms per liter (ug/L), and NDMA was present at concentrations averaging about 0.03 ug/L, which is above the NL of 0.01 ug/L. The results of COC analyses performed on samples from RD-10 show perchlorate to be present at concentrations above the NL of 6 ug/L, and 1,4-dioxane to be present at concentrations below the NL of 3 ug/L. NDMA was not detected in RD-10. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

RD-10 lies within the Happy Valley perchlorate source area. The increasing concentrations of perchlorate after pumping ceased at RD-1 and water levels began to recover is likely caused by the rising water table encountering additional perchlorate-impacted matrix that had been dewatered by pumping at RD-1. Note that the relatively high residual water saturation of about 70% (on average) in SSFL sandstone above the water table provides a relatively large capacity to store contaminant mass in the dissolved phase in the residual matrix porewater, and where chemical-specific properties exhibit such behavior, in the sorbed and vapor phases within the bedrock dewatered by pumping. The higher concentrations observed from second quarter 2002 through second quarter 2004 are likely the result of analyzing composite samples from multiple ports of a FLUTe multilevel system that was installed in RD-10 during that period. Perchlorate concentrations detected in samples from RD-10 after removal of the FLUTe system returned to values below 100 ug/L as shown on Table 8.

Canyon Plume
Extraction Well WS-5

The groundwater elevation in WS-5[2] rose about 202 feet from the time that the pump was turned off at WS-5 in October of 2000 through the first quarter of 2006. The groundwater elevation in monitoring well RD-45C rose about 330 feet during the same period. The positions of the wells and the changes in water levels are shown on Figures 5 and 6 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

Concentrations of both TCE and cDCE in samples from WS-5 decreased after pumping ceased and the water level began to recover. Though WS-5 was designated a source area well in the 2000 work plan (Table 2), subsequent analysis of available data showed that the saturated portion of WS-5 is on the northwest side of the Shear Zone within groundwater unit 2, and most directly communicates hydraulically with well RD-45C (Figure 3). As such, it appears that the groundwater in WS-5 is not representative of the Canyon source area. TCE and cDCE were not detected in samples from RD-45C.

Perchlorate was not detected in samples collected from WS-5 and analyzed for COCs during the study period, and 1,4-dioxane concentrations have averaged about 2 ug/L, slightly below the NL of 3 ug/L. NDMA was detected only rarely at concentrations below the NL of 0.01 ug/L. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

Bowl Plume
Extraction well RD-2 and Monitoring Well RD-44

The groundwater elevation in RD-2 rose about 68 feet from the time that the pump was turned off at RD-2 in September of 2000 through the first quarter of 2006. The groundwater elevation

[2] In the 2000 work plan (Montgomery Watson), the position of extraction well WS-5 was placed in groundwater unit 1B. However, subsequent analysis of available data (see MWH, 2002) showed that the position of the saturated portions of WS-5 are within groundwater unit 2, due to the presence of a fault referred to as the Shear Zone. This analysis also showed that WS-5 was most directly connected to monitoring well RD-45C. As such, information on both water level and chemical concentration changes in RD-45C are also presented and discussed.

in monitoring well RD-44 rose about 21 feet during the same period. The positions of the wells and the changes in water levels are shown on Figures 5 and 6 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

RD-2 is a source area well (Table 2), and the concentrations of both TCE and cDCE increased after pumping ceased and groundwater recovery began. Concentrations of both TCE and cDCE remained below the method reporting limit in plume boundary well RD-44, and neither TCE nor cDCE was detected in the other plume boundary wells as shown in Tables 6 and 7, respectively, and Figures 5 and 6, respectively.

The results of COC sampling and analysis show that perchlorate was not detected in either RD-2 or RD-44. 1,4-dioxane was detected in RD-44 on only two occasions, and the single detection of NDMA in RD-44 was not confirmed or repeatable. 1,4-dioxane was generally detected in samples collected from RD-2 at concentrations below the NL of 3 ug/L, and NDMA was detected periodically at concentrations below the NL of 0.01 ug/L. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

2.3.2 Groundwater Unit 2

Alfa/Bravo Plume
Extraction well WS-6 and monitoring wells RD-49A, RD-49B and RD-49C

The groundwater elevation rose about 109 feet in WS-6 from the time that the pump was turned off at WS-6 in March of 2001 through the first quarter of 2006. The groundwater elevation fell about one foot in monitoring well RD-49A, and rose about 28 feet and 76 feet in wells RD-49B and RD-49C, respectively, during the same period. The positions of the wells and the changes in water levels are shown on Figures 7 and 8 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

WS-6 was designated a source area well in the 2000 work plan (Table 2), but the TCE and cDCE concentration trends indicate that this well is more likely outside of the source area but within the plume interior. WS-6 exhibited no appreciable change in cDCE concentration, and the TCE concentration decreased after pumping ceased and the water level began to recover. Monitoring well RD-49A is a source area well (Table 2), and the concentrations of both TCE and cDCE slightly increased after pumping ceased, though the groundwater elevation in RD-49A did not exhibit a recovery trend paralleling that of WS-6 after pumping cessation (Appendix A). RD-49B is within the plume interior in vertical profile, and exhibited slight increases in TCE and cDCE concentrations after pumping ceased at WS-6. RD-49C is also within the plume interior in vertical profile and has the deepest open interval of this well cluster (Appendix A). RD-49C exhibited no appreciable change in cDCE concentration, and a slight decrease in TCE concentration after pumping ceased at WS-6. This vertical well cluster also showed consistently decreasing concentrations with depth (i.e., from A to B to C). HAR-21, another plume interior well, exhibited no appreciable changes in TCE or cDCE concentrations. The plume boundary wells showed no appreciable changes in TCE or cDCE concentrations, or no detections as shown in Tables 6 and 7, respectively, and Figures 7 and 8, respectively.

Perchlorate was not detected in any of the wells sampled and analyzed for COCs. 1,4-dioxane was periodically detected in these wells at concentrations generally below the NL of 3 ug/L. NDMA was detected occasionally in WS-6 and RD-49A at concentrations below the NL of 0.01 ug/L. NDMA was consistently detected at concentrations above the NL in RD-49B and RD-49C, with consistently lower concentrations in deeper well RD-49C. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

Alfa/Bravo Plume
Extraction wells RD-4 and WS-9 and monitoring well HAR-20

The groundwater elevation in RD-4 rose about 103 feet from the time that the pump was turned off at RD-4 in December of 2000 through the first quarter of 2006, and rose about 75 feet in WS-9 from the time that its pump was turned off in July 2002 to the first quarter of 2006. The groundwater elevation in monitoring well HAR-20 rose to about 33 feet above the bottom of the well during the same period, but the total rise at this location is unknown because HAR-20 was dry at the time that the pump in well WS-9 was turned off. The positions of the wells and the changes in water levels are shown on Figures 7 and 8 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

RD-4 and WS-9 are source area wells (Table 2), and HAR-20 is located within the plume interior. Concentrations of TCE and cDCE increased in all three of these wells after pumping ceased and the water level began to recover. Plume interior well HAR-21 exhibited no appreciable changes in TCE or cDCE concentrations. The plume boundary wells showed no appreciable changes in TCE or cDCE concentrations, or no detections as shown in Tables 6 and 7, respectively, and Figures 7 and 8, respectively.

Perchlorate was not detected in any of the wells sampled and analyzed for COCs. 1,4-dioxane was sporadically detected in wells RD-4 and WS-9 at concentrations below the NL of 3 ug/L. 1,4-dioxane was consistently detected at concentrations above the NL in well HAR-20. NDMA was occasionally detected in well RD-4 at concentrations above the NL of 0.01 ug/L, and in WS-9 at concentrations below the NL. NDMA was consistently detected in well HAR-20, more often at concentrations above the NL. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

2.3.3 Groundwater Unit 3

ELV/Bldg 204 Plume
Extraction well RD-9 and Monitoring Wells RD-51A, -B and -C

The groundwater elevation rose about 98 feet in RD-9 from the time that its pump was turned off in December of 2000 through the first quarter of 2006. The groundwater elevation in monitoring wells RD-51B and RD-51C rose about 65 feet and 92 feet, respectively, during the same period. Monitoring results from well RD-51A showed it either to be dry or to contain insufficient water for sampling throughout this time period. The positions of the wells and the changes in water levels are shown on Figures 7 and 8 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

RD-9 is a source area well (Table 2) that exhibited no appreciable change in cDCE concentration and a slight increase in TCE concentration after pumping ceased and the water level began to recover. Well RD-51B is within the plume interior in vertical profile, and showed slight increases in TCE and cDCE concentrations after pumping ceased at RD-9. Plume boundary well RD-51C (vertical plume boundary) showed no detections of TCE or cDCE after pumping ceased at RD-9. The other plume boundary wells showed no detections of either TCE or cDCE throughout the monitoring period as shown in Tables 6 and 7, respectively, and Figures 7 and 8, respectively.

Perchlorate was not detected in any of the wells sampled and analyzed for COCs. 1,4-dioxane was detected once in extraction well RD-9 and monitoring wells RD-51B and RD-51C at concentrations below the NL of 3 ug/L. NDMA was detected in only one sample from these wells at an estimated concentration below the method reporting limit and below the NL of 0.01 ug/L. None of these detections was confirmed in subsequent samples. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

FSDF Plume
Extraction well RD-21 and Monitoring Wells RD-7, RD-33A, RD-54A and –B, and RD-65

The pump was turned off at source area extraction well RD-21 in April of 2000. Net changes in groundwater elevation between April, 2000 and the first quarter of 2006 in RD-21 and in monitoring wells in this area could not be assessed because of the effects of a pumping test that was performed in the FSDF area during this period (the RD-54B pumping test). The positions of the wells are shown on Figures 9 and 10 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

Source area extraction well RD-21, plume interior monitoring wells RD-7, RD-33A, RD-54A and RD-65 exhibited TCE and cDCE concentration changes that are likely related to the initiation of sampling from a single port of the FLUTe multi-level systems that were installed in these wells (the installations were completed between April, 2002 and February, 2003). Trends in the discrete-interval data from the FLUTe system sampling cannot be directly correlated with the previous open-hole data. The pumping test performed at RD-54B further complicates the analysis of trends within the interior of this plume. Of greater importance, the plume boundary wells, whether they were retrofitted with FLUTe multilevel systems or not, showed no appreciable changes in TCE or cDCE concentrations, or no detections as shown in Tables 6 and 7, respectively, and Figures 9 and 10, respectively.

Only very limited COC sampling and analysis in the designated FSDF area wells was performed because of ongoing work in this area that included a pumping test and the installation of FLUTe multilevel systems in most of these wells. It was anticipated that because of this work, it would not be possible to evaluate trends in any COC data collected; this outcome is demonstrated by the TCE and cDCE results described above. The complete analytical histories for perchlorate, 1,4-dioxane, and NDMA for the designated FSDF area wells are tabulated in Appendix C. Perchlorate has been consistently detected in wells RD-7, RD-21, RD-54A, and RD-65 at concentrations above the NL of 6 ug/L. 1,4-dioxane has been consistently detected in samples from wells RD-54A and RD-65 at concentrations above the NL of 3 ug/L. NDMA has not been detected in any of the wells in this area, but there have been no NDMA analyses performed on samples from these wells with method detection limits below the NL of 0.01 ug/L.

RMHF Plume
Extraction well RD-63 and monitoring wells RD-34A and RD-34B

The pump in extraction well RD-63 continued to be operated through 2002 and intermittently from 2003 to 2006 (Figure 4). The pump was not turned off to facilitate the performance of CFOU field investigations, and thus did not become a part of the pumping cessation study. However, for completeness it is noted that source area extraction well RD-63 and plume interior well RD-30 exhibited no appreciable changes in TCE or cDCE concentrations during the study period. The plume boundary wells showed no appreciable changes in TCE or cDCE concentrations, or no detections during the study period as shown in Tables 6 and 7, respectively, and Figures 9 and 10, respectively.

2.3.4 Groundwater Unit 4

Delta/STL-IV Plume
Extraction well HAR-7 and monitoring wells HAR-8, RD-41A and RD-41B

The groundwater elevation rose about 21 feet in HAR-7 from the time that the pump was turned off at HAR-7 in November of 2002 through the first quarter of 2006. The groundwater elevation in monitoring wells HAR-8 and RD-41B rose about 10 feet and 17 feet, respectively, while the groundwater elevation in RD-41A fell about 11 feet during the same period. The positions of the wells and the changes in water levels are shown on Figures 11 and 12 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

HAR-7 is a source area well (Table 2), and the concentrations of both TCE and cDCE decreased after pumping ceased and the water level began to recover, though overall the concentrations remained relatively high. Plume interior wells HAR-8, RD-41A and RD-41B exhibited no appreciable changes in TCE or cDCE concentration with the exception of a slight increase in cDCE concentration at RD-41B after pumping at HAR-7 ceased. The plume boundary wells exhibited no appreciable changes in TCE or cDCE concentrations, or no detections as shown in Tables 6 and 7, respectively, and Figures 11 and 12, respectively.

Perchlorate was not detected in any of the wells sampled and analyzed for COCs. 1,4-dioxane was sporadically detected in these wells at concentrations below the NL of 3 ug/L. NDMA was detected at concentrations above the NL of 0.01 ug/L in HAR-7 and HAR-8. NDMA was occasionally detected at concentrations below the NL in wells RD-41A and RD-41B. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

Delta/STL-IV Plume
Extraction wells HAR-17 and HAR-18, Monitoring Wells RD-55A, RD-55B, RD-58A and RD-58B, and Extraction Well WS-9A

The groundwater elevation rose about 27 feet in HAR-18 from the time that its pump was turned off in November of 2002 through the first quarter of 2006. Groundwater elevations also rose about 42 feet in HAR-17 from February 2003 when its pump was turned off through the first quarter of 2006. The groundwater elevation in monitoring wells RD-55A, RD-55B, RD-58A, and RD-58B rose about 25 feet, 18 feet, 14 feet, and 12 feet, respectively, during the same period. Groundwater continued to be extracted from WS-9A until September of 2005 when the Topanga fire swept through portions of the SSFL and destroyed the groundwater collection and conveyance infrastructure associated with this extraction well. The groundwater elevation in WS-9A rose about 3 feet from the time the pump was turned off in this well through the first quarter of 2006. The positions of the wells and the changes in water levels are shown on Figures 11 and 12 along with corresponding TCE and cDCE concentrations, respectively. These data are also summarized in Tables 6 and 7 for TCE and cDCE, respectively.

HAR-17 and HAR-18 are source area extraction wells (Table 2), both of which exhibited no appreciable change in TCE concentration and a slight increase in cDCE concentration after pumping ceased and the water level began to recover. Plume interior extraction well WS-9A exhibited variable TCE and cDCE concentrations likely associated with the pumping activities at that well. Plume interior monitoring well RD-55A exhibited variable TCE and cDCE concentrations, but with consistently decreasing trends after pumping ceased. Plume interior monitoring well RD-55B exhibited slight increases in TCE and cDCE concentrations after pumping ceased, while plume interior monitoring well RD-58A showed an increase in cDCE concentration, but a slight decrease in TCE concentration. Plume boundary well RD-58B (vertical boundary) exhibited no detections of TCE or cDCE after pumping ceased.

Perchlorate was not detected in any of the wells sampled and analyzed for COCs. 1,4-dioxane was detected at concentrations above the NL of 3 ug/L in extraction wells HAR-17 and HAR-18, and was sporadically detected in the monitoring wells at concentrations below the NL. NDMA was consistently detected at concentrations above the NL of 0.01 ug/L in extraction wells HAR-17 and HAR-18, but was not detected in any of the monitoring wells. These data are summarized in Tables 8, 9 and 10 for perchlorate, 1,4-dioxane and NDMA, respectively.

3.0 RESULTS OF EVALUATION

Without exception, wells near edges of plumes or outside of plumes that before pumping ceased had exhibited TCE and cDCE concentrations of less than 5 ug/L or no detections (i.e. plume boundary wells) exhibited no appreciable concentration changes after pumping ceased. There were 29 such wells included in the evaluation. These results indicate that the studied plume boundaries are nearly stationary within the intervals intercepted by the monitoring wells.

With only one exception (source area well RD-49A), plume interior and source area wells that exhibited increasing TCE or cDCE concentrations after pumping ceased also exhibited a coinciding increase in groundwater elevation. It appears that in nearly all these cases, the increasing concentration trend is likely attributable to the recovering water table encountering additional contaminant mass dissolved in the residual matrix porewater or in sorbed or vapor phases in the bedrock that had been dewatered by the pumping. The relatively high residual water saturation of about 70% (on average) in SSFL sandstone above the water table provides a relatively large capacity to store contaminant mass in the dissolved phase in the residual matrix porewater, and where chemical-specific properties exhibit such behavior, in the sorbed and vapor phases within the bedrock dewatered by pumping. The only exceptions to this explanation are two plume interior "B" wells (RD-41B and RD-55B). These wells have open intervals considerably below the water table and would not be susceptible to concentration increases resulting from the water table rising into additional contaminated matrix (Appendix A). Nevertheless, RD-41B exhibited a slight increase in cDCE concentration (there was no appreciable change in TCE concentration), and RD-55B exhibited slight TCE and cDCE concentration increases. The slight concentration increases in these wells may be the result of minor movement in the plume interior as the water table recovers after pumping cessation, and the natural groundwater flowpaths are reestablished.

Well RD-10 is located in a perchlorate source area, and exhibited an increase in perchlorate concentration as the water table recovered after pumping ceased at nearby extraction well RD-1. This behavior also fits the interpretation of concentrations increasing as a result of a rising water table encountering additional contaminants within the bedrock that had been dewatered by pumping activities.

Extraction wells WS-5 and WS-6 were designated as source area wells in the October 2000 work plan. These two wells exhibited relatively low TCE and cDCE concentrations and showed stable to decreasing concentration trends after pumping ceased and the water table began to recover, suggesting that the saturated intervals of these two wells are not in source areas. In the case of WS-5, this conclusion is further supported by additional insight gained through the analysis of available data which indicates that the saturated portion of WS-5 is on the northwest side of the Shear Zone within groundwater unit 2, and most directly communicates hydraulically with well RD-45C rather than with the Canyon plume wells (MWH, 2002).

Concentration and elevation trends in plume interior and source area wells in the FSDF plume could not be assessed because the sampling methodology changed mid-way through the study period when FLUTe multilevel systems were installed in these wells as part of the CFOU field investigation activities. The discrete-depth groundwater sample results from the FLUTe systems cannot be readily correlated with previous open-hole sample results. The long-term pumping test performed at RD-54B during the study period further complicates any attempt to evaluate trends in contaminant concentrations and groundwater elevation in this area. Nevertheless, the FSDF plume boundary wells, whether retrofitted with FLUTe multilevel systems mid-way through the study period or not, exhibited no appreciable TCE or cDCE concentration changes or no detections throughout the study period.

3.1 SUMMARY OF RESULTS

This evaluation of groundwater elevation and concentration trends in groundwater extraction and monitoring wells indicates that there has not been an appreciable expansion of any plume following the cessation of pumping within the plume. Without exception, the 29 plume boundary wells included in the evaluation showed no appreciable concentration changes or no detections throughout the 6-year study period. These data indicate that the plume boundaries on the flow paths that are intercepted by these monitoring wells are nearly stationary.

This evaluation also shows that relatively large drawdown and hydraulic gradients toward the extraction wells can be induced by pumping at high flow rates over long periods of time. Conversely, it appears that mass removal efficiency (i.e., the mass of contaminants removed per unit volume of groundwater extracted) could be improved by pumping at lower flow rates to limit drawdown and increase the volume of contaminated matrix through which the groundwater flows. However, it should also be noted that the plume boundaries appear to be nearly stationary as indicated by the results of this study, and as expected because of the attenuating effects of matrix diffusion, sorption, dispersion and degradation.

4.0 REFERENCES

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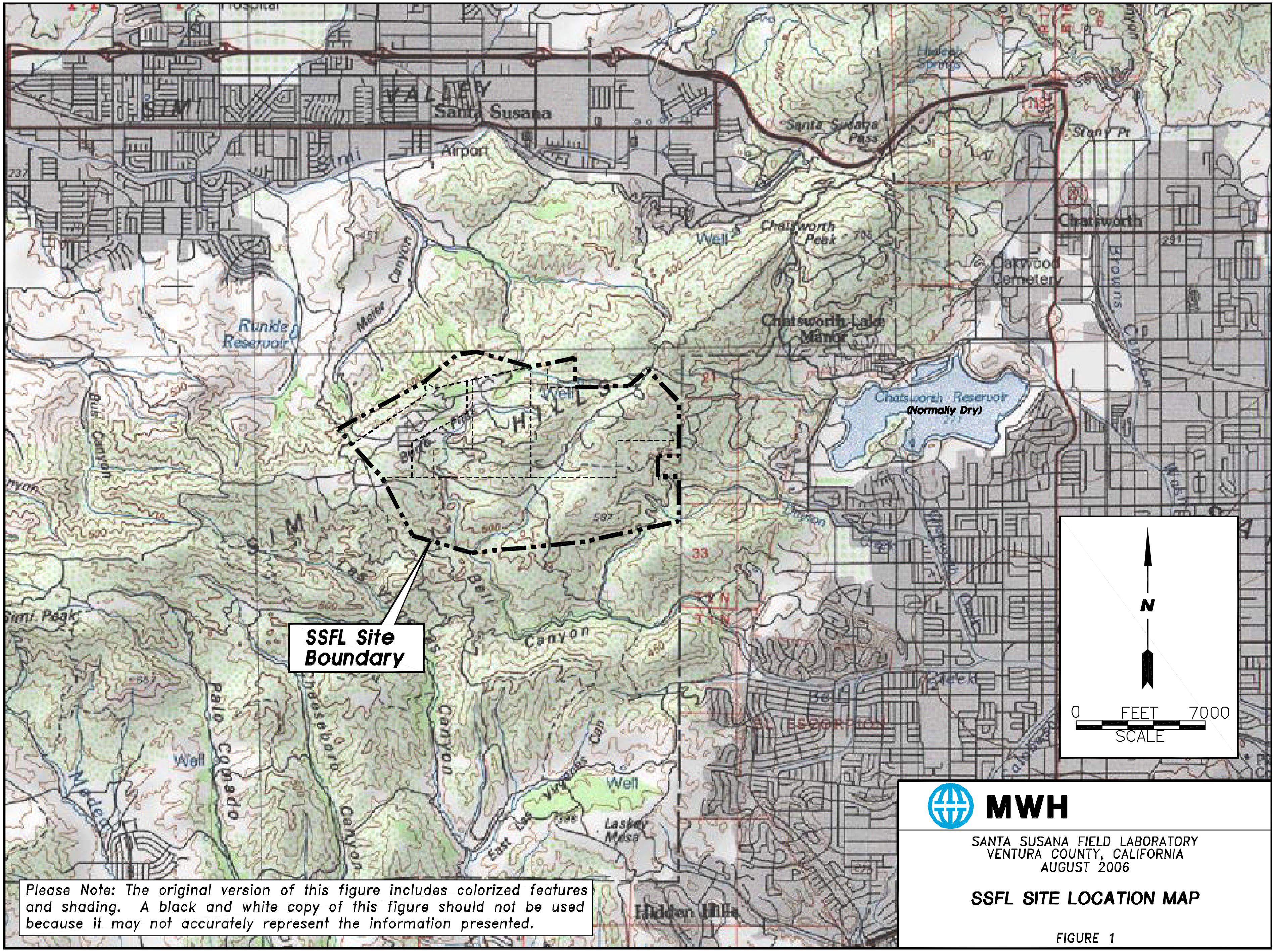
FIGURES

FILE: INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\EX WELL SHUTDOWN\SITE LOCATION 9 07

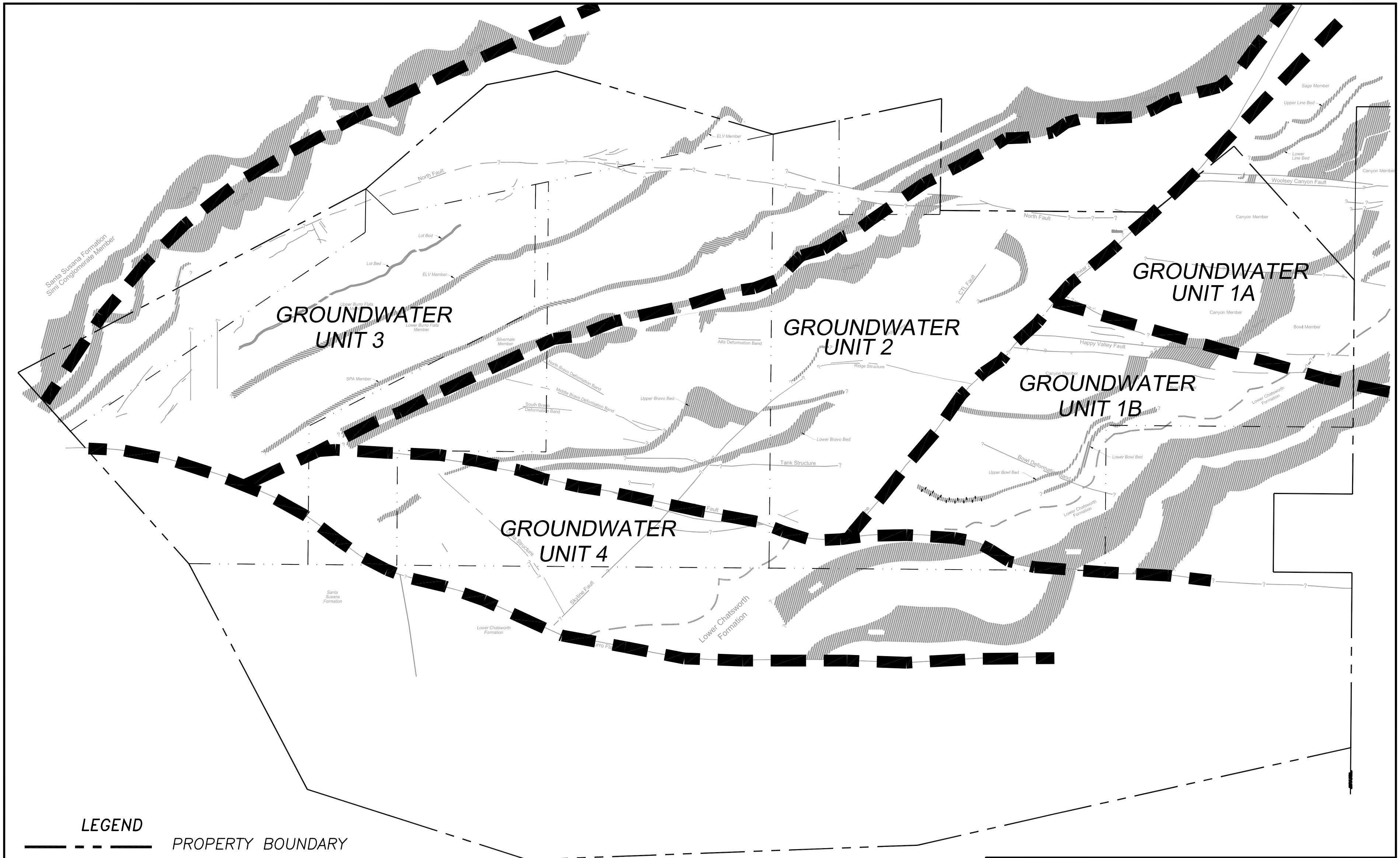
JOB No.



SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

SSFL SITE LOCATION MAP

FIGURE 1



FILE: CADMLUEBKE\BOEING SANTA SUSANA\EX WELL SHUTDOWN\GW UNIT LAYOUT 7 06

JOB No.

LEGEND

- PROPERTY BOUNDARY
- AREA BOUNDARY
- FINER GRAINED UNIT
- FAULT LOCATION
- INFERRED FAULT LOCATION
- APPROXIMATE GROUNDWATER UNIT BOUNDARY

0 FEET 1800
SCALE

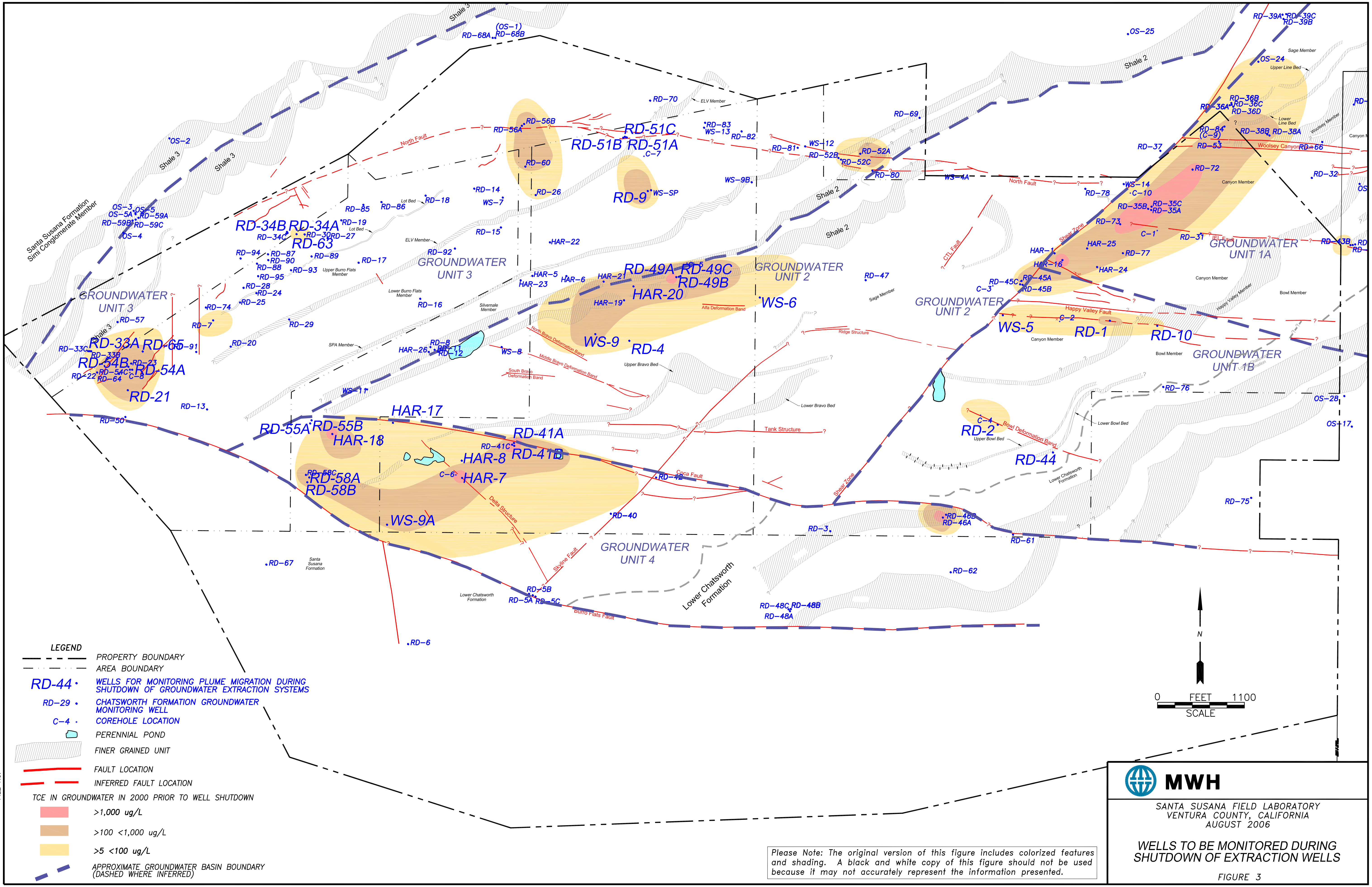
N

MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

GROUNDWATER UNITS OF THE SSFL AS IDENTIFIED IN THE 2000 WORK PLAN

FIGURE 2



GROUNDWATER UNIT 1A
GROUNDWATER UNIT 1B
GROUNDWATER UNIT 2
GROUNDWATER UNIT 3
GROUNDWATER UNIT 4
North Fault
Skyline Fault
Coca Fault
Burro Flats Fault
Happy Valley Fault
Shear Zone
Delta Structure
Lower Chatsworth Formation
Santa Susana Formation
Simi Conglomerate Member
RD-1
RD-2
RD-4
RD-9
RD-10
RD-21
RD-44
RD-63
HAR-7
HAR-8
HAR-17
HAR-18
HAR-20
WS-5
WS-6
WS-9
WS-9A
LEGEND
PROPERTY BOUNDARY
AREA BOUNDARY
RD-44 WELLS FOR MONITORING PLUME MIGRATION DURING SHUTDOWN OF GROUNDWATER EXTRACTION SYSTEMS
RD-29 CHATSWORTH FORMATION GROUNDWATER MONITORING WELL
C-4 COREHOLE LOCATION
PERENNIAL POND
FINER GRAINED UNIT
FAULT LOCATION
INFERRED FAULT LOCATION
TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN
>1,000 ug/L
>100 <1,000 ug/L
>5 <100 ug/L
APPROXIMATE GROUNDWATER BASIN BOUNDARY (DASHED WHERE INFERRED)
N
0 FEET 1100
SCALE
Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.
MWH
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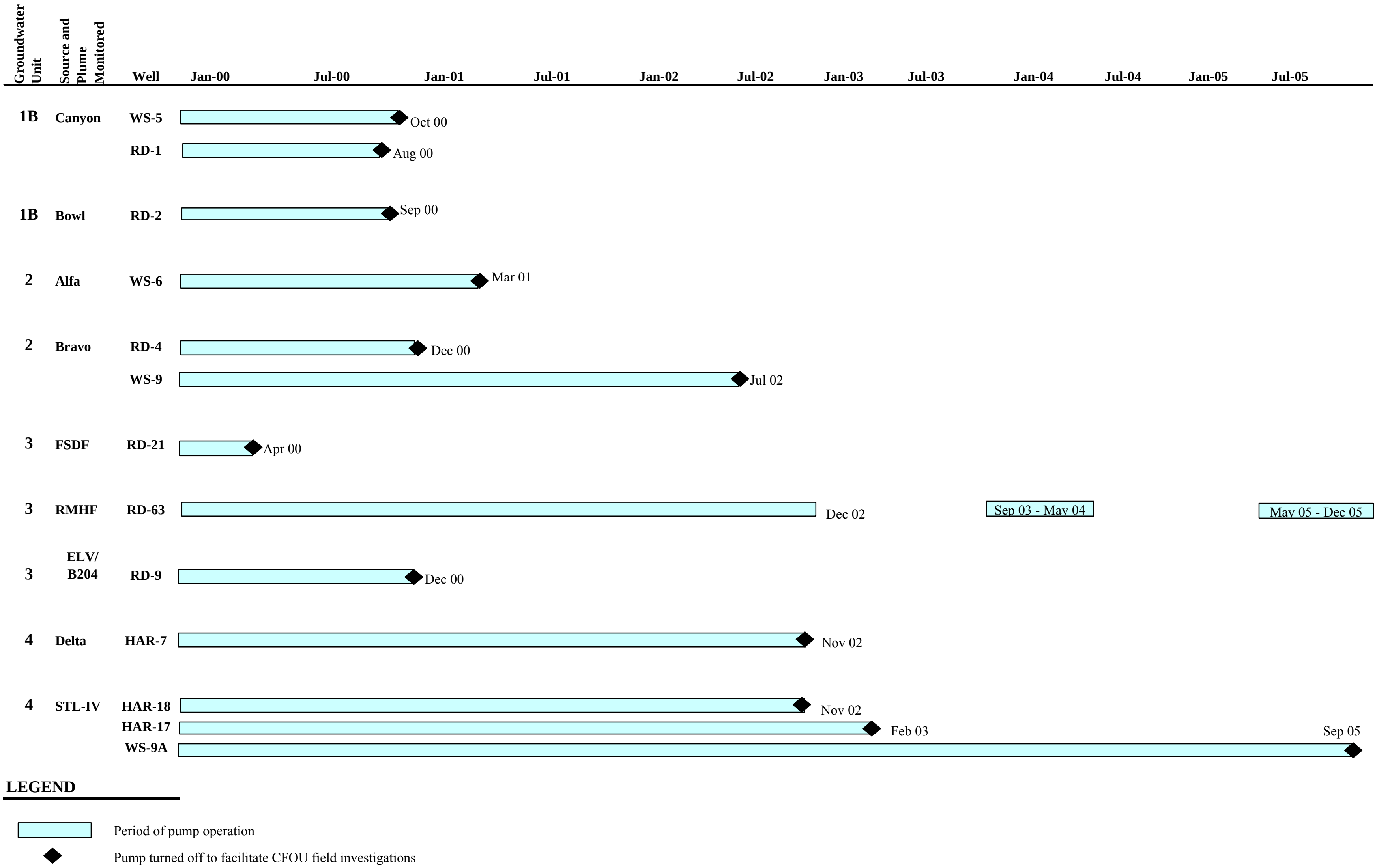
AUGUST 2006
WELLS TO BE MONITORED DURING SHUTDOWN OF EXTRACTION WELLS
FIGURE 3
JOB No. FILE No. CAD MLUEBKE\BOEING\SANTA SUSANA\ex well shutdown\WELLS MONITORED 7 26 06



FILE: CADMLUEBKE\BOEING SANTA SUSANA\EX WELL SHUTDOWN\WELL SHUTDOWN GRAPH

JOB No.

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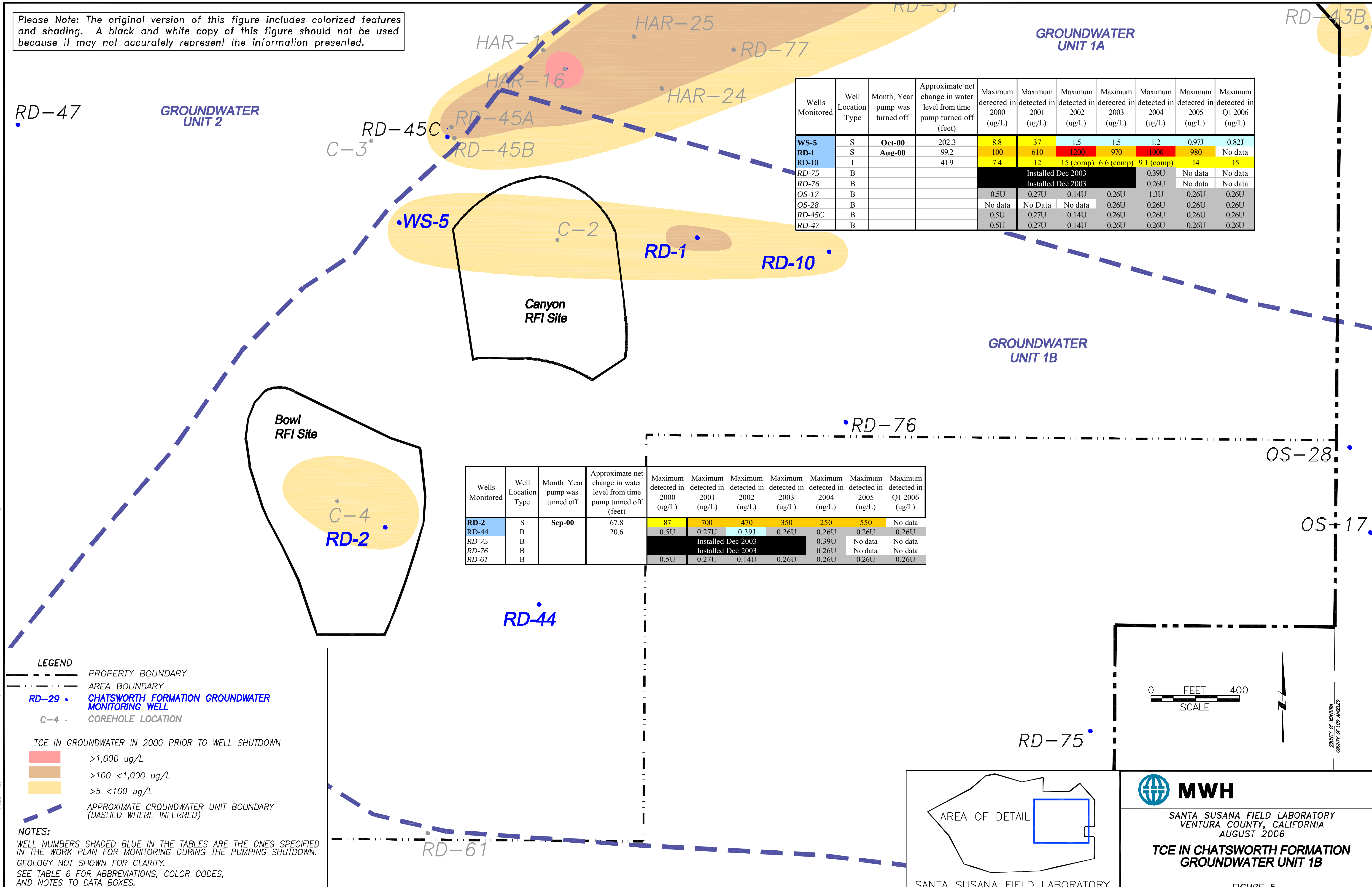
SHUTDOWN SEQUENCE OF EXTRACTION WELLS FOR GROUNDWATER CHARACTERIZATION

FIGURE 4

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.



Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
WS-5	S	**Oct-00**	202.3	8.8	37	1.5	1.5	1.2	0.97J	0.82J
RD-1	S	**Aug-00**	99.2	100	610	1200	970	1000	980	No data
RD-10	I		41.9	7.4	12	15 (comp)	6.6 (comp)	9.1 (comp)	14	15
RD-75	B			Installed Dec 2003				0.39U	No data	No data
RD-76	B			Installed Dec 2003				0.26U	No data	No data
OS-17	B			0.5U	0.27U	0.14U	0.26U	1.3U	0.26U	0.26U
OS-28	B			No data	No Data	No data	0.26U	0.26U	0.26U	0.26U
RD-45C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
RD-47	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-2	S	**Sep-00**	67.8	87	700	470	350	250	550	No data
RD-44	B		20.6	0.5U	0.27U	0.39J	0.26U	0.26U	0.26U	0.26U
RD-75	B			Installed Dec 2003				0.39U	No data	No data
RD-76	B			Installed Dec 2003				0.26U	No data	No data
RD-61	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U

LEGEND

- PROPERTY BOUNDARY
- AREA BOUNDARY
- RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL
- C-4 • COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN

- >1,000 ug/L
- >100 <1,000 ug/L
- >5 <100 ug/L
- APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTES:

WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.
GEOLOGY NOT SHOWN FOR CLARITY.
SEE TABLE 6 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

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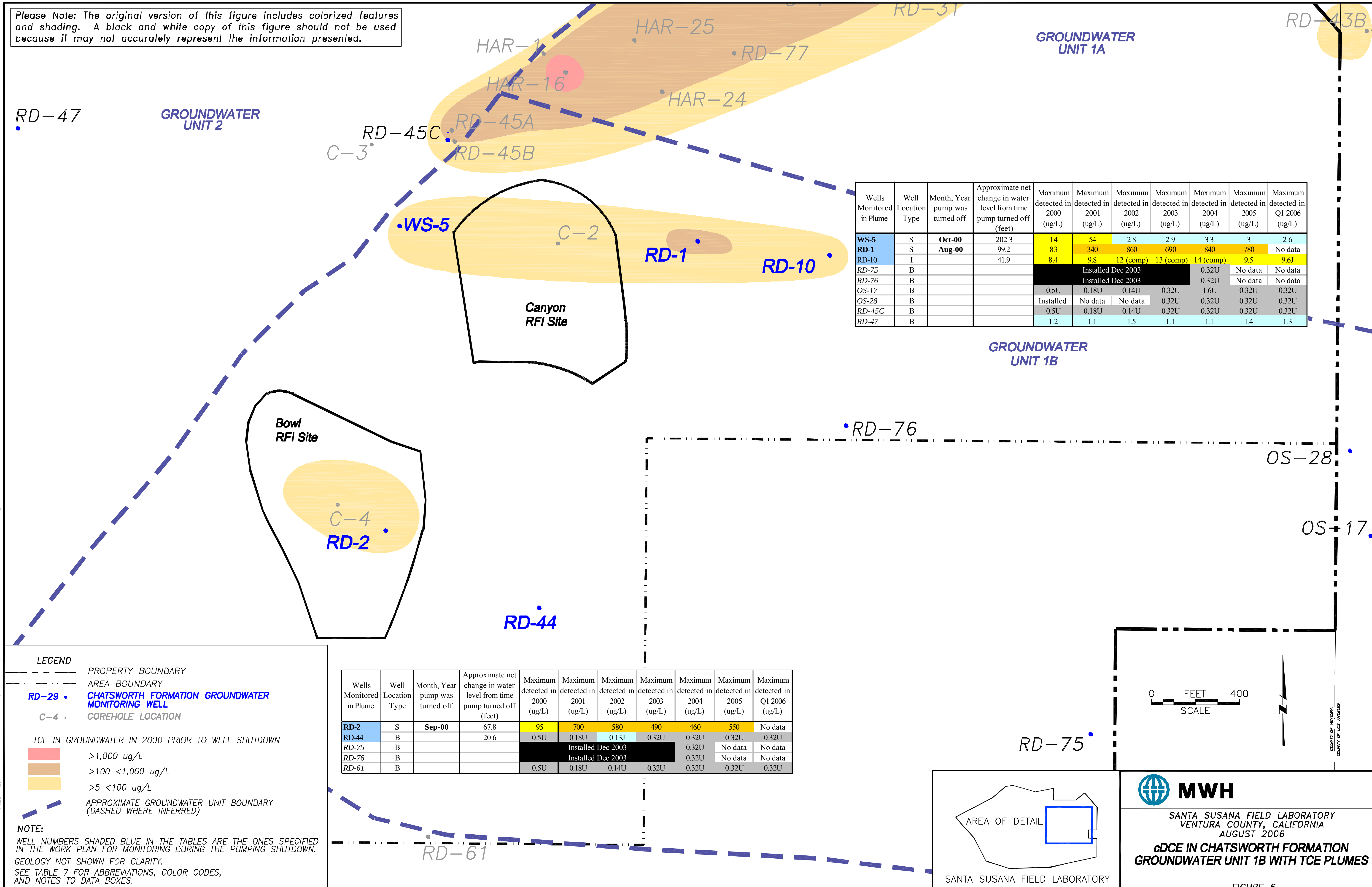
AUGUST 2006

TCE IN CHATSWORTH FORMATION GROUNDWATER UNIT 1B

FIGURE 5

JOB No. FILE No. CAD MLUEBKE\BOEING\SANTA SUSANA\ex well shutdown\gw units 1 08



Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
WS-5	S	**Oct-00**	202.3	14	54	2.8	2.9	3.3	3	2.6
RD-1	S	**Aug-00**	99.2	83	340	860	690	840	780	No data
RD-10	I		41.9	8.4	9.8	12 (comp)	13 (comp)	14 (comp)	9.5	9.6J
RD-75	B			Installed Dec 2003				0.32U	No data	No data
RD-76	B			Installed Dec 2003				0.32U	No data	No data
OS-17	B			0.5U	0.18U	0.14U	0.32U	1.6U	0.32U	0.32U
OS-28	B			Installed	No data	No data	0.32U	0.32U	0.32U	0.32U
RD-45C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-47	B			1.2	1.1	1.5	1.1	1.1	1.4	1.3

Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-2	S	**Sep-00**	67.8	95	700	580	490	460	550	No data
RD-44	B		20.6	0.5U	0.18U	0.13J	0.32U	0.32U	0.32U	0.32U
RD-75	B			Installed Dec 2003				0.32U	No data	No data
RD-76	B			Installed Dec 2003				0.32U	No data	No data
RD-61	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U

NOTE:
WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.
GEOLOGY NOT SHOWN FOR CLARITY.
SEE TABLE 7 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

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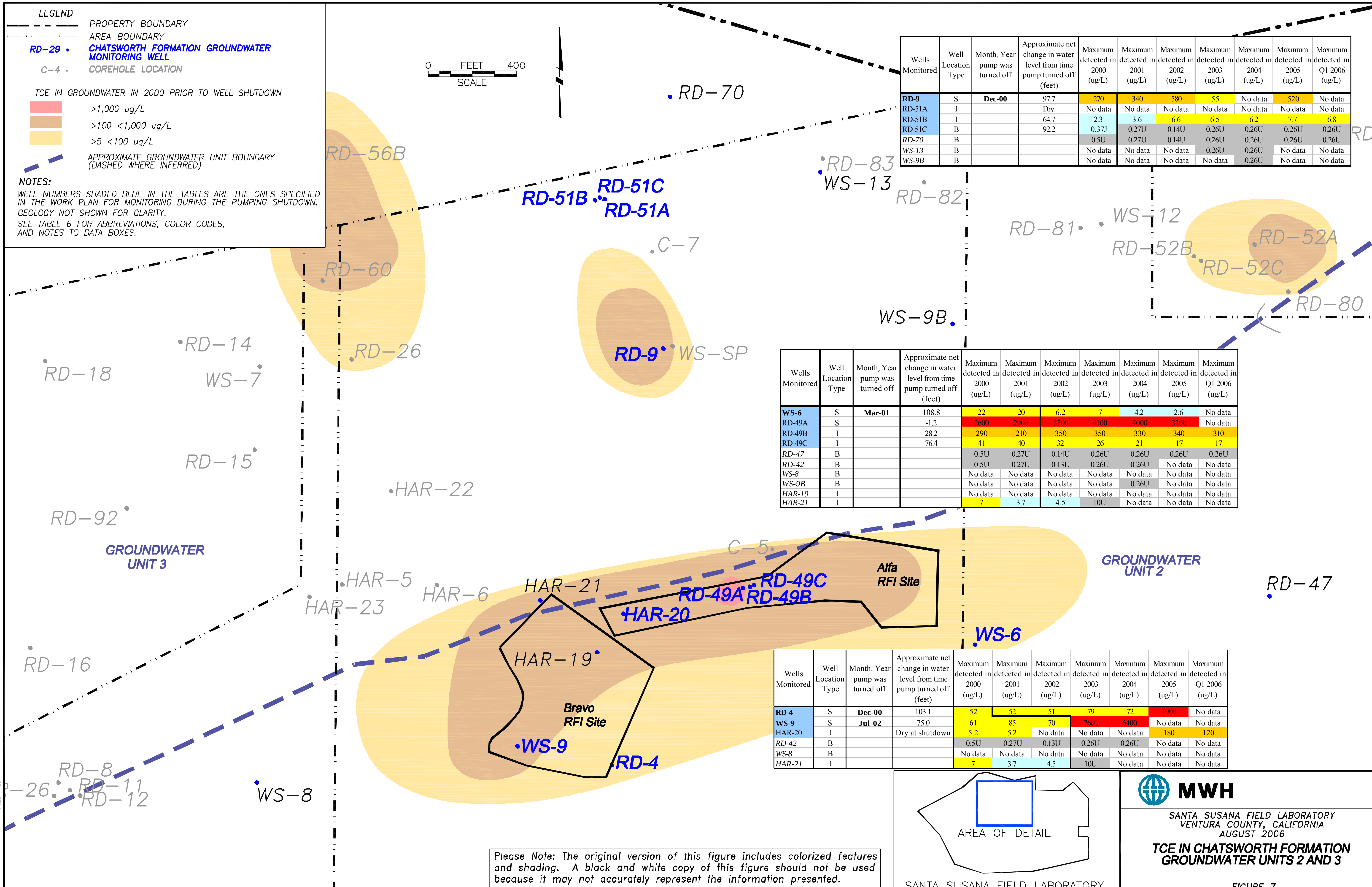
AUGUST 2006

cDCE IN CHATSWORTH FORMATION GROUNDWATER UNIT 1B WITH TCE PLUMES

FIGURE 6

JOB No. ___ FILE No. ___ CAD MLUEBKE\BOEING\SANTA SUSANA\ex well shutdown\gw units 1 08 CIS DCE



LEGEND

PROPERTY BOUNDARY
AREA BOUNDARY
RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL
C-4 • COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN
- >1,000 ug/L
- >100 <1,000 ug/L
- >5 <100 ug/L

APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTES:
WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.
GEOLOGY NOT SHOWN FOR CLARITY.
SEE TABLE 6 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-9	S	**Dec-00**	97.7	270	340	580	55	No data	520	No data
RD-51A	I		Dry	No data	No data	No data	No data	No data	No data	No data
RD-51B	I		64.7	2.3	3.6	6.6	6.5	6.2	7.7	6.8
RD-51C	B		92.2	0.37J	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
RD-70	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
WS-13	B			No data	No data	No data	0.26U	0.26U	No data	No data
WS-9B	B			No data	No data	No data	No data	0.26U	No data	No data

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
WS-6	S	**Mar-01**	108.8	22	20	6.2	7	4.2	2.6	No data
RD-49A	S		-1.2	2600	2900	3500	4100	4000	3100	No data
RD-49B	I		28.2	290	210	350	350	330	340	310
RD-49C	I		76.4	41	40	32	26	21	17	17
RD-47	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data
WS-8	B			No data	No data	No data	No data	No data	No data	No data
WS-9B	B			No data	No data	No data	No data	0.26U	No data	No data
HAR-19	I			No data	No data	No data	No data	No data	No data	No data
HAR-21	I			7	3.7	4.5	10U	No data	No data	No data

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-4	S	**Dec-00**	103.1	52	52	51	79	72	1900	No data
WS-9	S	**Jul-02**	75.0	61	85	70	7600	6400	No data	No data
HAR-20	I		Dry at shutdown	5.2	5.2	No data	No data	No data	180	120
RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data
WS-8	B			No data	No data	No data	No data	No data	No data	No data
HAR-21	I			7	3.7	4.5	10U	No data	No data	No data

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

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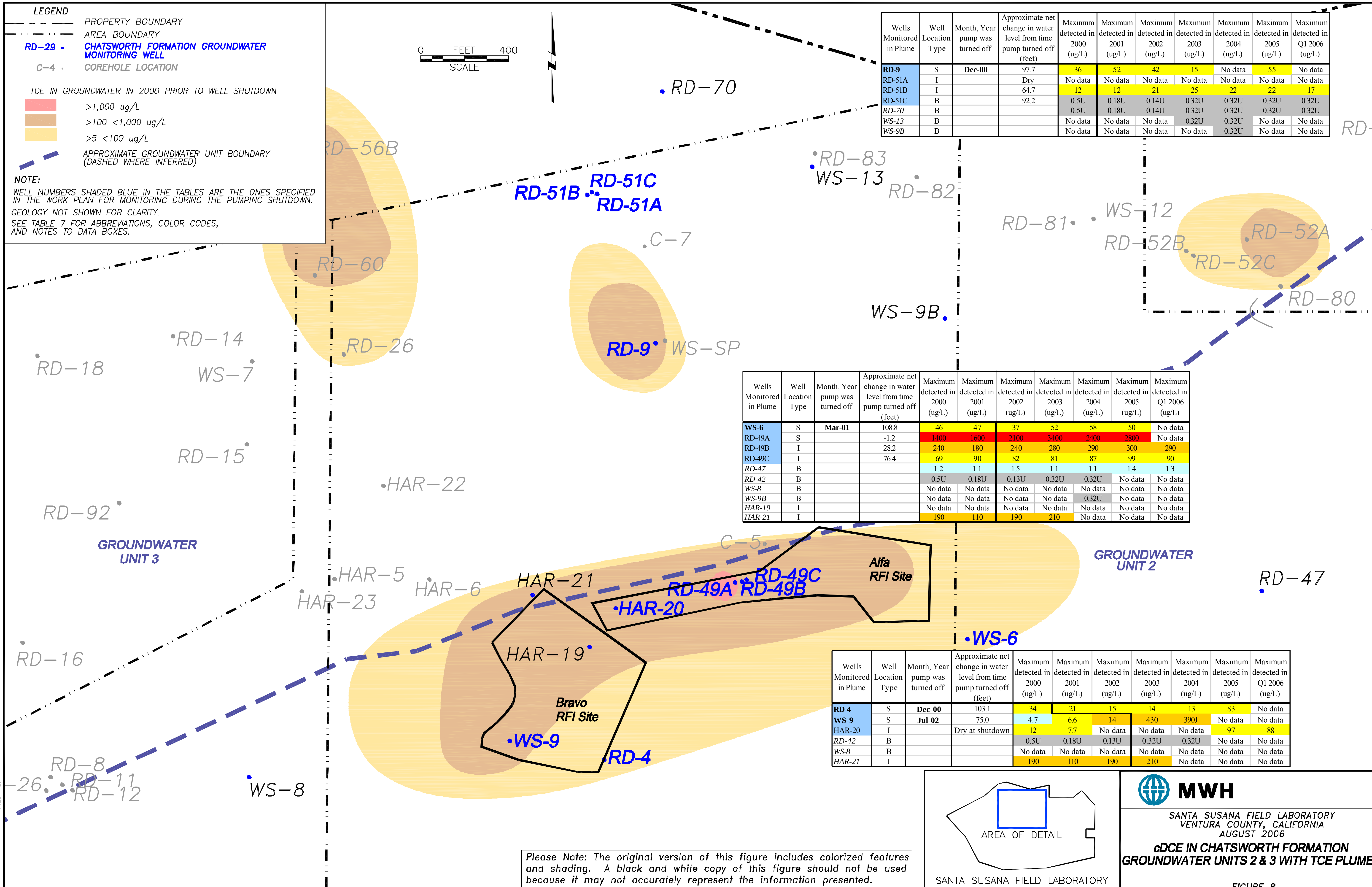
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

TCE IN CHATSWORTH FORMATION GROUNDWATER UNITS 2 AND 3

FIGURE 7

JOB No. __ FILE No. CAD MLUEBKE\BOEING\SANTA SUSANA\ex well shutdown\gw units 1 08



Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-9	S	**Dec-00**	97.7	36	52	42	15	No data	55	No data
RD-51A	I		Dry	No data	No data	No data	No data	No data	No data	No data
RD-51B	I		64.7	12	12	21	25	22	22	17
RD-51C	B		92.2	0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-70	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
WS-13	B			No data	No data	No data	0.32U	0.32U	No data	No data
WS-9B	B			No data	No data	No data	No data	0.32U	No data	No data

Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
WS-6	S	**Mar-01**	108.8	46	47	37	52	58	50	No data
RD-49A	S		-1.2	1400	1600	2100	3400	2400	2800	No data
RD-49B	I		28.2	240	180	240	280	290	300	290
RD-49C	I		76.4	69	90	82	81	87	99	90
RD-47	B			1.2	1.1	1.5	1.1	1.1	1.4	1.3
RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data
WS-8	B			No data	No data	No data	No data	No data	No data	No data
WS-9B	B			No data	No data	No data	No data	0.32U	No data	No data
HAR-19	I			No data	No data	No data	No data	No data	No data	No data
HAR-21	I			190	110	190	210	No data	No data	No data

Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-4	S	**Dec-00**	103.1	34	21	15	14	13	83	No data
WS-9	S	**Jul-02**	75.0	4.7	6.6	14	430	390J	No data	No data
HAR-20	I		Dry at shutdown	12	7.7	No data	No data	No data	97	88
RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data
WS-8	B			No data	No data	No data	No data	No data	No data	No data
HAR-21	I			190	110	190	210	No data	No data	No data

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

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VENTURA COUNTY, CALIFORNIA
AUGUST 2006

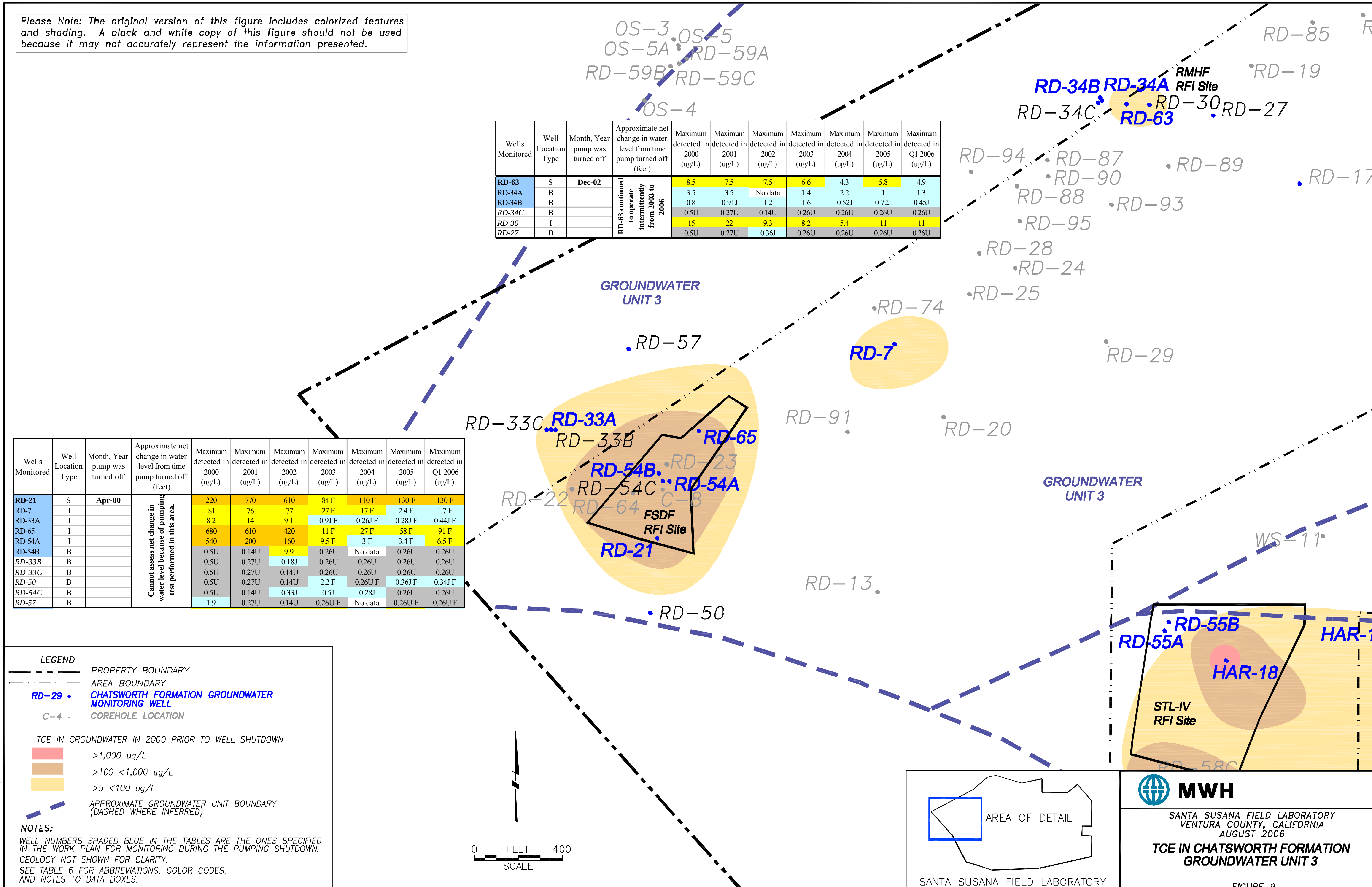
cDCE IN CHATSWORTH FORMATION GROUNDWATER UNITS 2 & 3 WITH TCE PLUMES

FIGURE 8

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-63	S	**Dec-02**	**RD-63 continued to operate intermittently from 2003 to 2006**	8.5	7.5	7.5	6.6	4.3	5.8	4.9
RD-34A	B			3.5	3.5	No data	1.4	2.2	1	1.3
RD-34B	B			0.8	0.91J	1.2	1.6	0.52J	0.72J	0.45J
RD-34C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
RD-30	I			15	22	9.3	8.2	5.4	11	11
RD-27	B			0.5U	0.27U	0.36J	0.26U	0.26U	0.26U	0.26U

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-21	S	**Apr-00**	**Cannot assess net change in water level because of pumping test performed in this area.**	220	770	610	84 F	110 F	130 F	130 F
RD-7	I			81	76	77	27 F	17 F	2.4 F	1.7 F
RD-33A	I			8.2	14	9.1	0.9J F	0.26J F	0.28J F	0.44J F
RD-65	I			680	610	420	11 F	27 F	58 F	91 F
RD-54A	I			540	200	160	9.5 F	3 F	3.4 F	6.5 F
RD-54B	B			0.5U	0.14U	9.9	0.26U	No data	0.26U	0.26U
RD-33B	B			0.5U	0.27U	0.18J	0.26U	0.26U	0.26U	0.26U
RD-33C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U
RD-50	B			0.5U	0.27U	0.14U	2.2 F	0.26U F	0.36J F	0.34J F
RD-54C	B			0.5U	0.14U	0.33J	0.5J	0.28J	0.26U	0.26U
RD-57	B			1.9	0.27U	0.14U	0.26U F	No data	0.26U F	0.26U F



LEGEND

PROPERTY BOUNDARY

AREA BOUNDARY

RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL

C-4 · COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN

>1,000 ug/L

>100 <1,000 ug/L

>5 <100 ug/L

APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTES:

WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.

GEOLOGY NOT SHOWN FOR CLARITY.

SEE TABLE 6 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

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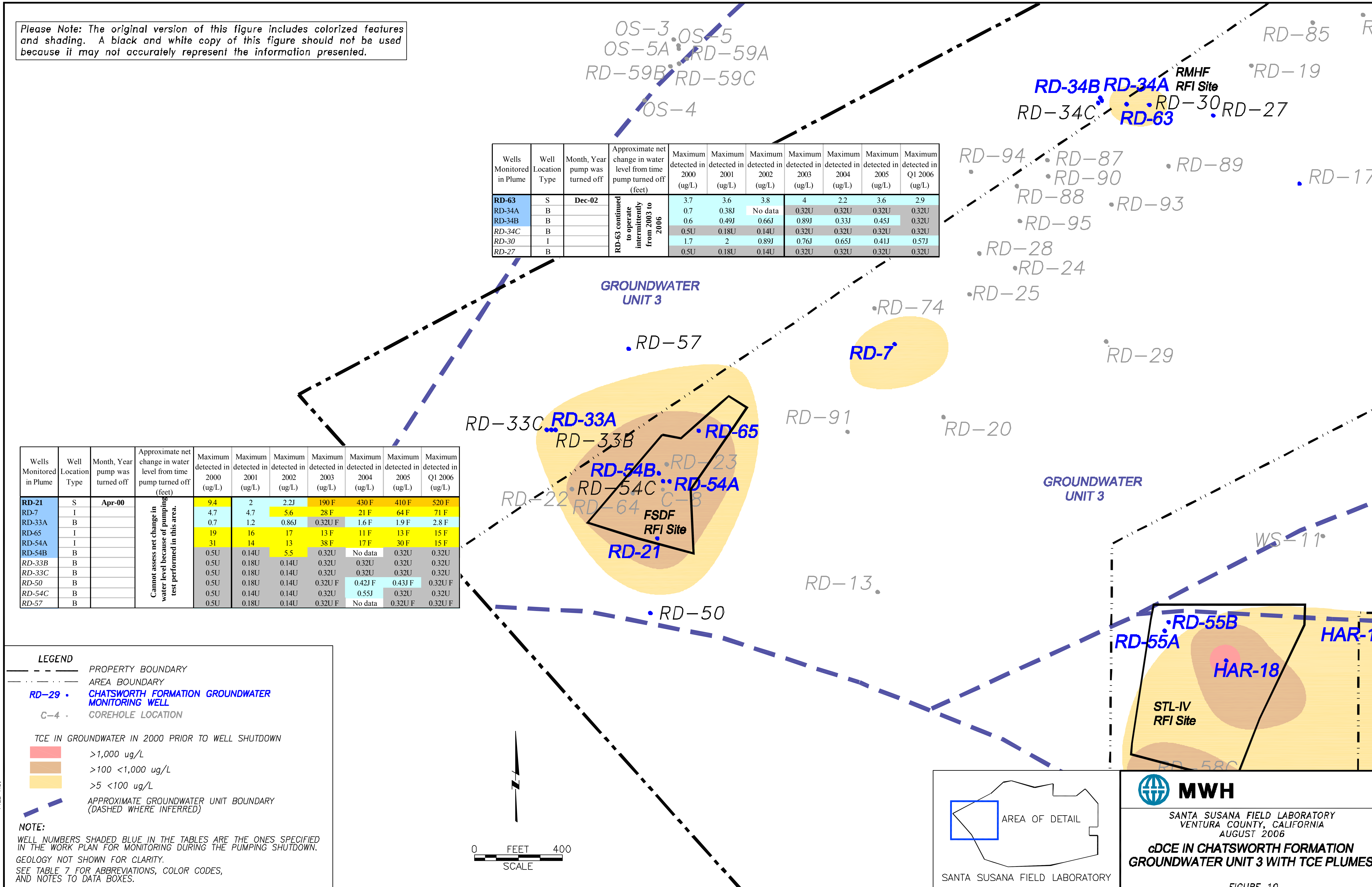
AUGUST 2006

TCE IN CHATSWORTH FORMATION GROUNDWATER UNIT 3

FIGURE 9

JOB No. FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\NSGW REPORT\SSFL WELL NETWORK 1 27 06

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.



Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-63	S	**Dec-02**	**RD-63 continued to operate intermittently from 2003 to 2006**	3.7	3.6	3.8	4	2.2	3.6	2.9
RD-34A	B			0.7	0.38J	No data	0.32U	0.32U	0.32U	0.32U
RD-34B	B			0.6	0.49J	0.66J	0.89J	0.33J	0.45J	0.32U
RD-34C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-30	I			1.7	2	0.89J	0.76J	0.65J	0.41J	0.57J
RD-27	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U

Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
RD-21	S	**Apr-00**	**Cannot assess net change in water level because of pumping test performed in this area.**	9.4	2	2.2J	190 F	430 F	410 F	520 F
RD-7	I			4.7	4.7	5.6	28 F	21 F	64 F	71 F
RD-33A	B			0.7	1.2	0.86J	0.32U F	1.6 F	1.9 F	2.8 F
RD-65	I			19	16	17	13 F	11 F	13 F	15 F
RD-54A	I			31	14	13	38 F	17 F	30 F	15 F
RD-54B	B			0.5U	0.14U	5.5	0.32U	No data	0.32U	0.32U
RD-33B	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-33C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-50	B			0.5U	0.18U	0.14U	0.32U F	0.42J F	0.43J F	0.32U F
RD-54C	B			0.5U	0.14U	0.14U	0.32U	0.55J	0.32U	0.32U
RD-57	B			0.5U	0.18U	0.14U	0.32U F	No data	0.32U F	0.32U F

LEGEND

PROPERTY BOUNDARY

AREA BOUNDARY

RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL

C-4 · COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN

>1,000 ug/L

>100 <1,000 ug/L

>5 <100 ug/L

APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTE:

WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.

GEOLOGY NOT SHOWN FOR CLARITY.

SEE TABLE 7 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

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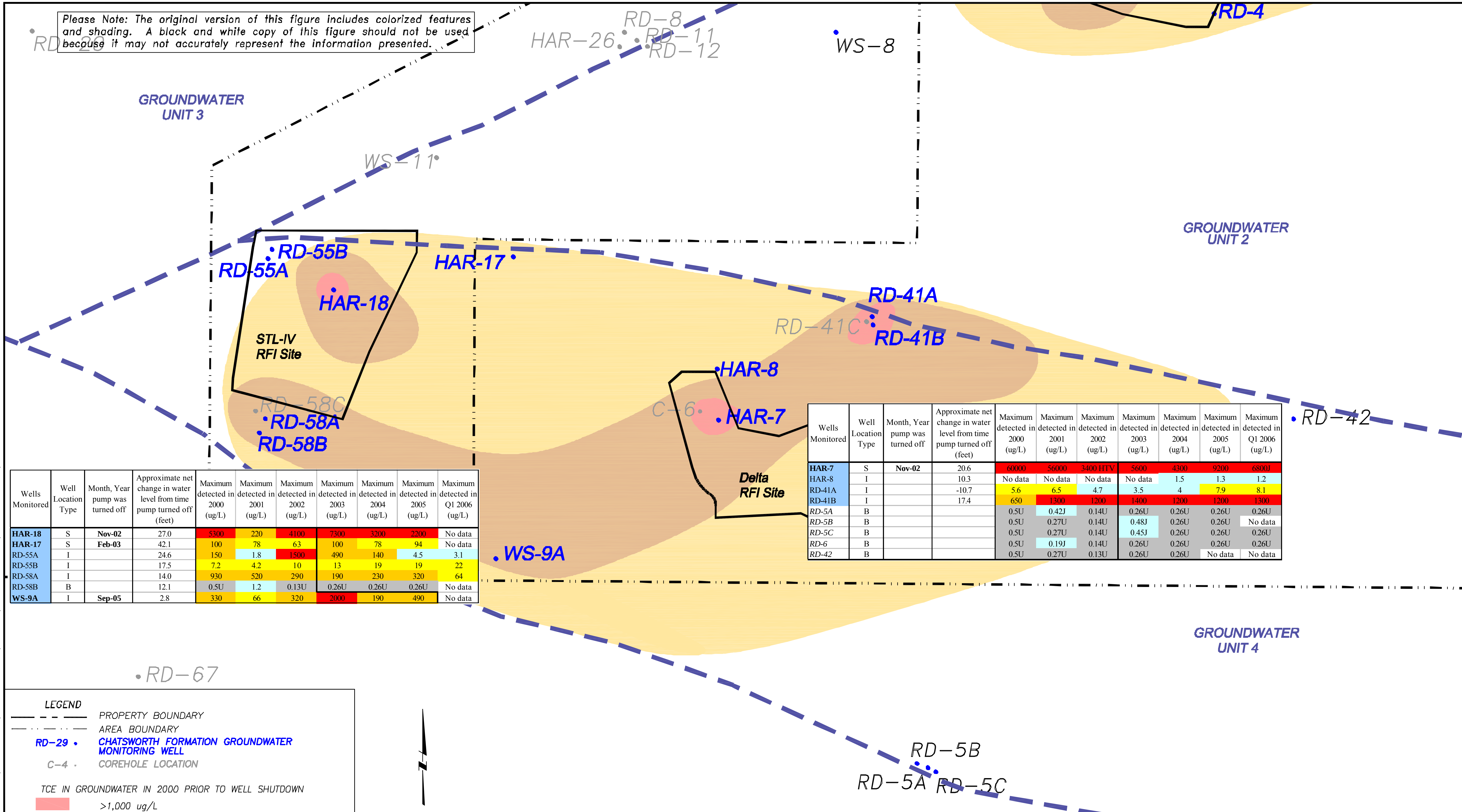
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

cDCE IN CHATSWORTH FORMATION GROUNDWATER UNIT 3 WITH TCE PLUMES

FIGURE 10

CAD MLUEBKE\BOEING\SANTA SUSANA\ex well shutdown\gw units 7 06 CIS DCE FILE No. JOB No.

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.



Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
HAR-18	S	**Nov-02**	27.0	5300	220	4100	7300	3200	2200	No data
HAR-17	S	**Feb-03**	42.1	100	78	63	100	78	94	No data
RD-55A	I		24.6	150	1.8	1500	490	140	4.5	3.1
RD-55B	I		17.5	7.2	4.2	10	13	19	19	22
RD-58A	I		14.0	930	520	290	190	230	320	64
RD-58B	B		12.1	0.5U	1.2	0.13U	0.26U	0.26U	0.26U	No data
WS-9A	I	**Sep-05**	2.8	330	66	320	2000	190	490	No data

Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
HAR-7	S	**Nov-02**	20.6	60000	56000	3400 HTV	5600	4300	9200	6800J
HAR-8	I		10.3	No data	No data	No data	No data	1.5	1.3	1.2
RD-41A	I		-10.7	5.6	6.5	4.7	3.5	4	7.9	8.1
RD-41B	I		17.4	650	1300	1200	1400	1200	1200	1300
RD-5A	B			0.5U	0.42J	0.14U	0.26U	0.26U	0.26U	0.26U
RD-5B	B			0.5U	0.27U	0.14U	0.48J	0.26U	0.26U	No data
RD-5C	B			0.5U	0.27U	0.14U	0.45J	0.26U	0.26U	0.26U
RD-6	B			0.5U	0.19J	0.14U	0.26U	0.26U	0.26U	0.26U
RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data

LEGEND

PROPERTY BOUNDARY

AREA BOUNDARY

RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL

C-4 • COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN

>1,000 ug/L

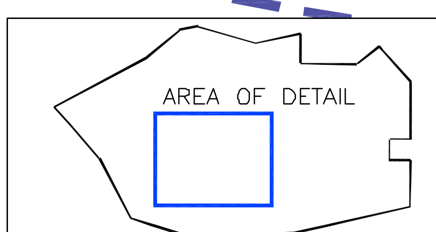
>100 <1,000 ug/L

>5 <100 ug/L

APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTES:

WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.
GEOLOGY NOT SHOWN FOR CLARITY.
SEE TABLE 6 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.



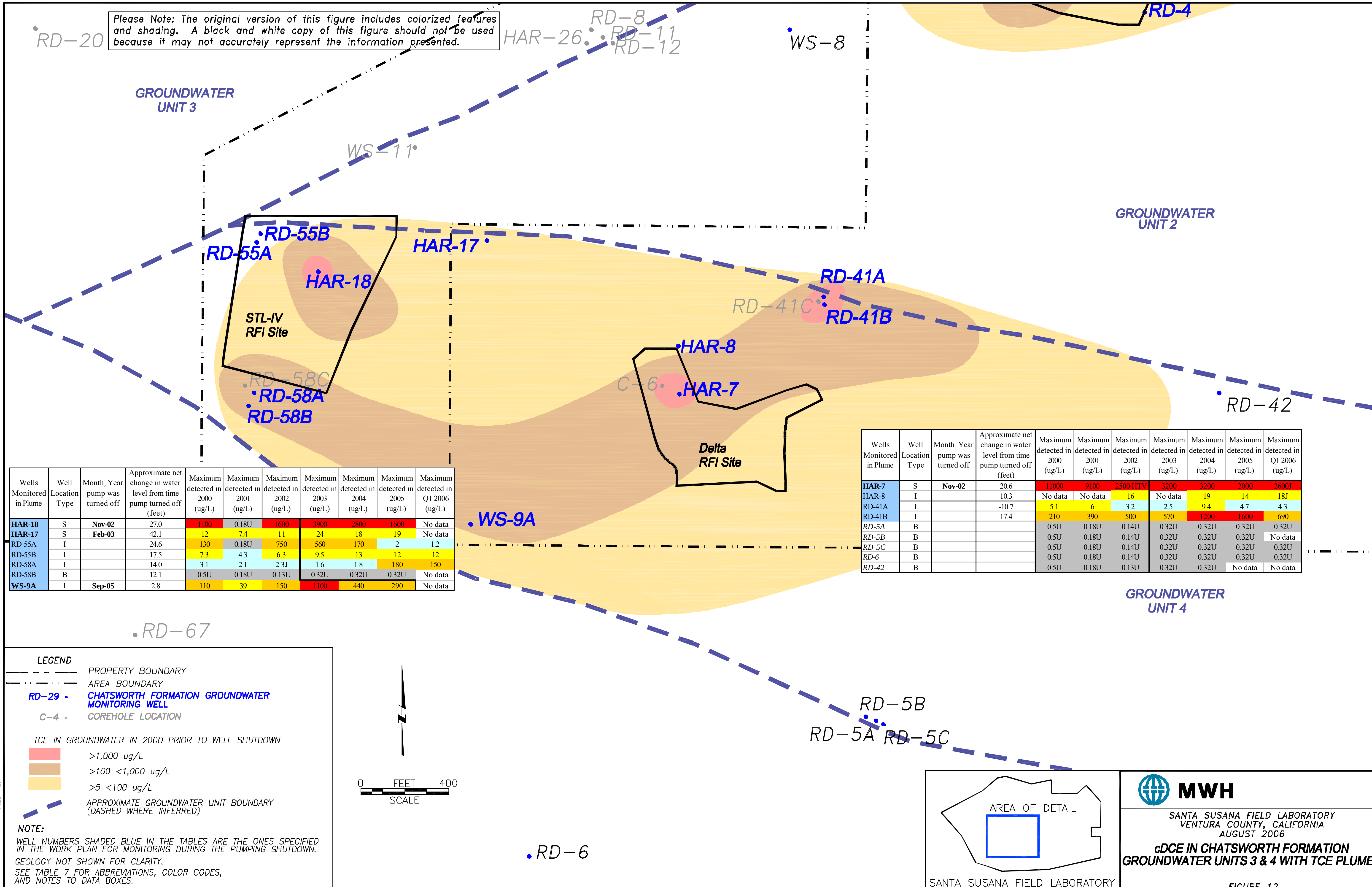
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

TCE IN CHATSWORTH FORMATION GROUNDWATER UNITS 3 AND 4

FIGURE 11

JOB No. FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\NSGW REPORT\SSFL WELL NETWORK 1 27 06



Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
HAR-18	S	**Nov-02**	27.0	1100	0.18U	1600	3900	2800	1600	No data
HAR-17	S	**Feb-03**	42.1	12	7.4	11	24	18	19	No data
RD-55A	I		24.6	130	0.18U	750	560	170	2	1.2
RD-55B	I		17.5	7.3	4.3	6.3	9.5	13	12	12
RD-58A	I		14.0	3.1	2.1	2.3J	1.6	1.8	180	150
RD-58B	B		12.1	0.5U	0.18U	0.13U	0.32U	0.32U	0.32U	No data
WS-9A	I	**Sep-05**	2.8	110	39	150	1100	440	290	No data

Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)
HAR-7	S	**Nov-02**	20.6	11000	9100	2500 HTV	3200	3200	2000	2600J
HAR-8	I		10.3	No data	No data	16	No data	19	14	18J
RD-41A	I		-10.7	5.1	6	3.2	2.5	9.4	4.7	4.3
RD-41B	I		17.4	210	390	500	570	1200	1600	690
RD-5A	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-5B	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	No data
RD-5C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-6	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U
RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data

LEGEND

PROPERTY BOUNDARY

AREA BOUNDARY

RD-29 • CHATSWORTH FORMATION GROUNDWATER MONITORING WELL

C-4 • COREHOLE LOCATION

TCE IN GROUNDWATER IN 2000 PRIOR TO WELL SHUTDOWN

>1,000 ug/L

>100 <1,000 ug/L

>5 <100 ug/L

APPROXIMATE GROUNDWATER UNIT BOUNDARY (DASHED WHERE INFERRED)

NOTE:

WELL NUMBERS SHADED BLUE IN THE TABLES ARE THE ONES SPECIFIED IN THE WORK PLAN FOR MONITORING DURING THE PUMPING SHUTDOWN.

GEOLOGY NOT SHOWN FOR CLARITY.

SEE TABLE 7 FOR ABBREVIATIONS, COLOR CODES, AND NOTES TO DATA BOXES.

MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
AUGUST 2006

cDCE IN CHATSWORTH FORMATION GROUNDWATER UNITS 3 & 4 WITH TCE PLUMES

FIGURE 12

TABLES

Table 1
Summary of Chatsworth Formation Extraction Well Shut Down
SSFL Extraction Well Shutdowns

Groundwater Treatment System	Chatsworth Formation Extraction Wells Connected to System	Groundwater Unit	Month and Year of Shutdown
Area 1 Road Air Stripping System	RD-1 RD-2	1B	August 2000 September 2000
WS-5 UV/Peroxidation System	WS-5	1B/2	October 2000
Alfa Air Stripping System	WS-6	2	March 2001
Bravo Air Stripping System	WS-9 RD-4 RD-9	2 2 3	July 2002 December 2000 December 2000
Delta Air Stripping System	WS-9A HAR-7	4	Remained operational until Topanga fire in September 2005 November 2002
STL-IV Air Stripping System	HAR-17 HAR-18	4	February 2003 November 2002
FSDF (1)	RD-21	3	April 2000
RMHF (1)	RD-63	3	Remained operational with periods of intermittent shut-down
B/059 (1) (2)	RD-24 RD-25 RD-28	3	April 2004 (3)

(1) Interim Systems
(2) This groundwater extraction and treatment system was operated only to dewater the foundation of Building 059 and was not a part of the shutdown monitoring program described in the October 2000 work plan.
(3) Wells RD-25 and RD-28 were abandoned in April 2004 in conjunction with the decommissioning and demolition of Building 059. Additional groundwater extraction from RD-24 occurred in January and February 2005.

Table 2
Wells to be Monitored During Shut Down of Groundwater Extraction
SSFL Extraction Well Shutdown

Groundwater Unit	Monitoring Approach		
	Source Plume Being Monitored	**Well to be Monitored At Source**	**Wells to be Monitored in Dissolved Plume**
1A	IEL APTF	Continue with current monitoring program as these areas are currently outside of the influence of any groundwater extraction wells	
1B	Canyon	WS-5 RD-1	RD-10
	Bowl	RD-2	RD-44
2	Alfa	WS-6 RD-49A	RD-49B RD-49C
	Bravo	RD-4 WS-9	HAR-20
3	FSDF	RD-21	RD-7 RD-54A RD-54B RD-33A RD-65
	RMHF	RD-63	RD-34A RD-34B
	ELV/Bldg 204	RD-9	RD-51A RD-51B RD-51C
4	Delta	HAR-7	HAR-8 RD-41A RD-41B
	STL-IV	HAR-18 HAR-17	RD-55A RD-55B RD-58A RD-58B WS-9A

Table 3
VOC Sampling Frequencies
SSFL Extraction Well Shutdown

Well	Mo/Yr	2000				2001				2002				2003				2004				2005				2006
	Pump Off	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WS-05	**Oct-00**	√	--	--	√	√	√	√	√	√	√	√	√	√	√	--	--	--	√	√	√	--	--	--	--	√
RD-01	**Aug-00**	√	--	--	√	√	√	√	√	--	--	--	√	--	√	--	--	--	√	√	√	√	√	√	--	--
RD-10		√	--	√	√	√	√	√	√	√	√	√	√	√	√	--	--	--	√	--	--	--	√	√	--	√
RD-02	**Sep-00**	√	--	--	√	√	√	√	√	√	√	--	√	√	√	√	√	√	√	√	√	√	√	√	--	--
RD-44		√	√	√	√	--	√	√	√	√	√	√	√	√	√	√	--	√	√	√	√	√	√	√	√	√
WS-06	**Mar-01**	√	√	√	√	√	√	√	--	√	√	√	√	√	√	√	√	√	√	--	--	√	√	√	--	--
RD-49A		√	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	--
RD-49B		--	√	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	--	√	√
RD-49C		√	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
RD-04	**Dec-00**	√	--	--	--	--	√	--	--	√	√	√	√	√	√	√	√	√	√	√	--	√	√	√	--	--
WS-09	**Jul-02**	√	--	--	--	√	--	--	√	√	√	√	√	√	√	--	--	√	√	√	√	--	--	--	--	--
HAR-20		--	√	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	--	√
RD-09	**Dec-00**	√	--	--	--	√	--	--	--	√	--	√	--	√	--	--	--	--	--	--	--	--	√	√	--	--
RD-51A		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√
RD-51B		--	--	--	√	√	--	--	--	√	√	√	--	√	--	√	--	√	√	√	√	√	√	√	√	√
RD-51C		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
HAR-07	**Nov-02**	√	√	--	--	√	√	--	--	--	√	--	--	--	√	--	√	--	√	--	--	√	√	√	√	√
HAR-08		--	--	--	--	--	--	--	--	--	--	--	√	--	--	--	--	--	√	--	--	--	--	--	√	√
RD-41A		√	--	--	--	√	--	--	--	√	--	--	--	√	--	--	--	--	√	√	√	√	√	√	√	√
RD-41B		√	--	--	--	√	--	--	--	√	--	--	--	√	--	--	--	√	√	√	√	√	√	√	√	√
HAR-18	**Nov-02**	√	--	--	--	--	√	--	--	√	--	√	--	√	--	√	--	--	√	--	--	--	√	√	--	--
HAR-17	**Feb-03**	--	√	--	√	--	√	--	--	--	√	--	--	--	√	--	√	--	√	--	--	--	√	--	√	--
RD-55A		√	--	--	√	√	--	--	--	√	--	√	√	√	√	√	--	√	√	√	√	√	√	√	√	√
RD-55B		√	--	--	√	√	--	--	--	√	--	√	--	√	√	√	--	√	√	√	√	√	√	√	√	√
RD-58A		√	--	--	√	√	--	--	√	√	--	--	√	√	√	--	√	--	√	√	√	√	√	√	√	√
RD-58B		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	--
WS-09A	**Sep-05**	√	--	--	--	√	--	--	√	√	--	√	√	√	√	√	√	√	--	√	--	--	√	√	--	--

- Period preceding pump shutdown

WS-05 - Extraction well

RD-10 - Monitoring well

Table 4
COC Sampling Frequencies
SSFL Extraction Well Shutdown

Well	Mo/Yr Pump Off	2000				2001				2002				2003				2004				2005				2006
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WS-05	**Oct-00**	--	--	--	--	√	√	√	√	√	√	√	√	√	√	--	--	--	√	√	√	√	√	√	√	√
RD-01	**Aug-00**	--	--	--	--	√	√	√	√	--	--	--	√	--	√	--	--	--	√	√	√	√	√	√	--	--
RD-10		--	--	√	√	√	√	√	√	√	√	√	√	√	√	--	--	--	√	√	--	--	√	√	--	√
RD-02	**Sep-00**	--	--	--	--	√	√	√	√	√	√	--	√	--	√	√	√	√	√	√	√	√	√	√	--	--
RD-44		--	--	√	√	--	√	√	√	√	√	√	√	√	√	√	--	√	√	√	√	√	√	√	√	√
WS-06	**Mar-01**	--	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	--	--	--	√	√	√	--	--
RD-49A		--	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	--
RD-49B		--	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	--	√	√
RD-49C		--	--	--	--	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
RD-04	**Dec-00**	--	--	--	--	--	--	--	--	--	--	√	√	√	√	√	√	√	√	√	--	√	√	√	--	--
WS-09	**Jul-02**	--	--	--	--	√	--	--	√	--	--	√	√	√	√	--	--	√	√	√	√	--	--	--	--	--
HAR-20		--	--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	--	√
RD-09	**Dec-00**	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	--	--
RD-51A		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RD-51B		--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	√	√	√	√	√
RD-51C		--	--	√	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	√	√	√	√	√
HAR-07	**Nov-02**	--	√	--	--	√	√	--	--	--	√	--	--	--	--	--	--	--	--	--	--	√	√	√	√	√
HAR-08		--	--	--	--	--	--	--	--	--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	√	√
RD-41A		√	--	--	--	√	--	--	--	√	--	--	--	--	--	--	--	--	--	√	√	√	√	√	√	√
RD-41B		√	--	--	--	√	--	--	--	√	--	--	--	--	--	--	--	--	--	√	√	√	√	√	√	√
HAR-18	**Nov-02**	--	--	--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	√	√	--	--
HAR-17	**Feb-03**	--	√	--	√	--	√	--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RD-55A		√	--	--	√	√	--	--	--	√	--	--	--	√	--	--	--	--	--	√	√	√	√	√	√	√
RD-55B		√	--	--	√	√	--	--	--	√	--	--	--	√	--	--	--	--	--	√	√	√	√	√	√	√
RD-58A		--	--	--	√	√	--	--	√	--	--	--	√	--	--	--	--	--	--	√	√	√	√	√	√	√
RD-58B		--	--	√	√	√	√	--	√	--	--	--	√	--	--	--	--	--	--	√	√	√	√	√	√	--
WS-09A	**Sep-05**	--	--	--	--	√	--	--	√	--	--	--	√	--	--	--	--	--	--	--	--	--	--	--	--	--

[shaded box] - Period preceding pump shutdown

WS-05 - Extraction well

RD-10 - Monitoring well

Table 5
Groundwater Elevation Changes
SSFL Extraction Well Shutdown

			Shut Down Water Level		Q1 2006 Water Level		
Groundwater Unit	**Source and Plume Monitored**	**Well**	**Date**	**GW Elev (feet)**	**Date**	**GW Elev (feet)**	**Change in GW Elev (feet)**
1B	Canyon	WS-05	08/02/00	1377.86	2/1/06	1580.15	202.29
		RD-01	08/02/00	1636.24	2/1/06	1735.42	99.18
		RD-10	08/02/00	1680.30	2/1/06	1722.15	41.85
		RD-45C	08/01/00	1378.53	01/31/06	1708.14	329.61
	Bowl	RD-02	08/02/00	1648.87	1/30/06	1716.71	67.84
		RD-44	08/02/00	1614.44	2/8/06	1635.01	20.57
2	Alpha	WS-06	02/02/00	1468.82	2/1/06	1577.66	108.84
		RD-49A	02/01/01	1851.77	2/1/06	1850.61	-1.16
		RD-49B	02/01/01	1586.81	2/1/06	1615.03	28.22
		RD-49C	02/01/01	1509.76	2/1/06	1586.14	76.38
	Bravo	RD-04	11/01/00	1476.15	2/1/06	1579.22	103.07
		WS-09	05/01/02	1506.31	2/1/06	1581.26	74.95
		HAR-20	05/01/02	1600.47(1)	2/1/06	1633.25	> 32.78
3(3)	ELV/ Bldg 204	RD-09	11/01/00	1652.96	1/30/06	1750.68	97.72
		RD-51A	11/02/00	1582.03	1/31/06	~1581(2)	> -1
		RD-51B	11/02/00	1506.21	2/1/06	1570.95	64.74
		RD-51C	11/02/00	1485.20	1/31/06	1577.40	92.2
4	Delta	HAR-07	11/05/02	1648.34	1/31/06	1668.95	20.61
		HAR-08	10/29/02	1684.14	1/31/06	1694.42	10.28
		RD-41A	10/29/02	1745.21	2/7/06	1734.48	-10.73
		RD-41B	10/29/02	1642.91	1/31/06	1660.32	17.41
	STL-IV	HAR-18	11/05/02	1704.45	1/31/06	1731.49	27.04
		HAR-17	11/05/02	1655.24	1/31/06	1697.38	42.14
		RD-55A	01/28/03	1720.41	1/31/06	1745.00	24.59
		RD-55B	01/28/03	1696.58	2/7/06	1714.07	17.49
		RD-58A	01/27/03	1665.19	2/3/06	1679.16	13.97
		RD-58B	01/27/03	1647.37	1/31/06	1659.47	12.10
		WS-09A	08/02/05	1622.59	1/31/06	1625.39	2.80

(1) Well dry May 2002; this is the approximate well bottom elevation
(2) Well dry January 2006; this is the approximate well bottom elevation
(3) Water elevation changes in FSDF area wells could not be assessed because of ongoing groundwater characterization work in that area; the pump in RMHF area extraction well RD-63 was not turned off to facilitate CFOU investigations and so the RMHF wells were not included in the study.

Table 6
Summary of TCE Concentration Trends
SSFL Extraction Well Shutdown

Groundwater Unit	Source and Plume Being Monitored	Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)	Comments
1B	Canyon	**WS-5**	S	**Oct-00**	202.3	8.8	37	1.5	1.5	1.2	0.97J	0.82J	Slight decrease in concentration in source area extraction well
		RD-1	S	**Aug-00**	99.2	100	610	1200	970	1000	980	No data	Increase in concentration in source area extraction well
		RD-10	I		41.9	7.4	12	15 (comp)	6.6 (comp)	9.1 (comp)	14	15	No appreciable change in concentration
		RD-75	B			Installed Dec 2003				0.39U	No data	No data	Limited data
		RD-76	B			Installed Dec 2003				0.26U	No data	No data	Limited data
		OS-17	B			0.5U	0.27U	0.14U	0.26U	1.3U	0.26U	0.26U	No appreciable change in concentration
		OS-28	B			No data	No Data	No data	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-45C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-47	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
1B	Bowl	**RD-2**	S	**Sep-00**	67.8	87	700	470	350	250	550	No data	Increase in concentration in source area extraction well
		RD-44	B		20.6	0.5U	0.27U	0.39J	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-75	B			Installed Dec 2003				0.39U	No data	No data	Limited data
		RD-76	B			Installed Dec 2003				0.26U	No data	No data	Limited data
		RD-61	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
2	Alfa	**WS-6**	S	**Mar-01**	108.8	22	20	6.2	7	4.2	2.6	No data	Decrease in concentration in source area extraction well
		RD-49A	S		-1.2	2600	2900	3500	4100	4000	3100	No data	Slight increase in concentration in source area well
		RD-49B	I		28.2	290	210	350	350	330	340	310	Slight increase in concentration in plume interior well
		RD-49C	I		76.4	41	40	32	26	21	17	17	Slight decrease in concentration in plume interior well
		RD-47	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data	No appreciable change in concentration
		WS-8	B			No data	No data	No data	No data	No data	No data	No data	No data
		WS-9B	B			No data	No data	No data	No data	0.26U	No data	No data	Limited data; no historical detects
		HAR-19	I			No data	No data	No data	No data	No data	No data	No data	No data
		HAR-21	I			7	3.7	4.5	10U	No data	No data	No data	No appreciable change in concentration
2	Bravo	**RD-4**	S	**Dec-00**	103.1	52	52	51	79	72	1900	No data	Increase in concentration in source area extraction well
		WS-9	S	**Jul-02**	75.0	61	85	70	7600	6400	No data	No data	Increase in concentration in source area extraction well
		HAR-20	I		Dry at shutdown	5.2	5.2	No data	No data	No data	180	120	Increase in concentration in plume interior well
		RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data	No appreciable change in concentration
		WS-8	B			No data	No data	No data	No data	No data	No data	No data	No data
		HAR-21	I			7	3.7	4.5	10U	No data	No data	No data	No appreciable change in concentration
3	FSDF	**RD-21**	S	**Apr-00**	**Cannot assess net change in water level because of pumping test performed in this area.**	220	770	610	84 F	110 F	130 F	130 F	Initial slight increase in concentration in source area extraction well RD-21; all five of these wells show a decrease in concentration as of 2003 that is likely associated with the intiation of sampling from the FLUTe multilevel systems that were installed in these wells at that time.
		RD-7	I			81	76	77	27 F	17 F	2.4 F	1.7 F	
		RD-33A	I			8.2	14	9.1	0.9J F	0.26J F	0.28J F	0.44J F	
		RD-65	I			680	610	420	11 F	27 F	58 F	91 F	
		RD-54A	I			540	200	160	9.5 F	3 F	3.4 F	6.5 F	
		RD-54B	B			0.5U	0.14U	9.9	0.26U	No data	0.26U	0.26U	No appreciable change in concentration
		RD-33B	B			0.5U	0.27U	0.18J	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-33C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-50	B			0.5U	0.27U	0.14U	2.2 F	0.26U F	0.36J F	0.34J F	No appreciable change in concentration
		RD-54C	B			0.5U	0.14U	0.33J	0.5J	0.28J	0.26U	0.26U	No appreciable change in concentration
		RD-57	B			1.9	0.27U	0.14U	0.26U F	No data	0.26U F	0.26U F	No appreciable change in concentration

Table 6
Summary of TCE Concentration Trends
SSFL Extraction Well Shutdown

Groundwater Unit	Source and Plume Being Monitored	Wells Monitored	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)	Comments
3	RMHF	**RD-63**	S	**Dec-02**	**RD-63 continued to operate intermittently from 2003 to 2006**	8.5	7.5	7.5	6.6	4.3	5.8	4.9	No appreciable change in concentration
		RD-34A	B			3.5	3.5	No data	1.4	2.2	1	1.3	No appreciable change in concentration
		RD-34B	B			0.8	0.91J	1.2	1.6	0.52J	0.72J	0.45J	No appreciable change in concentration
		RD-34C	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-30	I			15	22	9.3	8.2	5.4	11	11	No appreciable change in concentration
		RD-27	B			0.5U	0.27U	0.36J	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
3	ELV/Bldg 204	**RD-9**	S	**Dec-00**	97.7	270	340	580	55	No data	520	No data	Slight increase in concentration in source area extraction well
		RD-51A	I		Dry	No data	No data	No data	No data	No data	No data	No data	No data (dry or insufficient water to sample)
		RD-51B	I		64.7	2.3	3.6	6.6	6.5	6.2	7.7	6.8	Slight increase in concentration in plume interior well
		RD-51C	B		92.2	0.37J	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-70	B			0.5U	0.27U	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		WS-13	B			No data	No data	No data	0.26U	0.26U	No data	No data	No appreciable change in concentration
		WS-9B	B			No data	No data	No data	No data	0.26U	No data	No data	Limited data; no historical detects
4	Delta	**HAR-7**	S	**Nov-02**	20.6	60000	56000	3400 HTV	5600	4300	9200	6800J	Decrease in concentration in source area extraction well
		HAR-8	I		10.3	No data	No data	No data	No data	1.5	1.3	1.2	No appreciable change in concentration
		RD-41A	I		-10.7	5.6	6.5	4.7	3.5	4	7.9	8.1	No appreciable change in concentration
		RD-41B	I		17.4	650	1300	1200	1400	1200	1200	1300	No appreciable change in concentration
		RD-5A	B			0.5U	0.42J	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-5B	B			0.5U	0.27U	0.14U	0.48J	0.26U	0.26U	No data	No appreciable change in concentration
		RD-5C	B			0.5U	0.27U	0.14U	0.45J	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-6	B			0.5U	0.19J	0.14U	0.26U	0.26U	0.26U	0.26U	No appreciable change in concentration
		RD-42	B			0.5U	0.27U	0.13U	0.26U	0.26U	No data	No data	No appreciable change in concentration
4	STL-IV	**HAR-18**	S	**Nov-02**	27.0	5300	220	4100	7300	3200	2200	No data	No appreciable change in concentration
		HAR-17	S	**Feb-03**	42.1	100	78	63	100	78	94	No data	No appreciable change in concentration
		RD-55A	I		24.6	150	1.8	1500	490	140	4.5	3.1	Variable concentration, decreasing after pumping cessation
		RD-55B	I		17.5	7.2	4.2	10	13	19	19	22	Slight increase in concentration in plume interior well
		RD-58A	I		14.0	930	520	290	190	230	320	64	Slight decrease in concentration in plume interior well
		RD-58B	B		12.1	0.5U	1.2	0.13U	0.26U	0.26U	0.26U	No data	No appreciable change in concentration
		WS-9A	I	**Sep-05**	2.8	330	66	320	2000	190	490	No data	Variable concentration likely associated with pumping

Notes:

U - not detected at method detection limit shown
J - estimated value below method reporting limit
F - sample from discrete-interval of multi-level monitoring system
ND - not detected
ug/L - micrograms per liter
comp - composite sample from multiple discrete-intervals of a multi-level monitoring system

S - source area well (defined as such in October 2000 work plan)
I - plume interior well (>5 ug/L TCE or cDCE prior to extraction well shutdown)
B - plume boundary well (<5 ug/L TCE and cDCE prior to extraction well shutdown)
MDL - method detection limit
HTV - holding time violation

Bold vertical lines denote times when extraction wells were turned off; values immediately left of the bold lines are maximums detected that year before the pumps were turned off.

Legend for color-coding of concentration ranges (ug/L): ND | >MDL, <5 | >5, <100 | >100, <1000 | >1,000

RD-10 Well specified for monitoring in October 2000 work plan; bold indicates extraction well.

RD-75 Well added to analysis for completeness.

Table 7
Summary of cDCE Concentration Trends
SSFL Extraction Well Shutdown

Groundwater Unit	Source and Plume Being Monitored	Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)	Comments
1B	Canyon	**WS-5**	S	**Oct-00**	202.3	14	54	2.8	2.9	3.3	3	2.6	Decrease in concentration in source area extraction well
		RD-1	S	**Aug-00**	99.2	83	340	860	690	840	780	No data	Increase in concentration in source area extraction well
		RD-10	I		41.9	8.4	9.8	12 (comp)	13 (comp)	14 (comp)	9.5	9.6J	No appreciable change in concentration
		RD-75	B			Installed Dec 2003				0.32U	No data	No data	Limited data
		RD-76	B			Installed Dec 2003				0.32U	No data	No data	Limited data
		OS-17	B			0.5U	0.18U	0.14U	0.32U	1.6U	0.32U	0.32U	No appreciable change in concentration
		OS-28	B			Installed	No data	No data	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-45C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-47	B			1.2	1.1	1.5	1.1	1.1	1.4	1.3	No appreciable change in concentration
1B	Bowl	**RD-2**	S	**Sep-00**	67.8	95	700	580	490	460	550	No data	Increase in concentration in source area extraction well
		RD-44	B		20.6	0.5U	0.18U	0.13J	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-75	B			Installed Dec 2003				0.32U	No data	No data	Limited data
		RD-76	B			Installed Dec 2003				0.32U	No data	No data	Limited data
		RD-61	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
2	Alfa	**WS-6**	S	**Mar-01**	108.8	46	47	37	52	58	50	No data	No appreciable change in concentration in source area extraction well
		RD-49A	S		-1.2	1400	1600	2100	3400	2400	2800	No data	Slight increase in concentration in source area well
		RD-49B	I		28.2	240	180	240	280	290	300	290	Slight increase in concentration in plume interior well
		RD-49C	I		76.4	69	90	82	81	87	99	90	No appreciable change in concentration
		RD-47	B			1.2	1.1	1.5	1.1	1.1	1.4	1.3	No appreciable change in concentration
		RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data	No appreciable change in concentration
		WS-8	B			No data	No data	No data	No data	No data	No data	No data	No data
		WS-9B	B			No data	No data	No data	No data	0.32U	No data	No data	Limited data; no historical detects
		HAR-19	I			No data	No data	No data	No data	No data	No data	No data	No data
		HAR-21	I			190	110	190	210	No data	No data	No data	No appreciable change in concentration
2	Bravo	**RD-4**	S	**Dec-00**	103.1	34	21	15	14	13	83	No data	Slight increase in concentration in source area extraction well
		WS-9	S	**Jul-02**	75.0	4.7	6.6	14	430	390J	No data	No data	Increase in concentration in source area extraction well
		HAR-20	I		Dry at shutdown	12	7.7	No data	No data	No data	97	88	Increase in concentration in plume interior well
		RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data	No appreciable change in concentration
		WS-8	B			No data	No data	No data	No data	No data	No data	No data	No data
		HAR-21	I			190	110	190	210	No data	No data	No data	No appreciable change in concentration
3	FSDF	**RD-21**	S	**Apr-00**	**Cannot assess net change in water level because of pumping test performed in this area.**	9.4	2	2.2J	190 F	430 F	410 F	520 F	Initially stable concentrations in all five of these wells; the increase in concentration in 2003 and after in source area extraction well RD-21 and plume interior well RD-7 is likely associated with the initiation of sampling from the FLUTe multilevel systems that were installed in these wells at that time.
		RD-7	I			4.7	4.7	5.6	28 F	21 F	64 F	71 F	
		RD-33A	B			0.7	1.2	0.86J	0.32U F	1.6 F	1.9 F	2.8 F	
		RD-65	I			19	16	17	13 F	11 F	13 F	15 F	
		RD-54A	I			31	14	13	38 F	17 F	30 F	15 F	
		RD-54B	B			0.5U	0.14U	5.5	0.32U	No data	0.32U	0.32U	No appreciable change in concentration
		RD-33B	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-33C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-50	B			0.5U	0.18U	0.14U	0.32U F	0.42J F	0.43J F	0.32U F	No appreciable change in concentration
		RD-54C	B			0.5U	0.14U	0.14U	0.32U	0.55J	0.32U	0.32U	No appreciable change in concentration
		RD-57	B			0.5U	0.18U	0.14U	0.32U F	No data	0.32U F	0.32U F	No appreciable change in concentration

Table 7
Summary of cDCE Concentration Trends
SSFL Extraction Well Shutdown

Groundwater Unit	Source and Plume Being Monitored	Wells Monitored in Plume	Well Location Type	Month, Year pump was turned off	Approximate net change in water level from time pump turned off (feet)	Maximum detected in 2000 (ug/L)	Maximum detected in 2001 (ug/L)	Maximum detected in 2002 (ug/L)	Maximum detected in 2003 (ug/L)	Maximum detected in 2004 (ug/L)	Maximum detected in 2005 (ug/L)	Maximum detected in Q1 2006 (ug/L)	Comments
3	RMHF	**RD-63**	S	**Dec-02**	**RD-63 continued to operate intermittently from 2003 to 2006**	3.7	3.6	3.8	4	2.2	3.6	2.9	No appreciable change in concentration in source area extraction well
		RD-34A	B			0.7	0.38J	No data	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-34B	B			0.6	0.49J	0.66J	0.89J	0.33J	0.45J	0.32U	No appreciable change in concentration
		RD-34C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-30	I			1.7	2	0.89J	0.76J	0.65J	0.41J	0.57J	No appreciable change in concentration
		RD-27	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
3	ELV/Bldg 204	**RD-9**	S	**Dec-00**	97.7	36	52	42	15	No data	55	No data	No appreciable change in concentration in source area extraction well
		RD-51A	I		Dry	No data	No data	No data	No data	No data	No data	No data	No data (dry or insufficient water to sample)
		RD-51B	I		64.7	12	12	21	25	22	22	17	Slight increase in concentration in plume interior well
		RD-51C	B		92.2	0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-70	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		WS-13	B			No data	No data	No data	0.32U	0.32U	No data	No data	No appreciable change in concentration
		WS-9B	B			No data	No data	No data	No data	0.32U	No data	No data	Limited data; no historical detects
4	Delta	**HAR-7**	S	**Nov-02**	20.6	11000	9100	2500 HTV	3200	3200	2000	2600J	Decrease in concentration in source area extraction well
		HAR-8	I		10.3	No data	No data	16	No data	19	14	18J	No appreciable change in concentration
		RD-41A	I		-10.7	5.1	6	3.2	2.5	9.4	4.7	4.3	No appreciable change in concentration
		RD-41B	I		17.4	210	390	500	570	1200	1600	690	Slight increase in concentration in plume interior well
		RD-5A	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-5B	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	No data	No appreciable change in concentration
		RD-5C	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-6	B			0.5U	0.18U	0.14U	0.32U	0.32U	0.32U	0.32U	No appreciable change in concentration
		RD-42	B			0.5U	0.18U	0.13U	0.32U	0.32U	No data	No data	No appreciable change in concentration
4	STL-IV	**HAR-18**	S	**Nov-02**	27.0	1100	0.18U	1600	3900	2800	1600	No data	Slight increase in concentration in source area extraction well
		HAR-17	S	**Feb-03**	42.1	12	7.4	11	24	18	19	No data	Slight increase in concentration in source area extraction well
		RD-55A	I		24.6	130	0.18U	750	560	170	2	1.2	Variable concentration, decreasing after pumping cessation
		RD-55B	I		17.5	7.3	4.3	6.3	9.5	13	12	12	Slight increase in concentration in plume interior well
		RD-58A	I		14.0	3.1	2.1	2.3J	1.6	1.8	180	150	Increase in concentration in plume interior well
		RD-58B	B		12.1	0.5U	0.18U	0.13U	0.32U	0.32U	0.32U	No data	No appreciable change in concentration
		WS-9A	I	**Sep-05**	2.8	110	39	150	1100	440	290	No data	Variable concentration likely associated with pumping

Notes:

U - not detected at method detection limit shown
J - estimated value below method reporting limit
F - sample from discrete-interval of multi-level monitoring system
ND - not detected
ug/L - micrograms per liter
S - source area well (defined as such in October 2000 work plan)
I - plume interior well (>5 ug/L TCE or cDCE prior to extraction well shutdown)
B - plume boundary well (<5 ug/L TCE and cDCE prior to extraction well shutdown)
MDL - method detection limit
HTV - holding time violation
comp - composite sample from multiple discrete-intervals of a multi-level monitoring system
Bold vertical lines denote times when extraction wells were turned off; values immediately left of the bold lines are maximums detected that year before the pumps were turned off.
Legend for color-coding of concentration ranges (ug/L): ND | >MDL, <5 | >5, <100 | >100, <1000 | >1,000

RD-10	Well specified for monitoring in October 2000 work plan; bold indicates extraction well.
RD-75	Well added to analysis for completeness.

Table 8
Perchlorate Results Summary
SSFL Extraction Well Shutdown

Well	Mo/Yr	2000				2001				2002				2003				2004				2005				2006
	Pump Off	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WS-05	**Oct-00**	--	--	--	--	1 U	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-01	**Aug-00**	--	--	--	--	1 U	1 U	**5.8**	0.43 U	--	--	--	1.5 U	--	0.8 U	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--	--
RD-10		--	--	--	1 U	**12**	**31**	**55**	**52**	**54**	**280 F**	**180 C**	**160 C**	**160 C**	**220 C**	--	--	--	**210 C**	--	--	--	**88**	**95**	--	0.8 U
RD-02	**Sep-00**	--	--	--	--	1 U	1 U	0.43 U	0.43 U	0.43 U	0.43 U	--	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--	--
RD-44		--	--	--	1 U	--	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
WS-06	**Mar-01**	--	--	--	--	--	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--	--	--	0.8 U	0.8 U	0.8 U	--	--
RD-49A		--	--	--	--	--	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--
RD-49B		--	--	--	--	--	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--	0.8 U	0.8 U
RD-49C		--	--	--	--	--	1 U	0.43 U	0.43 U	0.43 U	0.43 U	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-04	**Dec-00**	--	--	--	--	--	--	--	--	--	--	0.43 U	1.5 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--	0.8 U	0.8 U	0.8 U	--	--
WS-09	**Jun-02**	--	--	--	--	--	--	--	--	--	--	0.43 U	1.5 U	0.8 U	0.8 U	--	--	0.8 U	0.8 U	0.8 U	0.8 U	--	--	--	--	--
HAR-20		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U	--	0.8 U
RD-09	**Dec-00**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U	--	--
RD-51A		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RD-51B		--	--	--	1 U	1 U	--	--	--	0.43 U	--	--	--	0.8 U	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-51C		--	--	--	1 U	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
HAR-07	**Nov-02**	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	--	--	--	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
HAR-08		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U
RD-41A		4 U	--	--	--	1 U	--	--	--	0.43 U	--	--	--	0.8 U	--	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-41B		4 U	--	--	--	1 U	--	--	--	0.43 U	--	--	--	0.8 U	--	--	--	0.8 U	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
HAR-18	**Nov-02**	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	--	--	--	--	--	--	--	0.8 U	0.8 U	--	--
HAR-17	**Feb-03**	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	--	--	--	--	--	--	--	--	--	--	--
RD-55A		4 U	--	--	1 U	1 U	--	--	--	0.43 U	--	--	--	0.8 U	--	--	--	0.8 U	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-55B		4 U	--	--	1 U	1 U	--	--	--	0.43 U	--	--	--	0.8 U	--	--	--	0.8 U	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-58A		--	--	--	1 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
RD-58B		--	--	--	1 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	--
WS-09A	**Sep-05**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Results of primary samples
Results in units of micrograms per liter (ug/L)
Bold vertical lines denote times when extraction wells were turned off; values immediately left of the bold lines are maximums detected that quarter before the pumps were turned off.
U = Not detected
J = Estimated value
B = Analyte detected in assocated method blank
F = Maximum concentration from FLUTe multilevel system ports
C = FLUTe composite
-- = No data

Table 9
1,4-Dioxane Results Summary
SSFL Extraction Well Shutdown

Well	Mo/Yr	2000				2001				2002				2003				2004				2005				2006
	Pump Off	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WS-05	Oct-00				20 U	20 U	20 U	3	4.64	3 U	0.32 U	0.32 U	5.86 J	2.17 J					0.28 U	2.1	0.36 U	3.2 J	2.31	2.6	2.1	2.2
RD-01	Aug-00				20 U	20 U	20 U	3 U	1 U				0.32 U						2.2		0.36 U	2 J	0.36 U	2.5		
RD-10				20 U	20 U	20 U	20 U	3 U	1 U	3 U	3 UF	0.32 UC	2.16 JC	0.448 JC	0.07 UC				0.75 JC				0.73 J	0.49 U		0.72 J
RD-02	Sep-00				20 U	20 U	20 U	3 U	1 U	3 U	0.32 U		0.32 U	1.82 J		1.64	1.8 U	2.5	0.28 U	1.8	0.36 U	2.7 J	0.36 U	2.4		
RD-44				20 U	20 U		20 U	3 U	1 U	3 U	0.32 U	0.32 U	4.17 J	0.07 U	0.147 U	0.07 U		0.28 U	0.28 U	0.28 U	0.36 U	1.6 J	0.36 U	0.49 U	0.49 U	0.49 U
WS-06	Mar-01					20 U	20 U	3 U	1 U	3 U	0.32 U	0.32 U	3.86 B	0.768 J	0.898 J	0.698 U	0.79 U	1.2				1.1	0.36 U	0.95 J		
RD-49A						20 U	20 U	3 U	1 U	3 U	0.32 U	0.32 U		0.414 J	0.65 J	0.07 U	0.68 U	0.59 J	0.28 U	0.28 U	0.903 U	2.3 J	0.36 U	0.49 U	0.49 U	
RD-49B						20 U	20 U	3 U	1 U	3 U	0.32 U	0.32 U	0.32 U	1.5 J		1.5		3	0.28 U	1.8	0.36 U	2.8 J	1.81		1.6 J	2.2
RD-49C						20 U	20 U	3 U	1 U	3 U	0.32 U	0.32 U	1.69 J	0.815 J	1.08	0.755 U	0.6 U	1	0.28 U	1.2	0.36 U	2.2 J	0.84 J	0.72 J	0.54 J	1
RD-04	Dec-00						20 U					0.32 U	0.3 U	0.265 J	0.331 U	0.249 U	0.28 U	0.36 J	0.28 U	0.28 U		1.8 J	0.36 U	1.8 U		
WS-09	Jun-02					20 U			1 U			0.32 U	0.32 U	1.93 J				1.21	0.28 U	0.28 U						
HAR-20						20 U																	3.86	3.6		5.8
RD-09	Dec-00	3 U				20 U																	0.36 U	2.2		
RD-51A																										
RD-51B					20 U	20 U														0.28 U	0.36 U	1.9 J	0.36 U	0.49 U	0.49 U	0.49 U
RD-51C				20 U	20 U	20 U	20 U													0.28 U	0.36 U	1.6 J	0.36 U	0.49 U	0.49 U	0.49 U
HAR-07	Nov-02		1.1 U			20 U	20 U				0.32 U				0.07 U				0.28 U			1.3	0.36 U	2.4 UJ	0.49 U	1.2 J
HAR-08																									1.1 J	1.3
RD-41A						20 U														0.28 U		1.9 J	0.36 U	0.49 U	0.49 U	0.49 U
RD-41B						20 U														0.28 U	0.36 U	0.36 U	1.14	0.68 J	1 J	1.3
HAR-18	Nov-02						20 U																17.9	25		
HAR-17	Feb-03		1.1 U		20 U		20 U				0.32 U				5.44				3.28				1.4			
RD-55A					20 U	20 U														0.28 U	0.36 U	1.5 J	0.36 U	0.49 UJ	0.49 U	0.49 U
RD-55B					20 U	20 U														0.28 U	0.36 U	1.7 J	0.36 U	0.49 UJ	0.49 U	0.49 U
RD-58A					20 U	20 U			1 U											0.28 U	0.36 U	2 J	0.36 U	0.49 U	0.49 U	0.49 U
RD-58B				20 U	20 U	20 U	20 U													0.28 U	0.36 U	1.7 J	0.58 J	0.49 J	0.49 U	
WS-09A	Sep-05					20 U			3 U																	

Results of primary samples
Results in units of micrograms per liter (ug/L)
Bold vertical lines denote times when extraction wells were turned off; values immediately left of the bold lines are maximums detected that quarter before the pumps were turned off.
U = Not detected
J = Estimated value
B = Analyte detected in assocated method blank
F = Maximum concentration from FLUTe multilevel system ports
C = FLUTe composite
-- = No data

Table 10
NDMA Results Summary
SSFL Extraction Well Shutdown

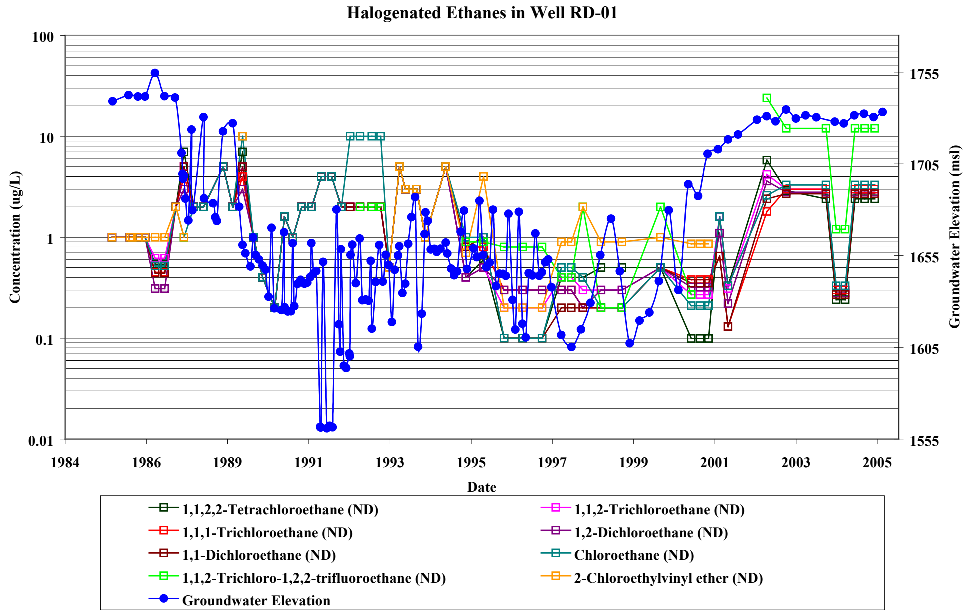
Well	Mo/Yr	2000				2001				2002				2003				2004				2005				2006
	Pump Off	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WS-05	**Oct-00**	--	--	--	--	0.02 U	1.9 U	10 U	**0.0026 B**	**0.0013 JB**	0.002 U	0.002 U	0.0005 U	0.0005 U	0.0007 U	--	--	--	0.0006 U	0.0006 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
RD-01	**Aug-00**	--	--	--	--	0.02 U	0.034 U	10 U	**0.0097 B**	--	--	--	**0.056**	--	0.0007 U	--	--	--	**0.0504**	**0.0329**	**0.0354**	**0.0202**	**0.0199**	**0.0256**	--	--
RD-10		--	--	--	0.02 U	0.02 U	1.9 U	0.002 U	0.0022 U	0.0012 U	0.0012 UJF	0.002 UC	0.0005 UC	0.0005 UC	0.0007 UC	--	--	--	10 UC	0.0006 U	--	--	0.0005 U	0.01 U	--	0.01 U
RD-02	**Sep-00**	--	--	--	--	0.02 U	**0.034**	10 U	0.002 U	0.0018 U	0.002 U	--	**0.011**	**0.0058**	**0.0062**	**0.0074**	3 U	**0.008**	**0.0068**	**0.0079**	**0.0081**	**0.0082**	**0.0075**	0.01 U	--	--
RD-44		--	--	--	0.02 U	--	1.9 U	10 U	0.0042 U	0.0018 U	0.002 U	0.004 U	0.0005 U	0.0005 U	0.0007 U	**0.00081**	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
WS-06	**Mar-01**	--	--	--	--	--	1.9 U	10 U	**0.0019 J**	**0.0018 JB**	0.002 U	**0.0022 J**	0.0005 U	0.0005 U	0.0007 U	0.0014 U	3 U	0.0005 U	--	--	--	**0.0008**	0.0005 U	0.01 U	--	--
RD-49A		--	--	--	--	--	1.9 U	10 U	**0.0042**	**0.0014 JB**	0.002 U	**0.0025**	0.0005 U	0.0005 U	**0.0018 J**	**0.0028**	3 U	**0.0018 J**	0.0018 U	0.0013 U	0.002 U	**0.0012 J**	**0.001 J**	0.01 U	0.01 U	--
RD-49B		--	--	--	--	--	1.9 U	10 U	**0.069 J**	**0.056**	**0.041**	**0.047**	**0.017**	**0.051**	**0.049**	**0.066**	3 U	**0.0703**	**0.0709**	**0.0659**	**0.0717**	**0.0642**	**0.0514**	--	**0.0496**	**0.0502**
RD-49C		--	--	--	--	--	1.9 U	10 U	**0.016 J**	**0.022**	**0.011**	**0.015**	**0.021**	**0.014**	**0.014**	3 U	3 U	**0.0137**	**0.0143**	3.7 U	**0.0153**	**0.0122**	**0.0136**	**0.0114**	0.01 U	0.01 U
RD-04	**Dec-00**	--	--	--	--	--	--	--	--	--	--	0.002 U	**0.026**	0.0005 U	**0.038**	0.0024 U	3 U	0.0005 U	0.0005 U	0.0007 U	--	0.0005 U	0.0005 U	0.01 U	--	--
WS-09	**Jun-02**	--	--	--	--	--	--	--	--	--	--	**0.0023**	**0.0058**	0.0005 U	**0.003**	--	--	**0.0021**	0.0024 U	0.0026 U	**0.0029**	--	--	--	--	--
HAR-20		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.0013 J**	**0.0871**	--	**0.0645**
RD-09	**Dec-00**	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.01 U	--	--
RD-51A		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RD-51B		--	--	--	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	**0.0005 J**	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
RD-51C		--	--	--	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
HAR-07	**Nov-02**	--	0.02 U	--	--	--	0.02 U	--	--	--	**0.062**	--	--	--	**0.055**	--	--	--	**0.0642 J**	--	--	**0.0248 J**	**0.027**	**0.0587**	**0.0472**	**0.05**
HAR-08		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.0169**	0.01 U
RD-41A		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.7 U	0.0006 U	**0.0006 J**	0.0005 U	0.01 U	0.01 U	0.01 U
RD-41B		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.001 U	**0.001 J**	**0.0039 J**	**0.0015 J**	0.01 U	0.01 U	0.01 U
HAR-18	**Nov-02**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	**0.3182**	**0.3472**	--	--
HAR-17	**Feb-03**	--	0.02 U	--	--	--	**0.038 J**	--	--	--	**0.082**	--	--	--	**0.033**	--	--	--	**0.0211 J**	--	--	--	**0.0145**	--	--	--
RD-55A		--	--	--	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
RD-55B		--	--	--	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
RD-58A		--	--	--	0.02 U	--	--	--	0.002 U	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	0.01 U
RD-58B		--	--	--	0.02 U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.01 U	0.01 U	--
WS-09A	**Sep-05**	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

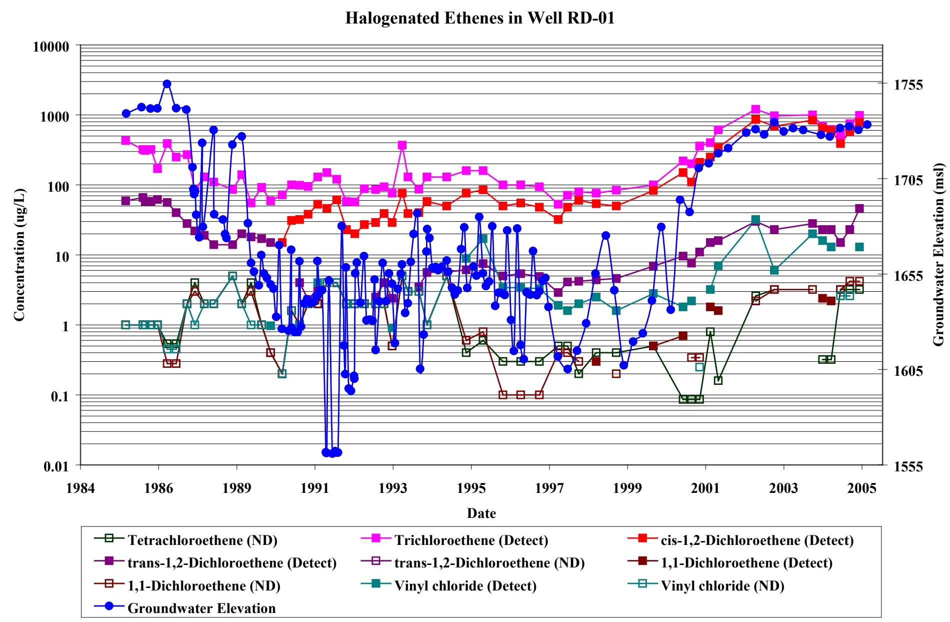
Results of primary samples
Results in units of micrograms per liter (ug/L)
Bold vertical lines denote times when extraction wells were turned off; values immediately left of the bold lines are maximums detected that quarter before the pumps were turned off.
U = Not detected
J = Estimated value
B = Analyte detected in assocated method blank
F = Maximum concentration from FLUTe multilevel system ports
C = FLUTe composite
-- = No data

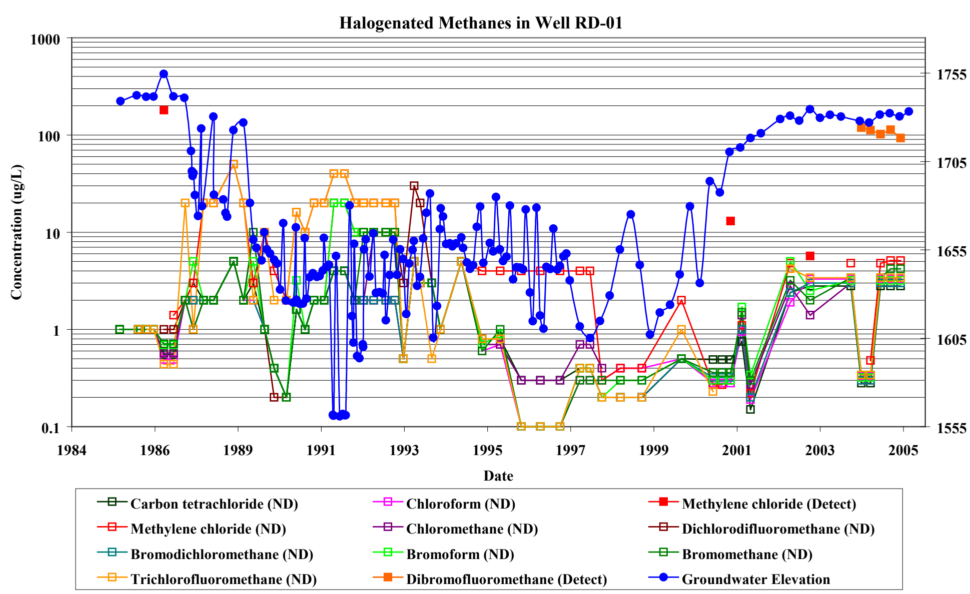
APPENDICES

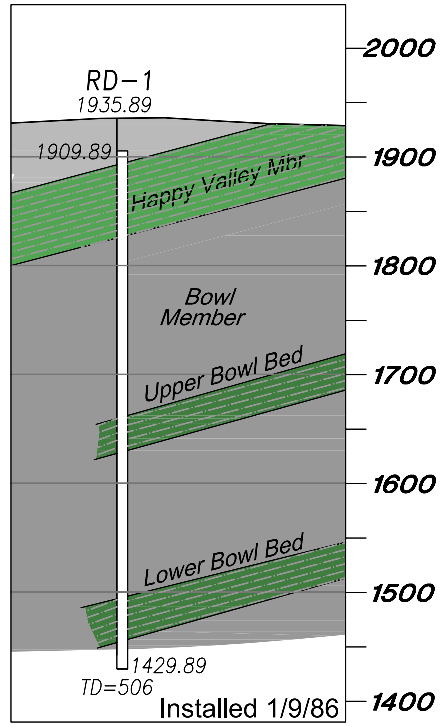
APPENDIX A

JOB No.________________ FILE: ______________________________________









Other Data:	Value	Units
1,4-dioxane:	2.1 (Avg)	ug/L
Perchlorate:	1.2 (Avg)	ug/L
Nitrate as NO_3:	0.7 (Avg)	mg/L
Sulfate:	104.4 (Avg)	mg/L
Chloride:	39.67 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.24/-40.23	permil
^{3}H:	1.75r ± 0.09	TU

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Perchlorate analyzed 16 times 1 detect-5.9 ug/L

Tritium (^{3}H) sampled 9/92

Location of high-resolution fluid temperature logging (by Pehme)

Grid Location C8

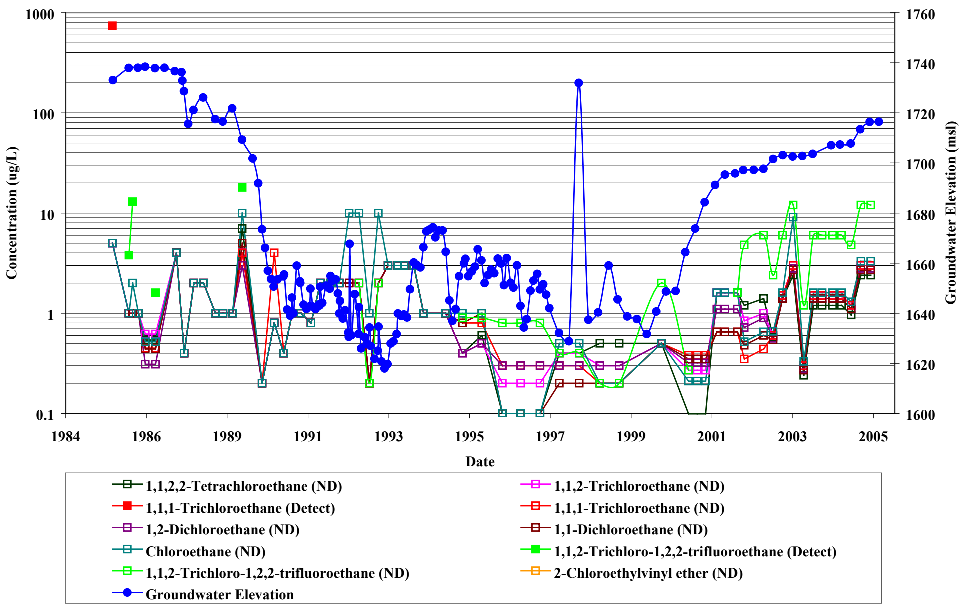
MWH

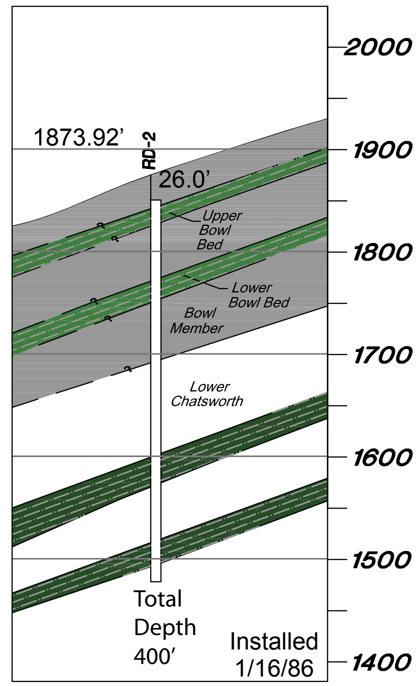
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-1

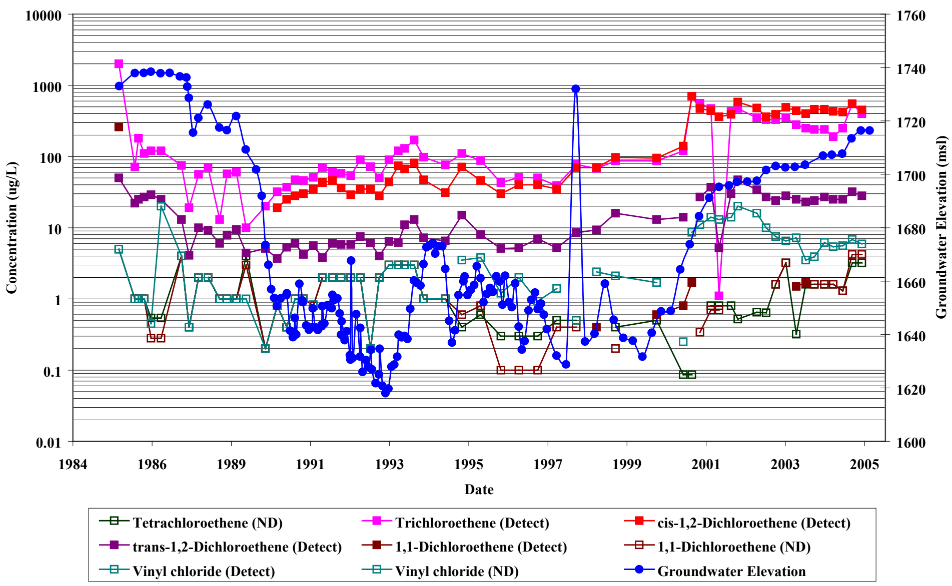
JOB No.__________________ FILE: ____

Halogenated Ethanes in Well RD-02





Halogenated Ethenes in Well RD-02



Other Data:	Value	Units
1,4-dioxane:	1.9 (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.2 (Avg)	mg/L
Sulfate:	167.4 (Avg)	mg/L
Chloride:	65.5 (Avg)	mg/L
$^{18}O/^{2}H$:	-6.66/-44.94	permil
^{3}H:	NA	TU

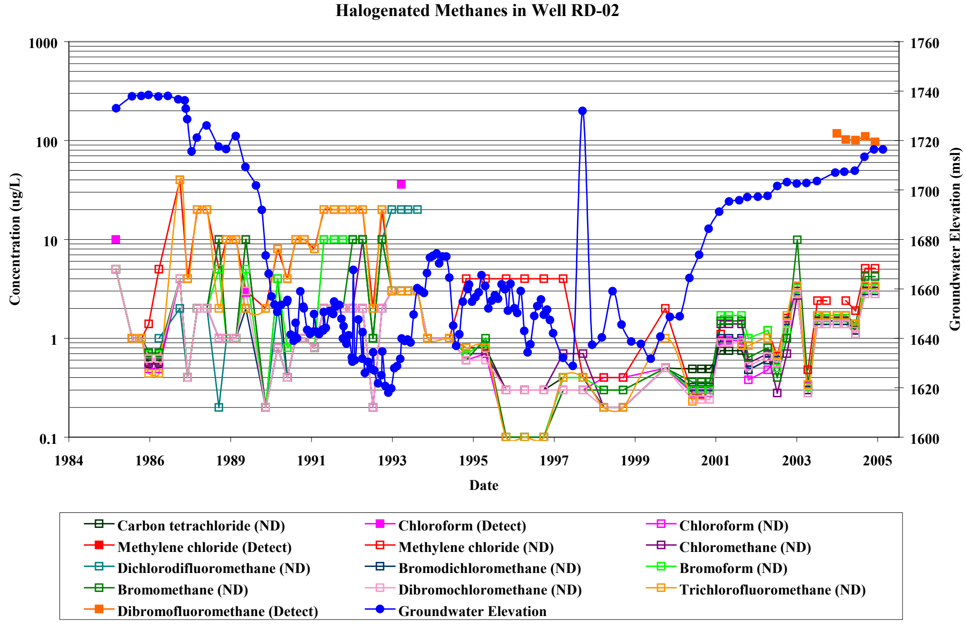
Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

1,4-dioxane: 26 analyses/7 detections

Halogenated Methanes in Well RD-02



Grid Location C7

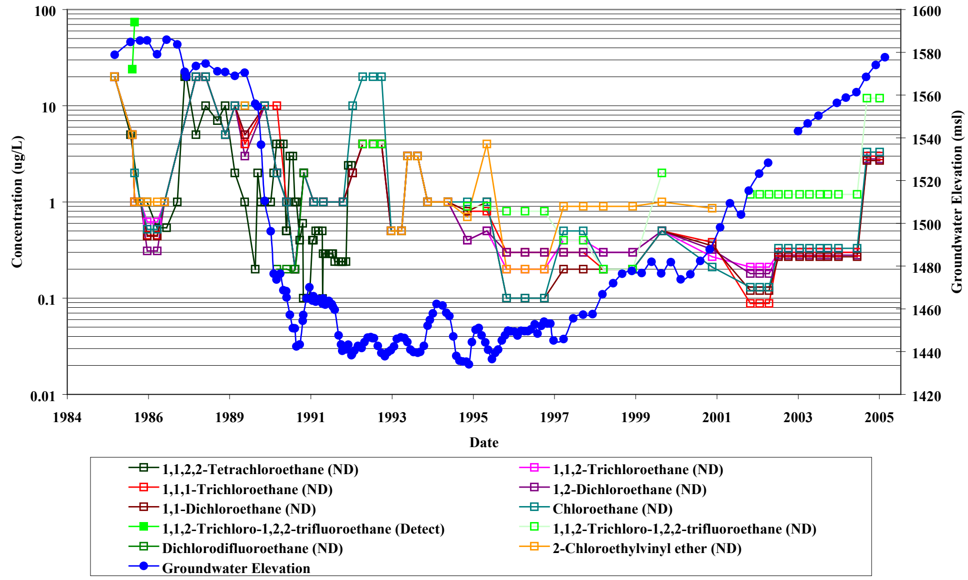
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

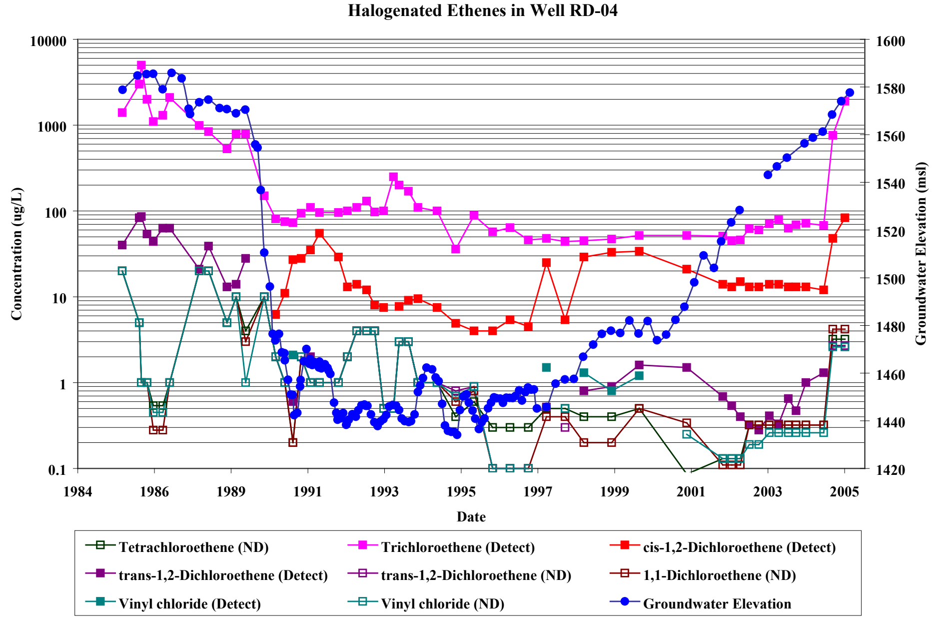
RD-2

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 4

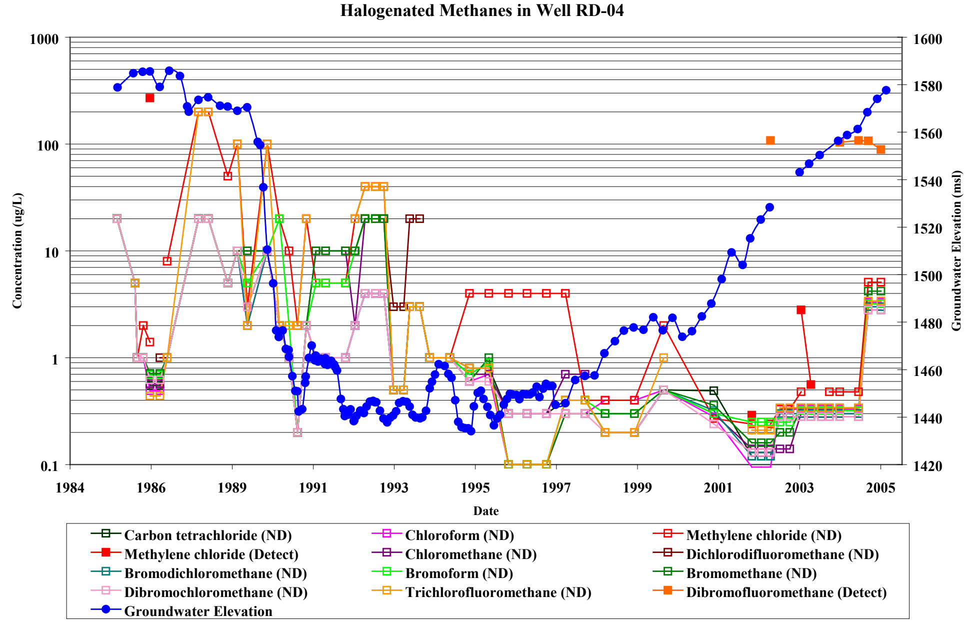
Halogenated Ethanes in Well RD-04

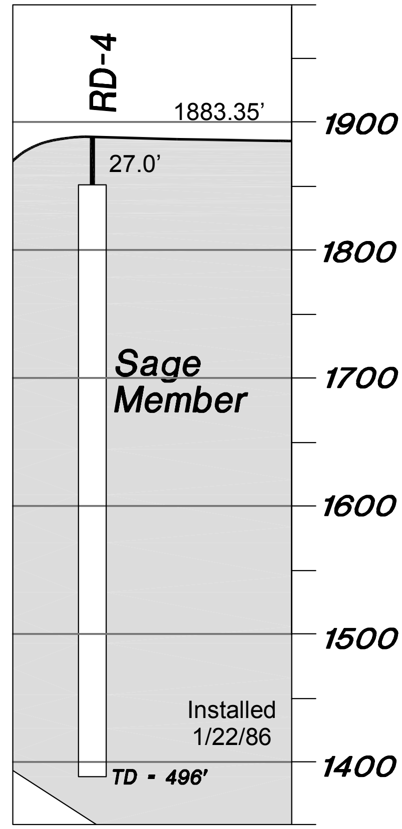


Halogenated Ethenes in Well RD-04



Halogenated Methanes in Well RD-04





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	ND (Avg)	mg/L
Sulfate:	147 (Avg)	mg/L
Chloride:	40.6 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.22/-41.78	permil
^{3}H:	0.28 ± 0.09	TU

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Tritium (^{3}H) sampled 6/90

Grid Location C5

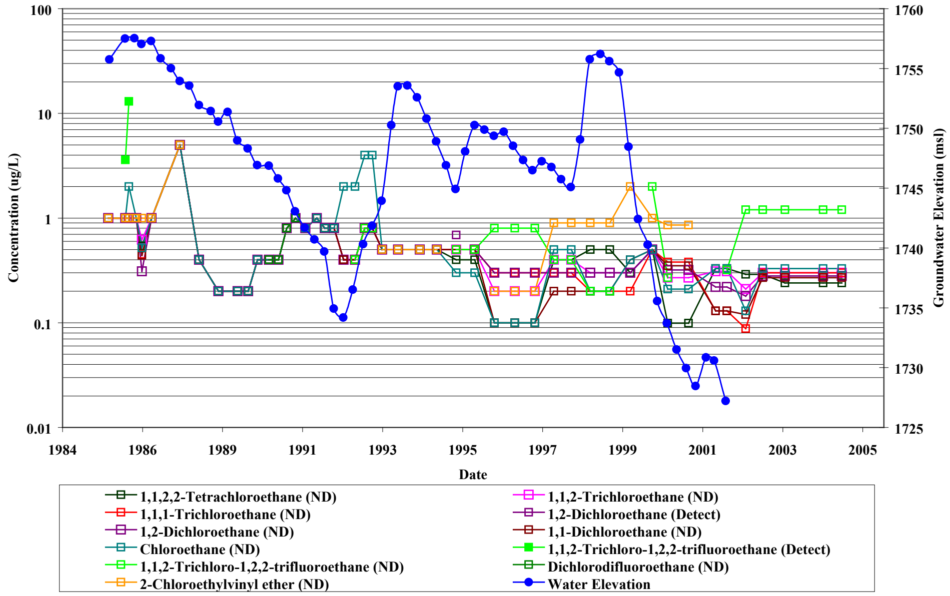
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

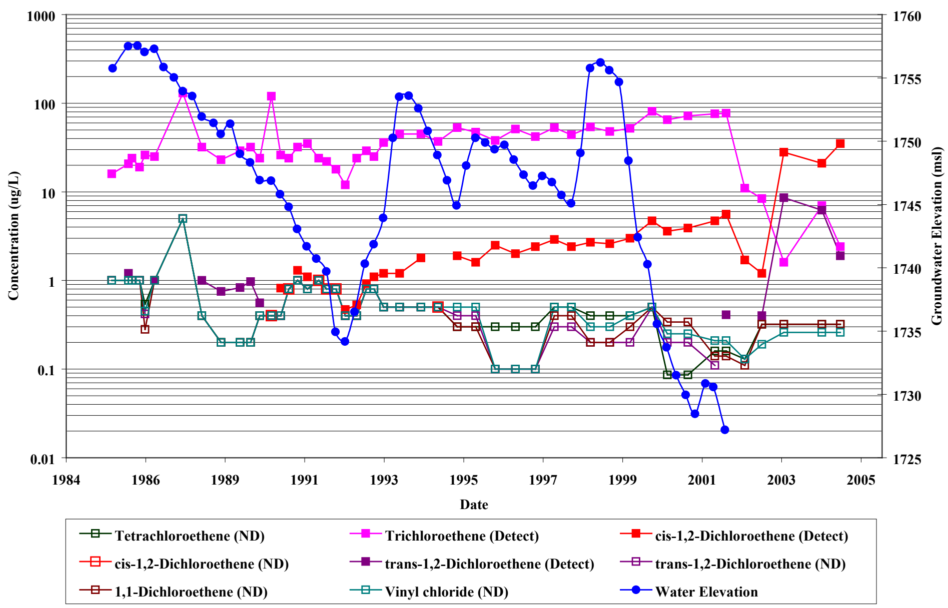
RD-4

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD-7

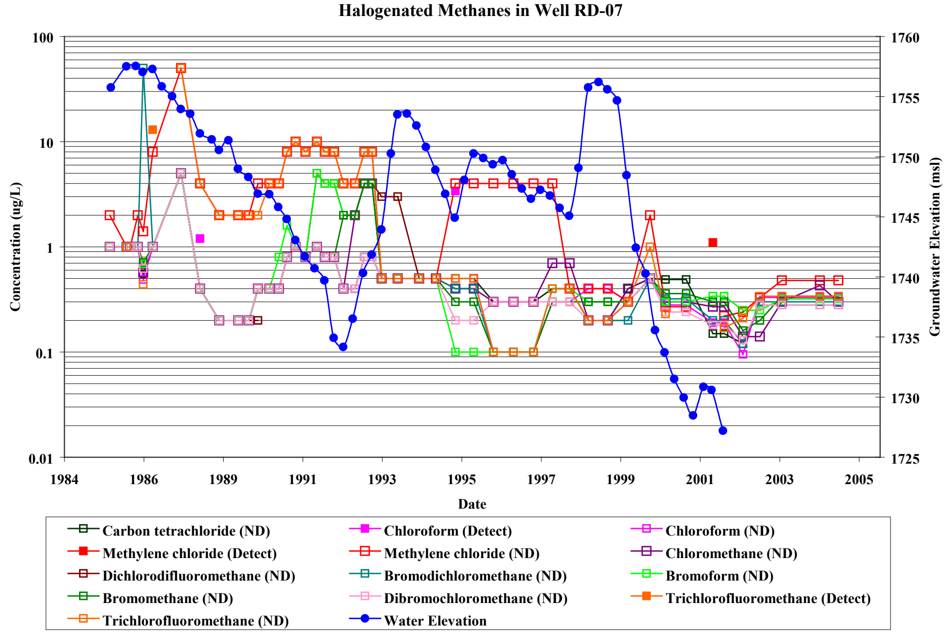
Halogenated Ethanes in Well RD-07

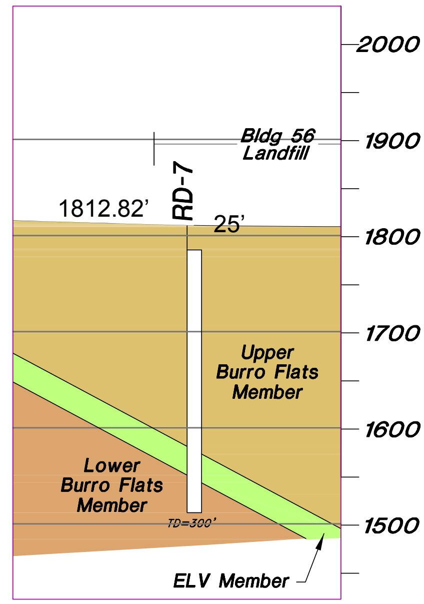


Halogenated Ethenes in Well RD-07



Halogenated Methanes in Well RD-07





Installed 1/8/86

Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	1.23 (Avg)	ug/L
Nitrate as NO_3:	15.5 (Avg)	mg/L
Sulfate:	89.5 (Avg)	mg/L
Chloride:	47.8 (Avg)	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	10.0 ± 7.96	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Perchlorate detected in Port 4; 3.7J in Port 7-11ug

Tritium (^{3}H) sampled 9/87

Multi-level installed 4/2002

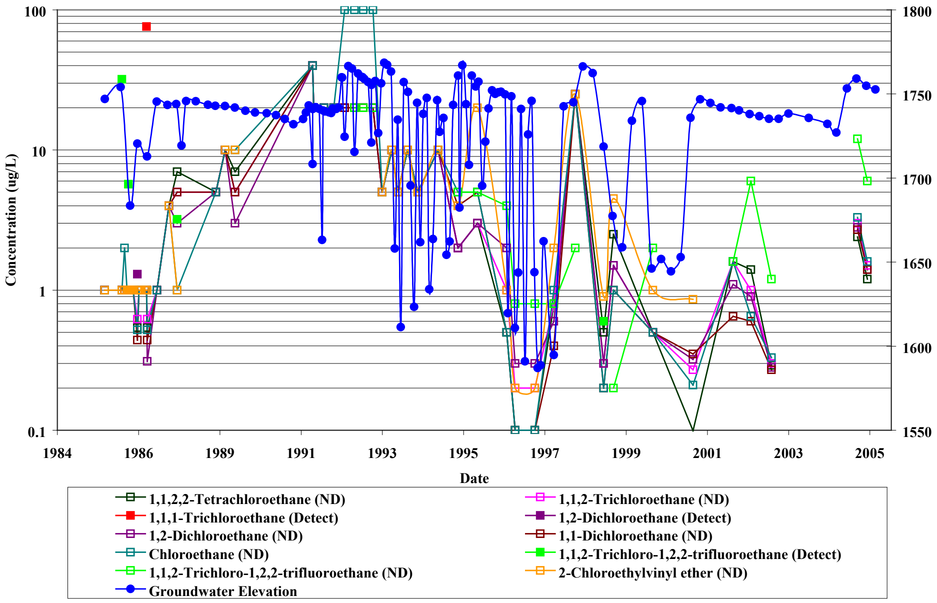
Grid Location C2

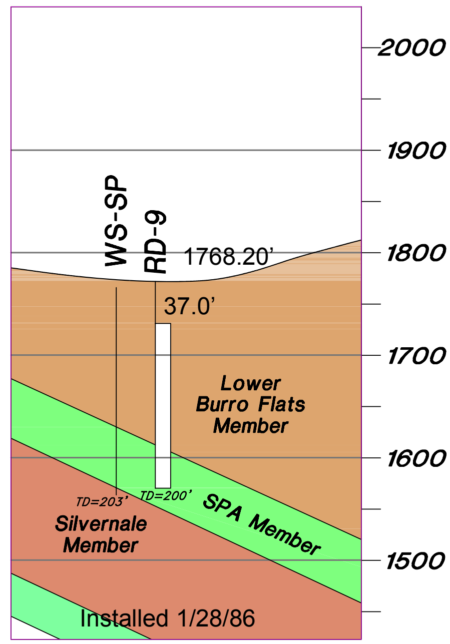
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

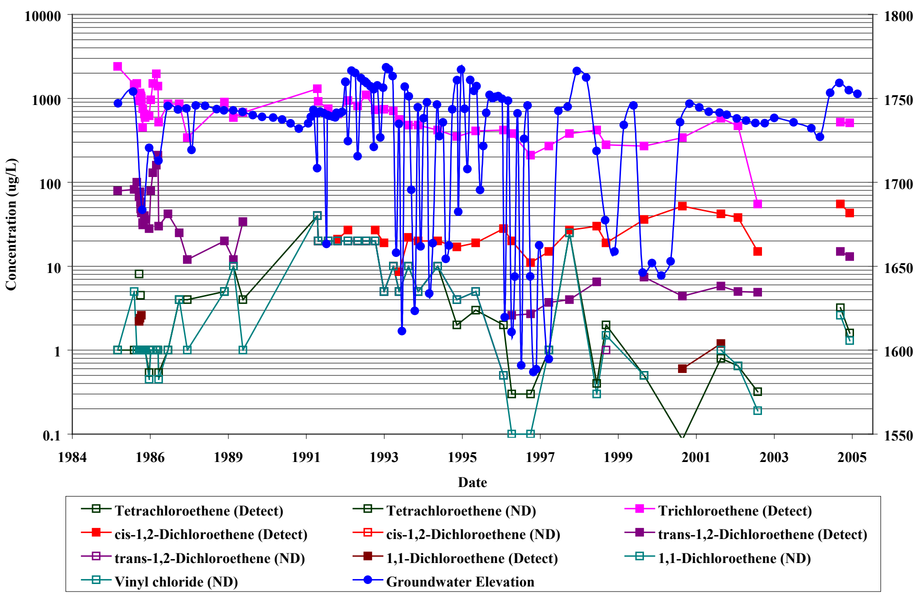
RD-7

Halogenated Ethanes in Well RD-09





Halogenated Ethenes in Well RD-09



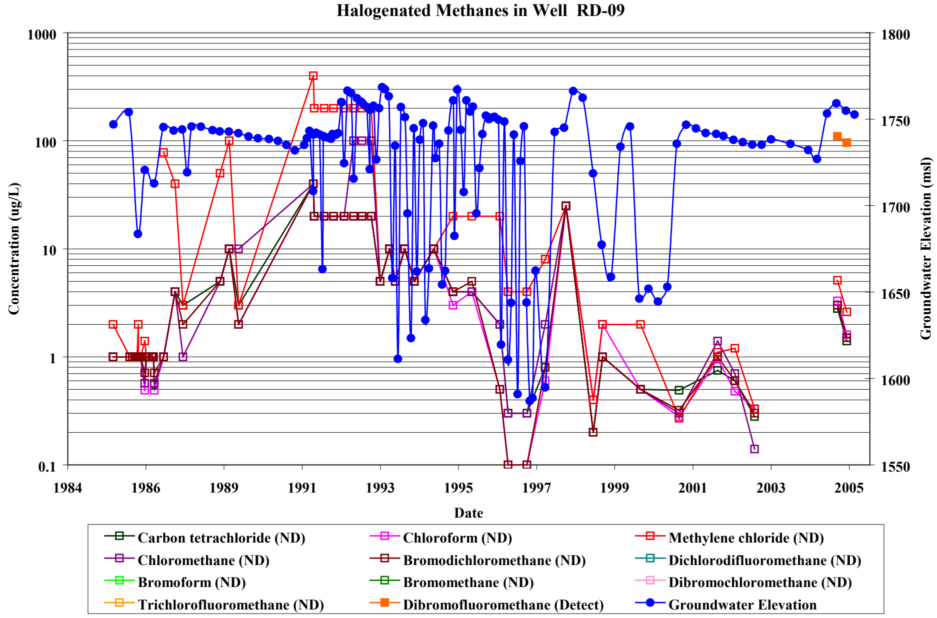
Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	0.8 (Avg)	mg/L
Sulfate:	227.5 (Avg)	mg/L
Chloride:	37.7 (Avg)	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Halogenated Methanes in Well RD-09



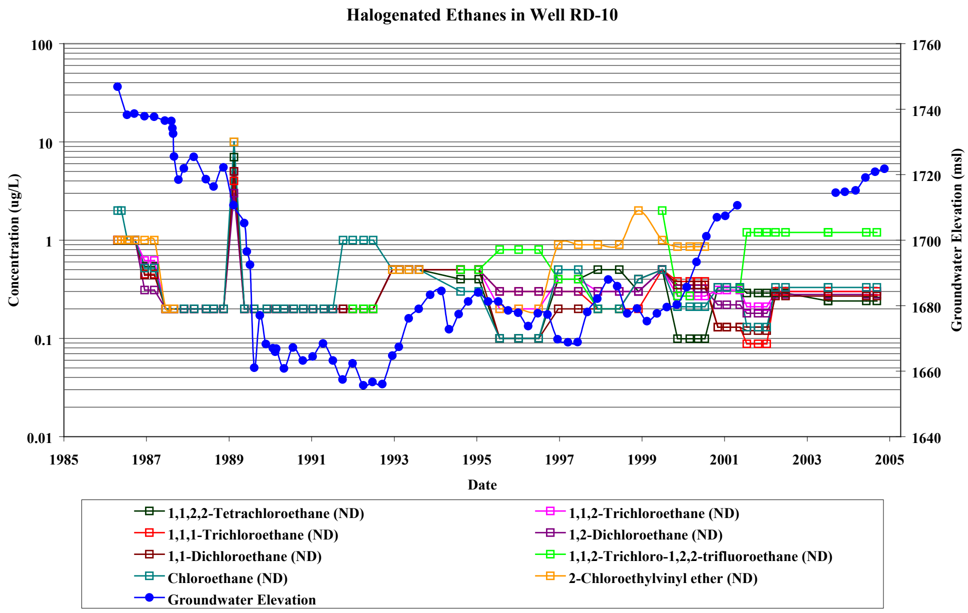
Grid Location B5

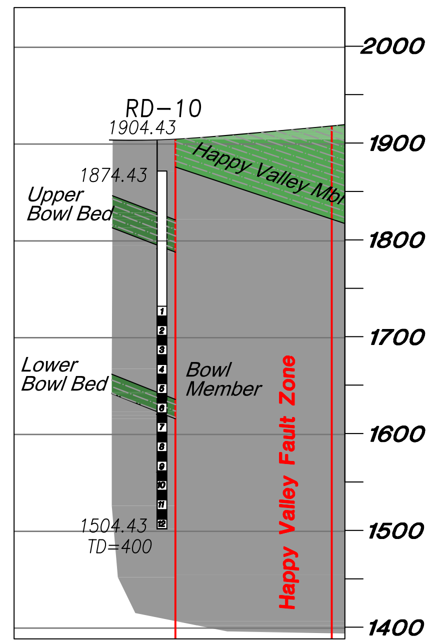
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-9

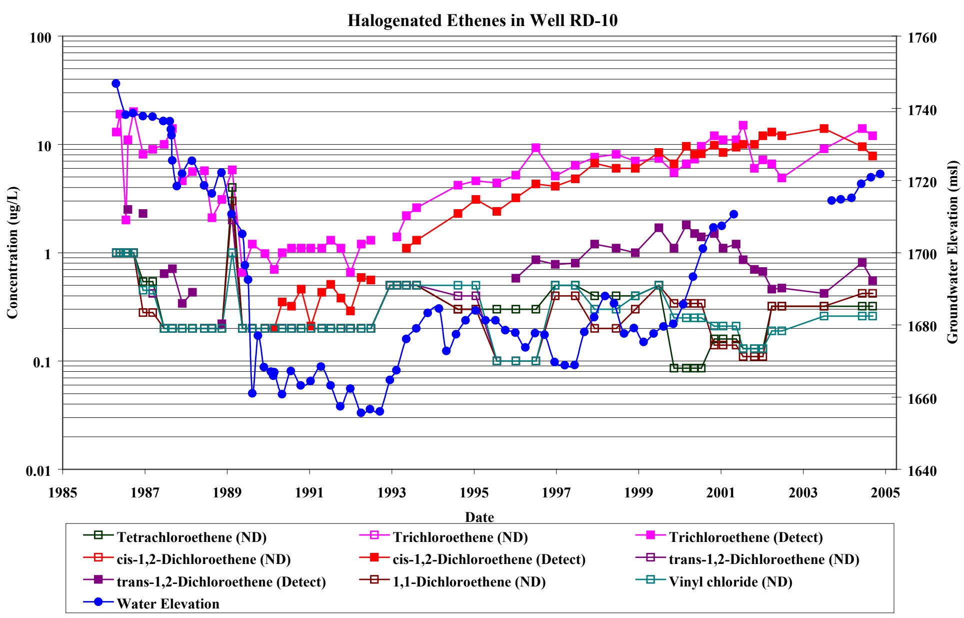
JOB No.____________ FILE: ______________________________

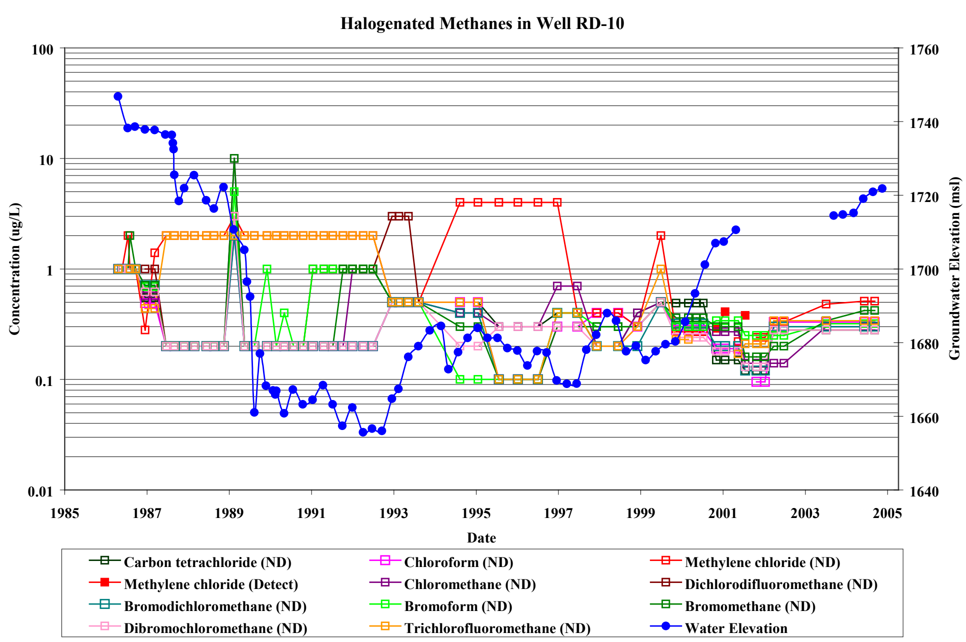




Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	112.2 (Avg)	ug/L
Nitrate as NO_3:	0.6 (Avg)	mg/L
Sulfate:	122 (Avg)	mg/L
Chloride:	44.4 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.3/-42.58	permil
^{3}H:	0.39r ± 0.09	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
Tritium (^{3}H) sampled 6/90

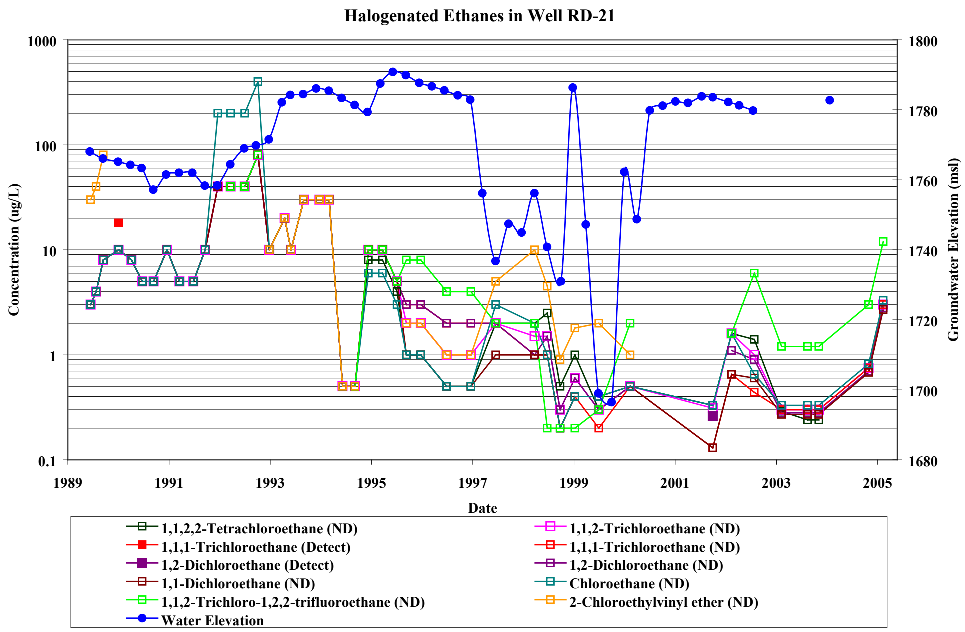


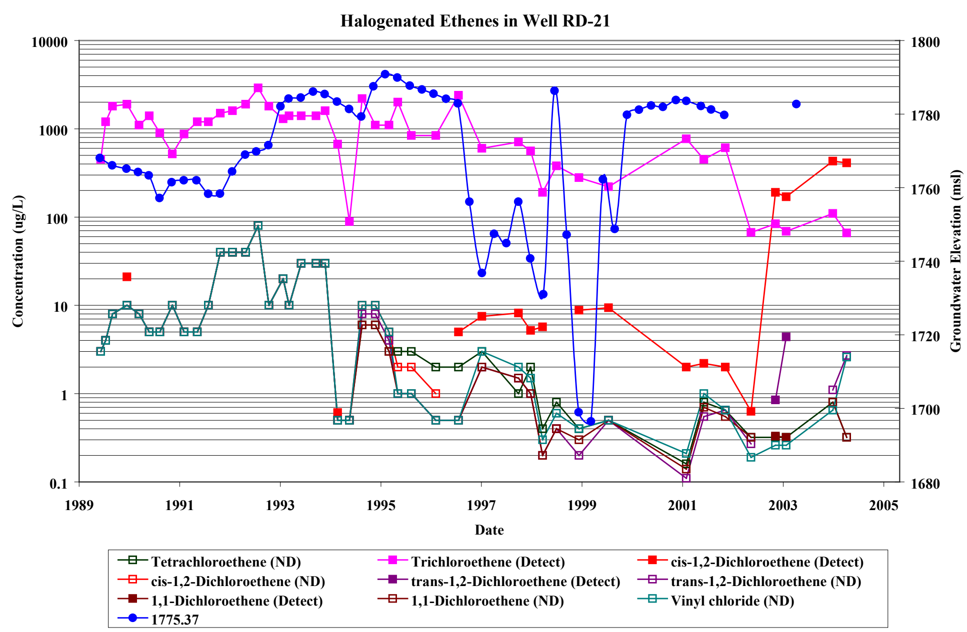


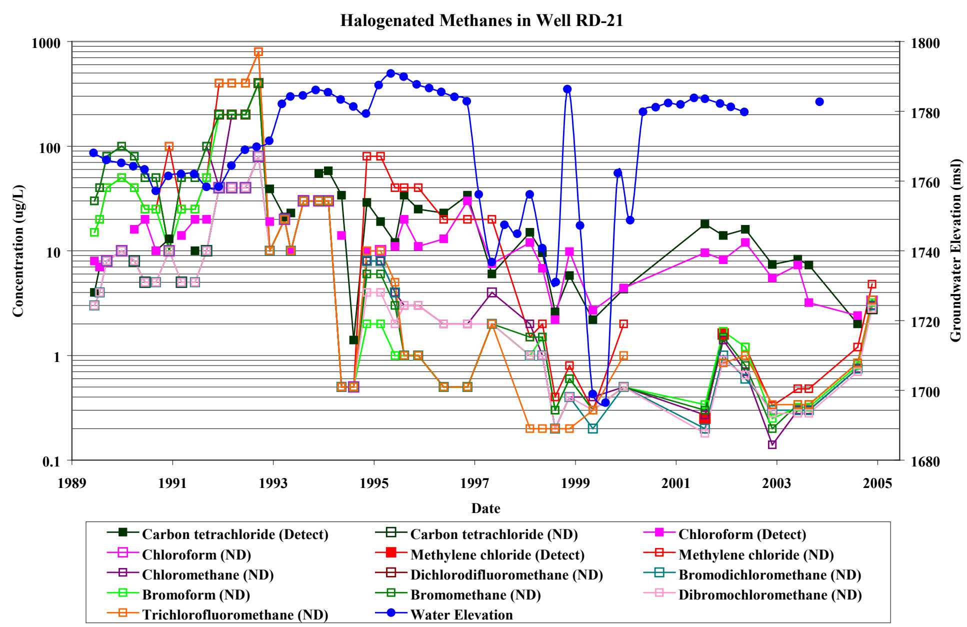
MWH

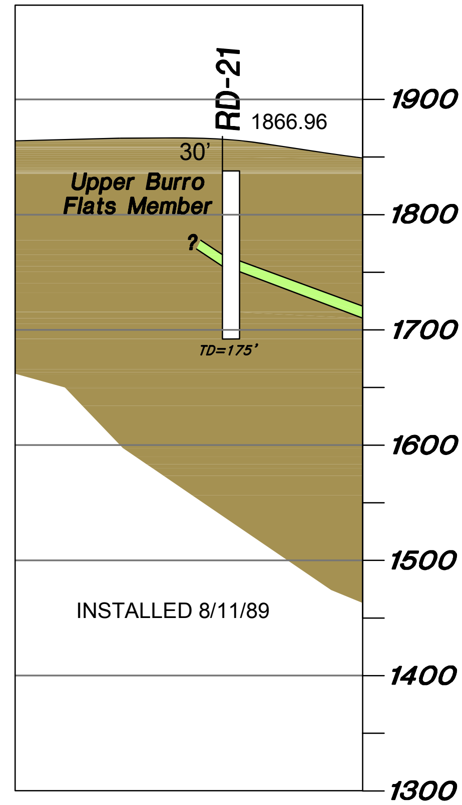
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD 10









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	7.9 (Avg)	ug/L
Nitrate as NO_3:	10.2	mg/L
Sulfate:	56	mg/L
Chloride:	85	mg/L
$^{18}O/^{2}H$:	-6.69/-45.17	permil

(detected in Port 2 of multi-level)

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

B = blank contamination J = estimated value

Multi-level installed 1/14/03

Well used for groundwater extraction between 1997 - 2000 as interim measure

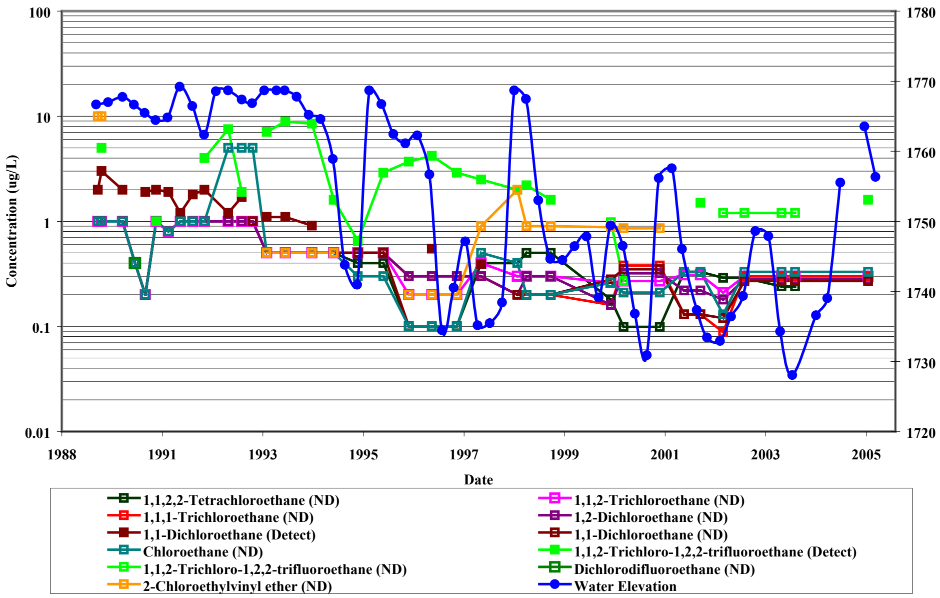
Grid Location C2

MWH

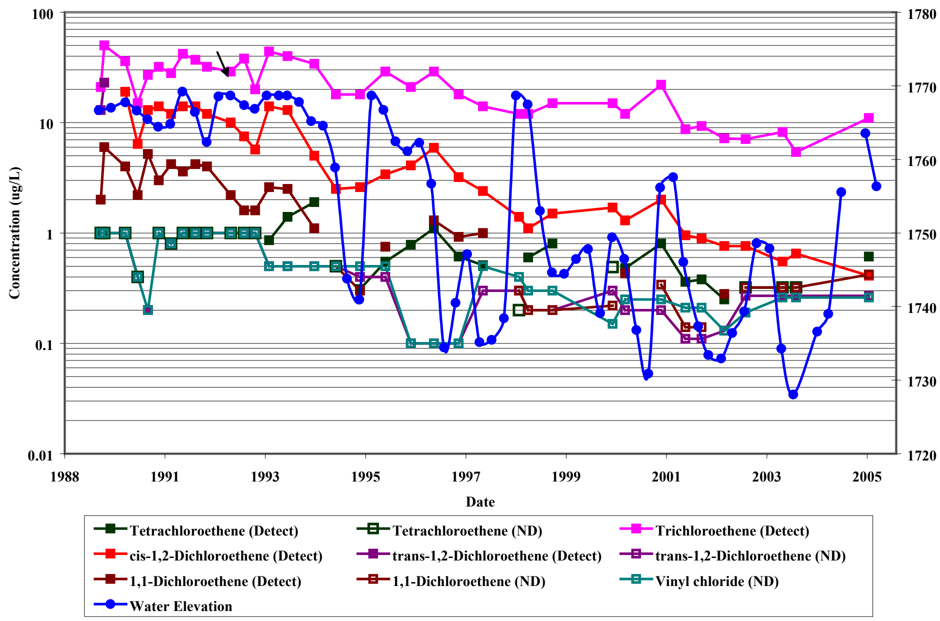
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-21

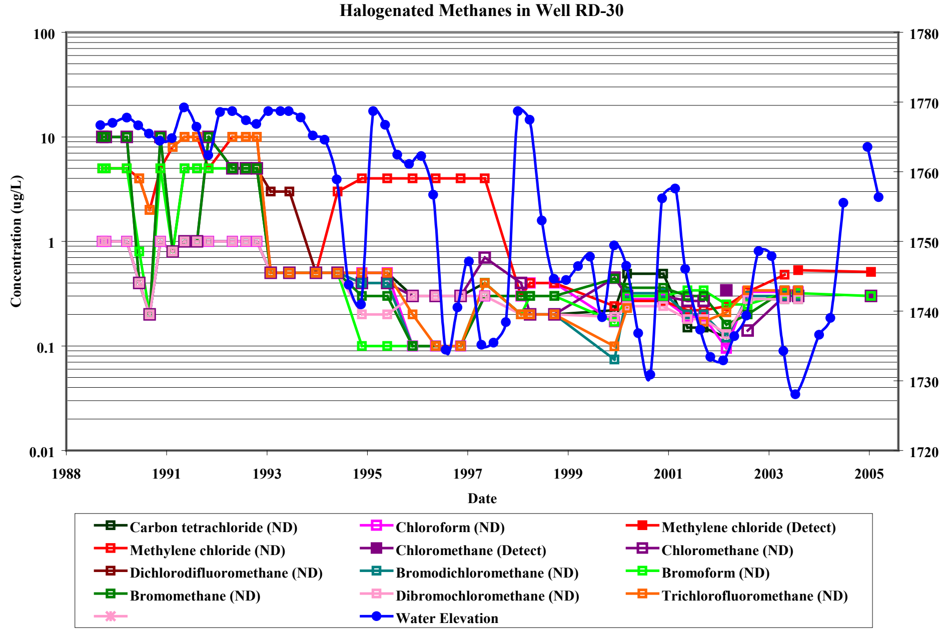
Halogenated Ethanes in Well RD-30

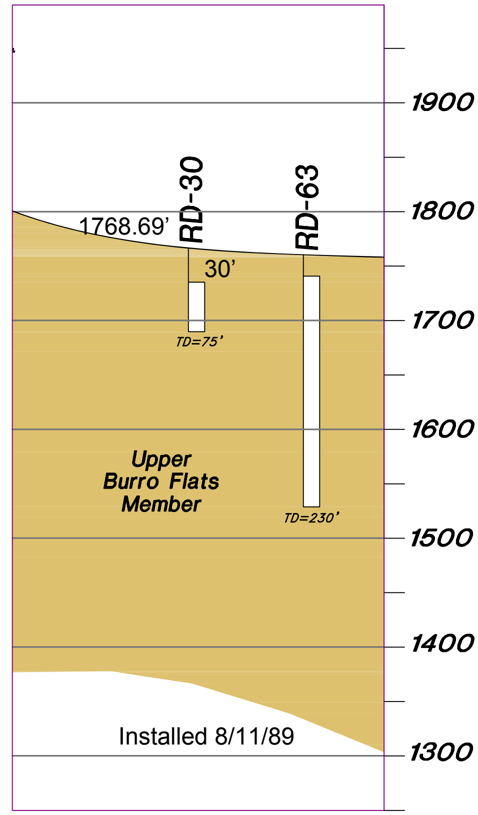


Halogenated Ethenes in Well RD-30



Halogenated Methanes in Well RD-30





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	10.6	mg/L
Sulfate:	130	mg/L
Chloride:	52.8	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

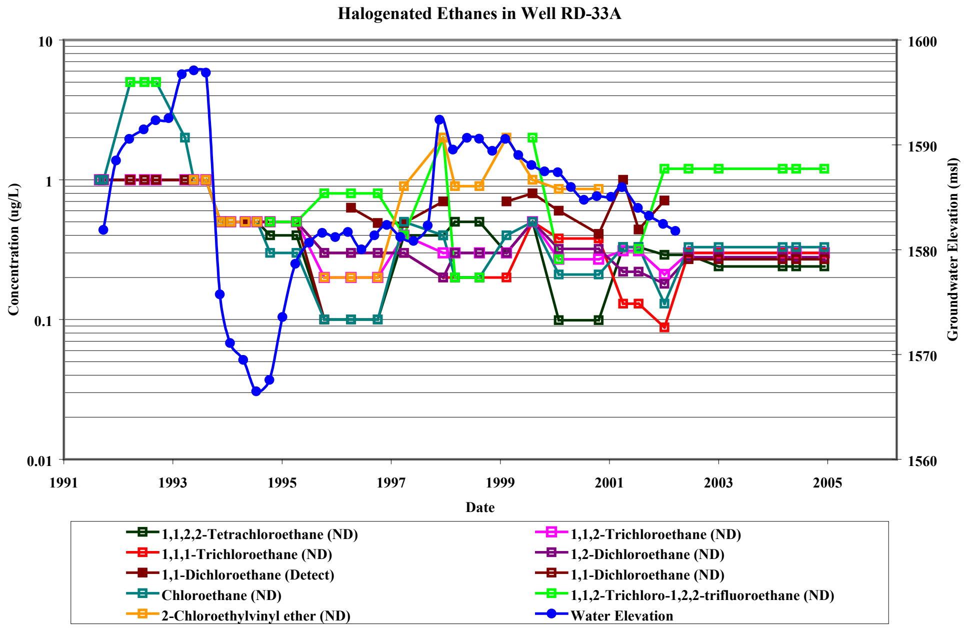
Avg - multiple results, average concentration

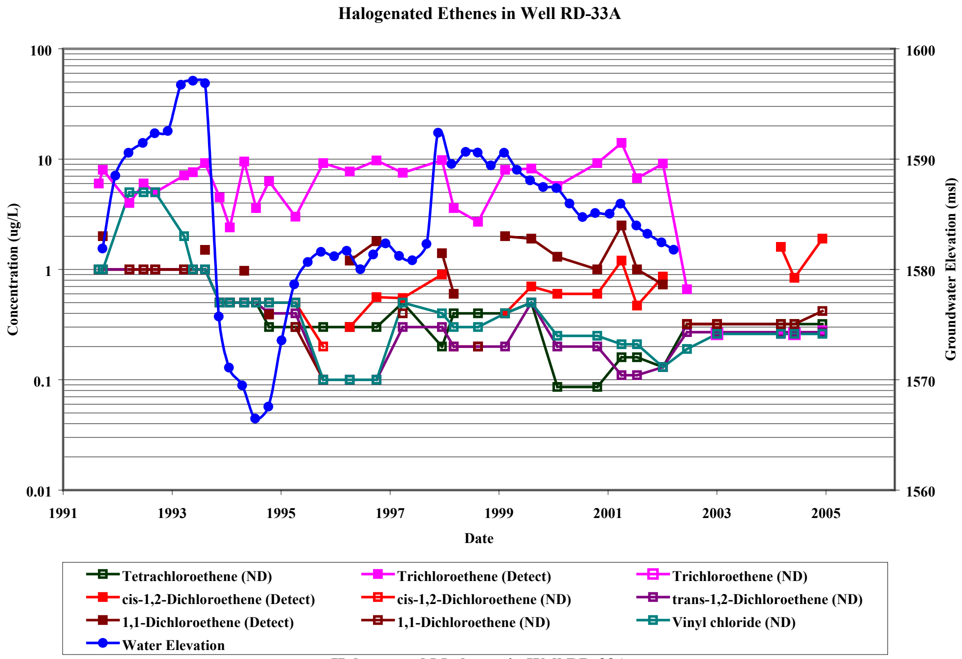
MWH

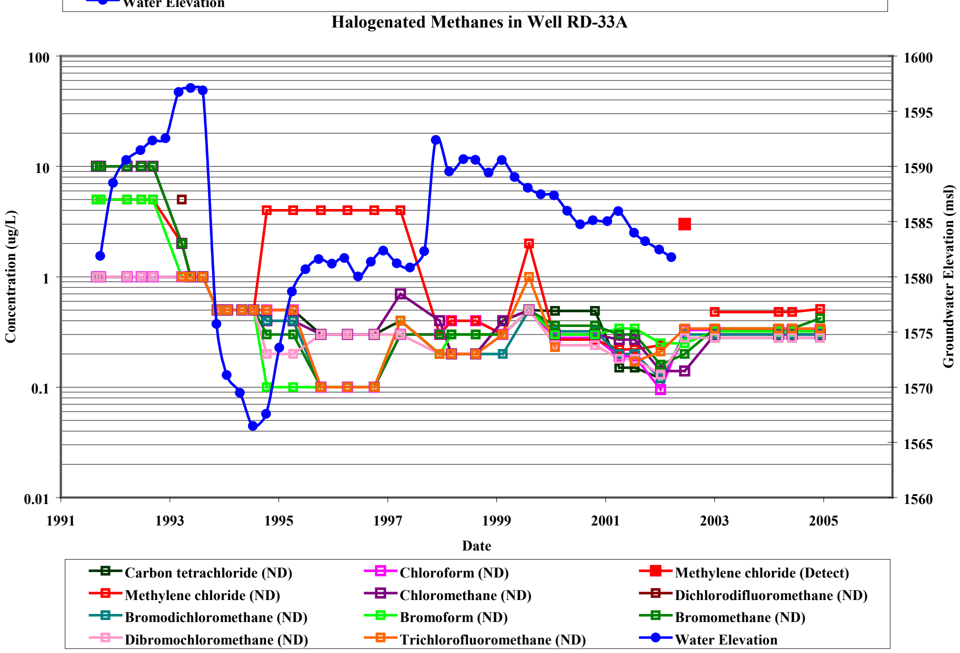
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

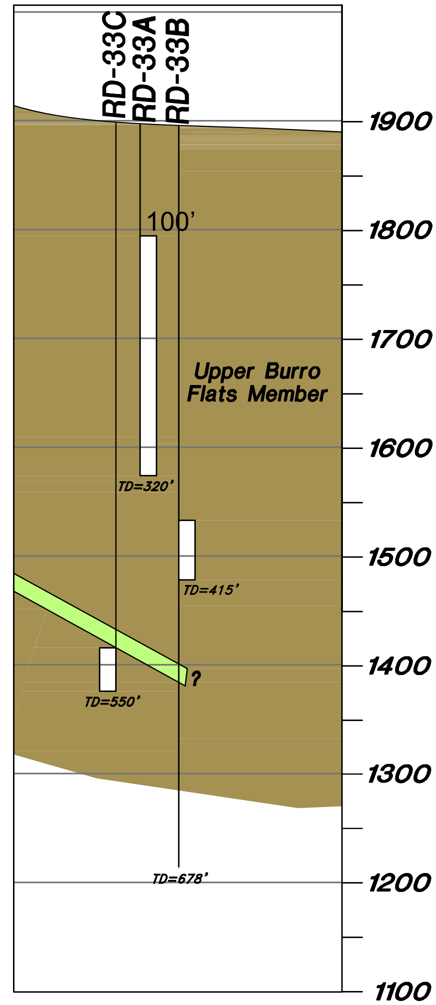
RD-30

JOB No.________________ FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK\RD 33A B C









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	1.13 (Avg)	ug/L
Nitrate as NO_3:	ND	mg/L
Sulfate:	132	mg/L
Chloride:	363/35	mg/L
$^{18}O/^{2}H$:	-7.14/-46.98	permil
	(port 2 of multi-level)	

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Perchlorate: 1 detect at 3.8 ug/L J

Multi-level installed 1/2003

Grid Location C2

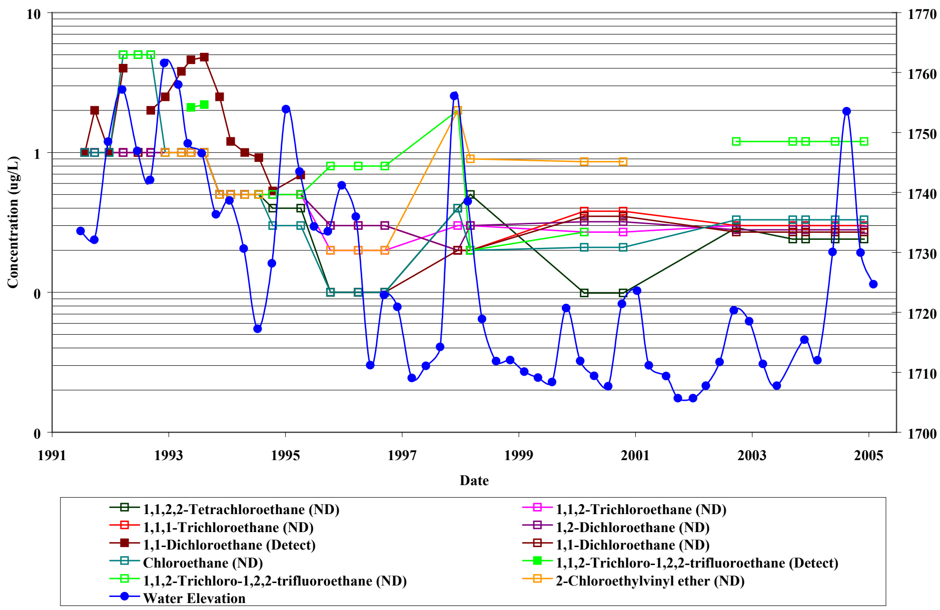
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

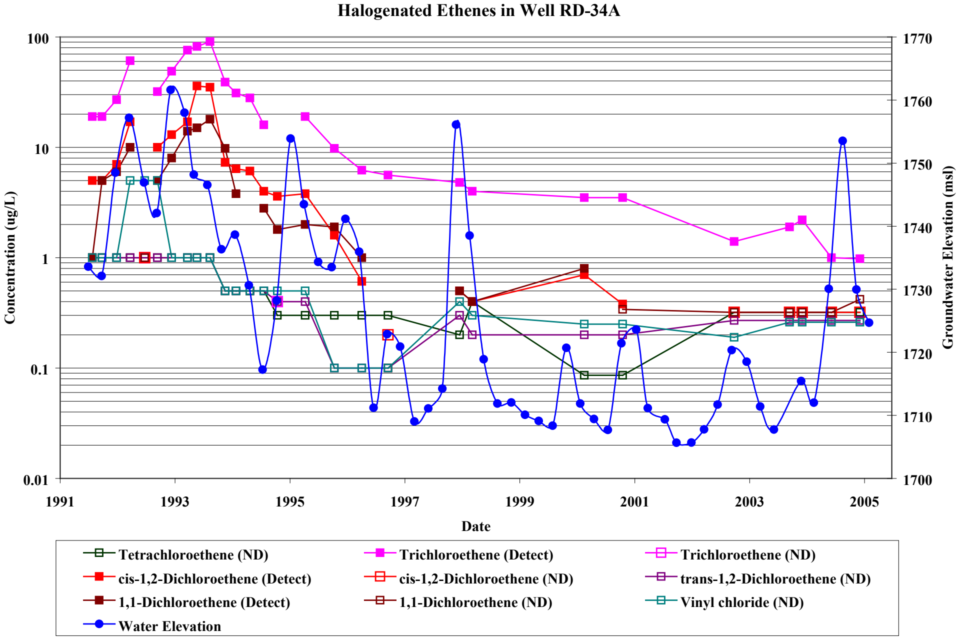
RD-33A

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 34 ABC

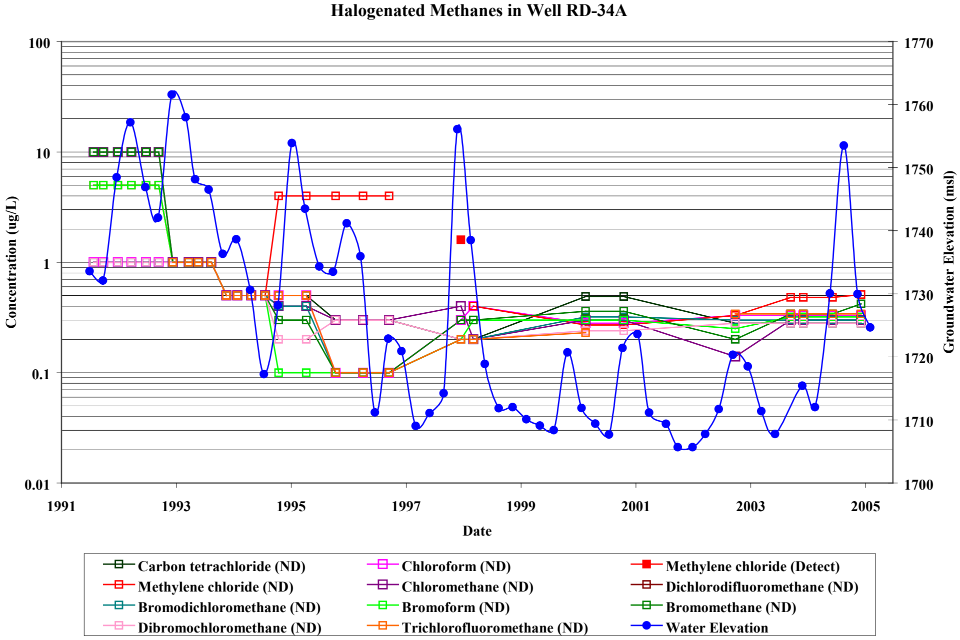
Halogenated Ethanes in Well RD-34A

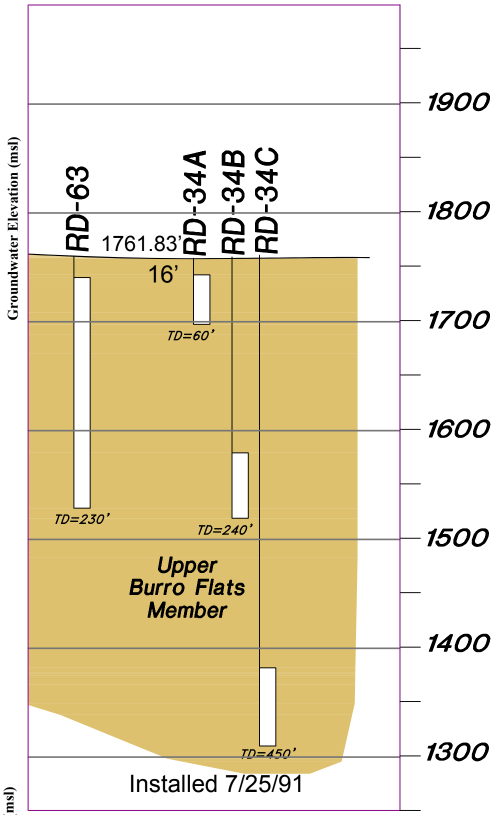


Halogenated Ethenes in Well RD-34A



Halogenated Methanes in Well RD-34A





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	0.73	mg/L
Sulfate:	192	mg/L
Chloride:	NA	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

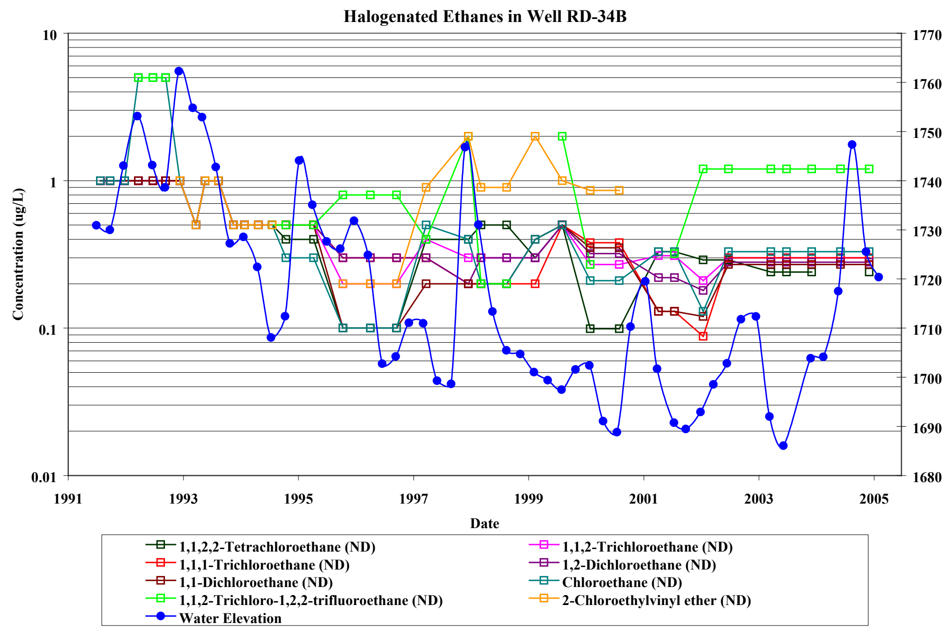
Avg - multiple results, average concentration

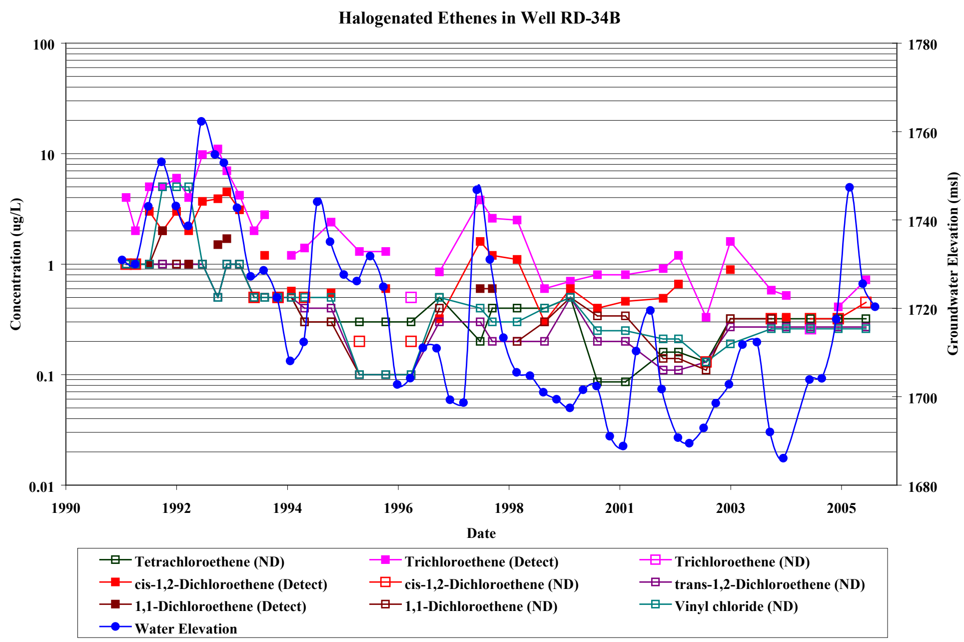
Grid Location B3

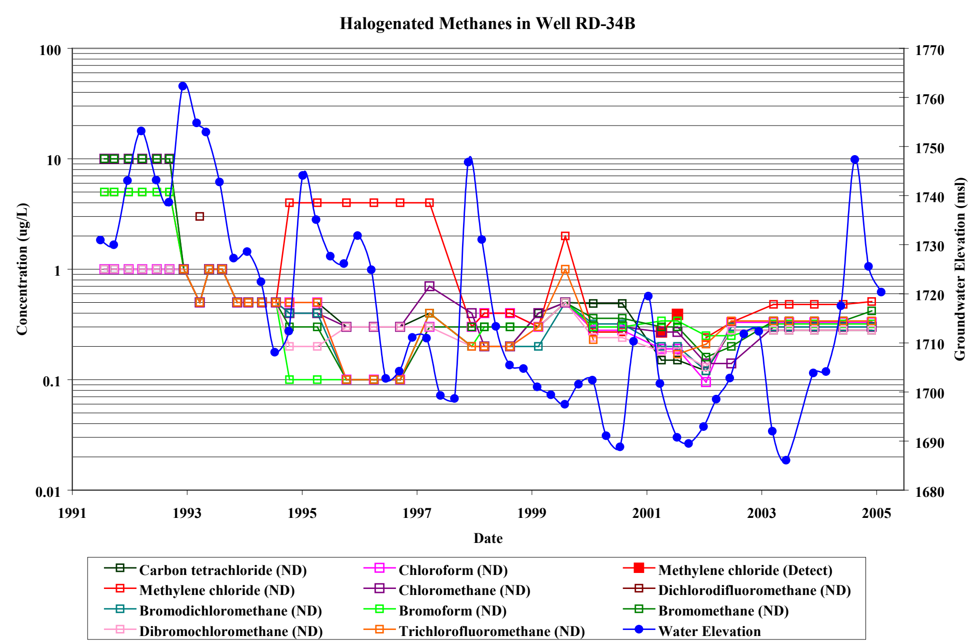
MWH

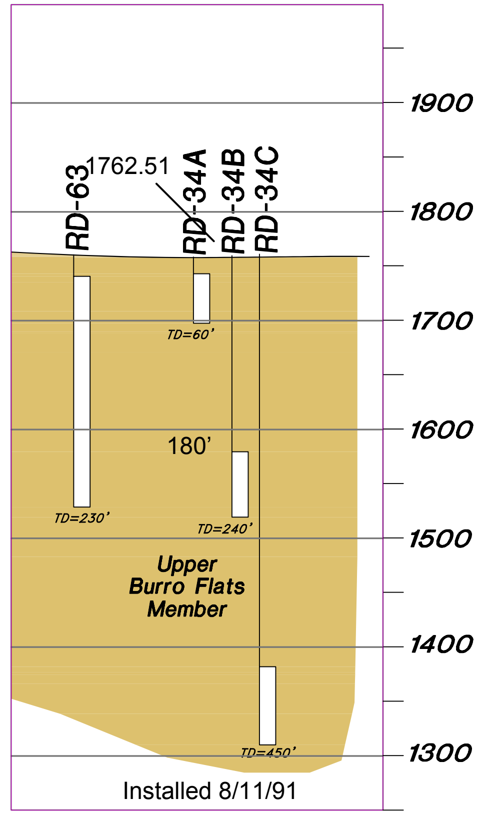
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-34A









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	ND	mg/L
Sulfate:	136	mg/L
Chloride:	40	mg/L
$^{18}O/^{2}H$:	-7.03/-42.68	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration

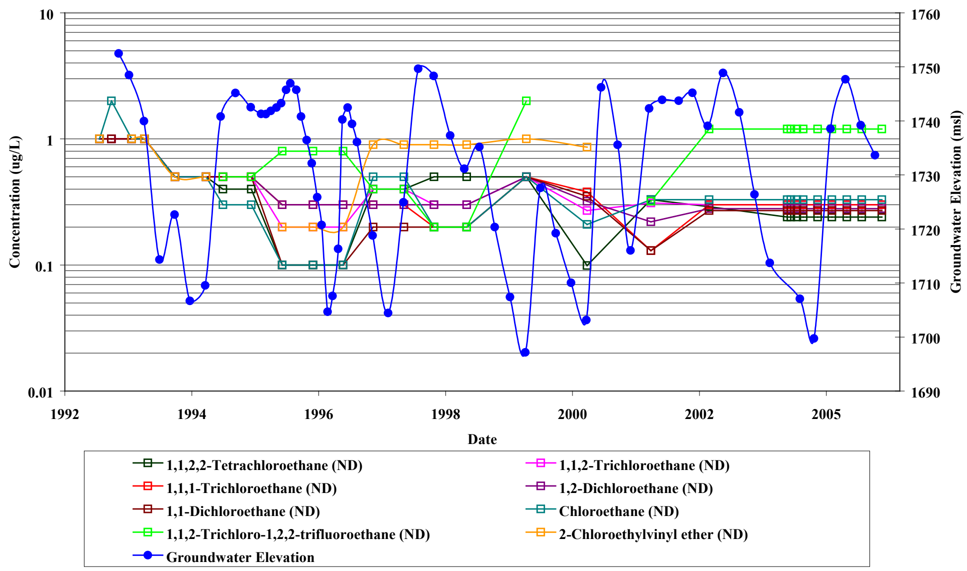
Grid Location B3

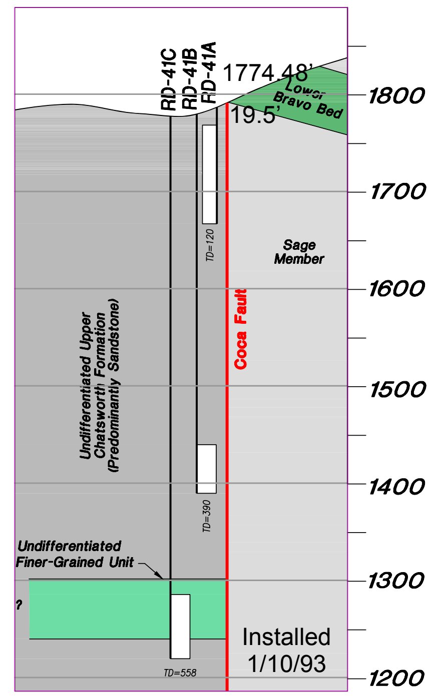
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

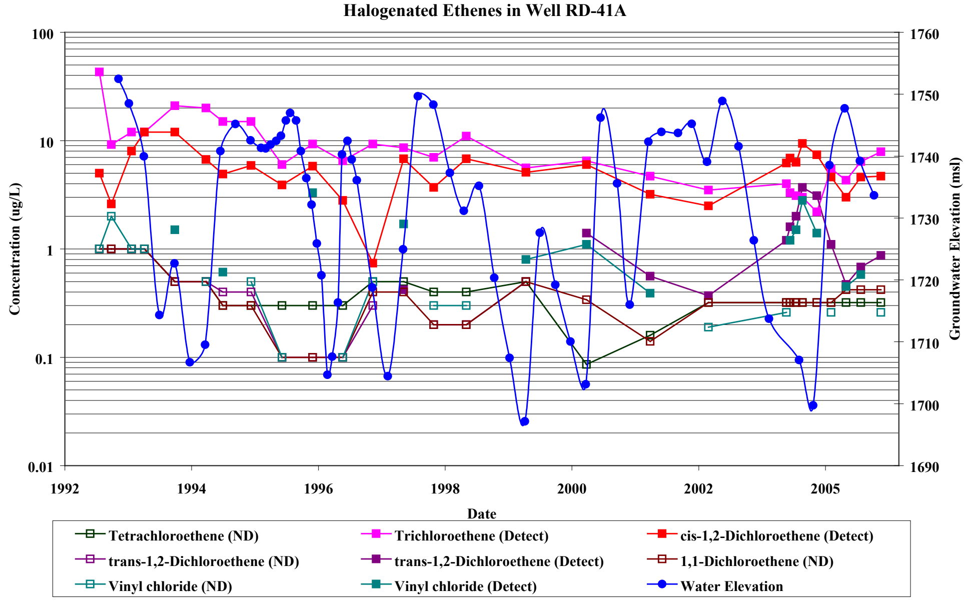
RD-34B

Halogenated Ethanes in Well RD-41A





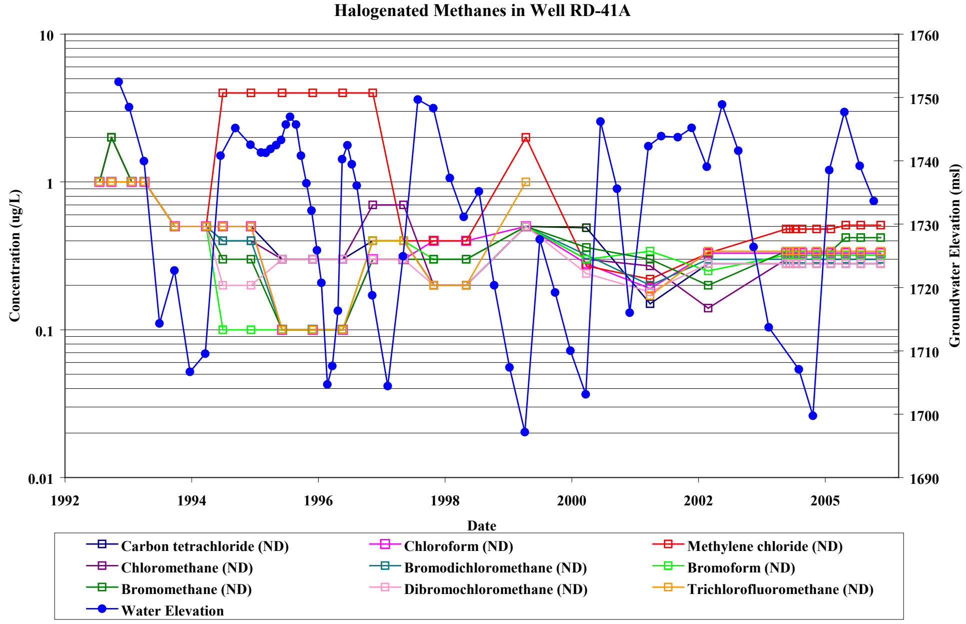
Halogenated Ethenes in Well RD-41A



Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.3 (Avg)	mg/L
Sulfate:	220	mg/L
Chloride:	69	mg/L
$^{18}O/^{2}H$:	-7.1/-46.91	permil
^{3}H:	7.25 ± 0.24	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
Tritium (^{3}H) sampled 4/93

Halogenated Methanes in Well RD-41A



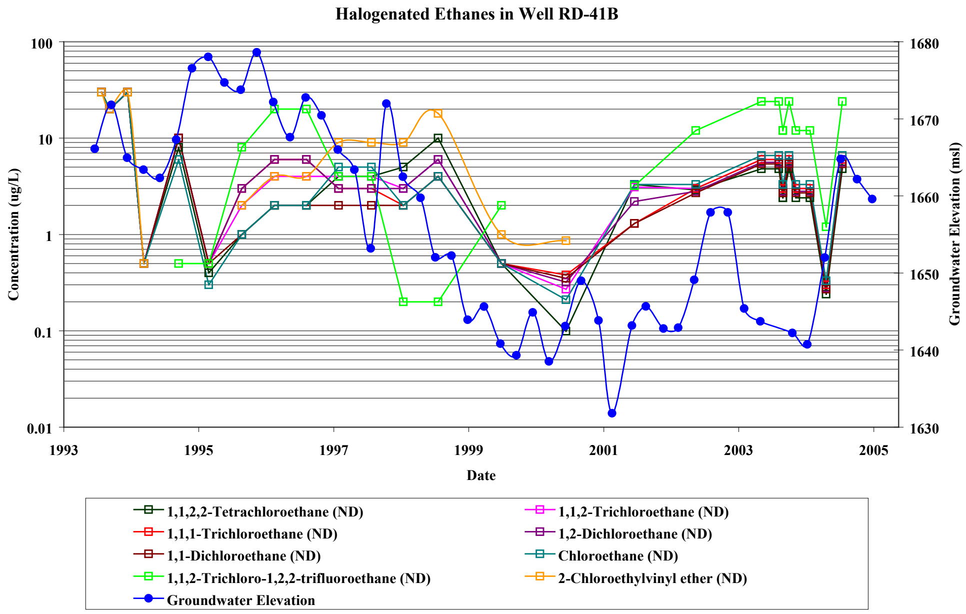
Grid Location D4

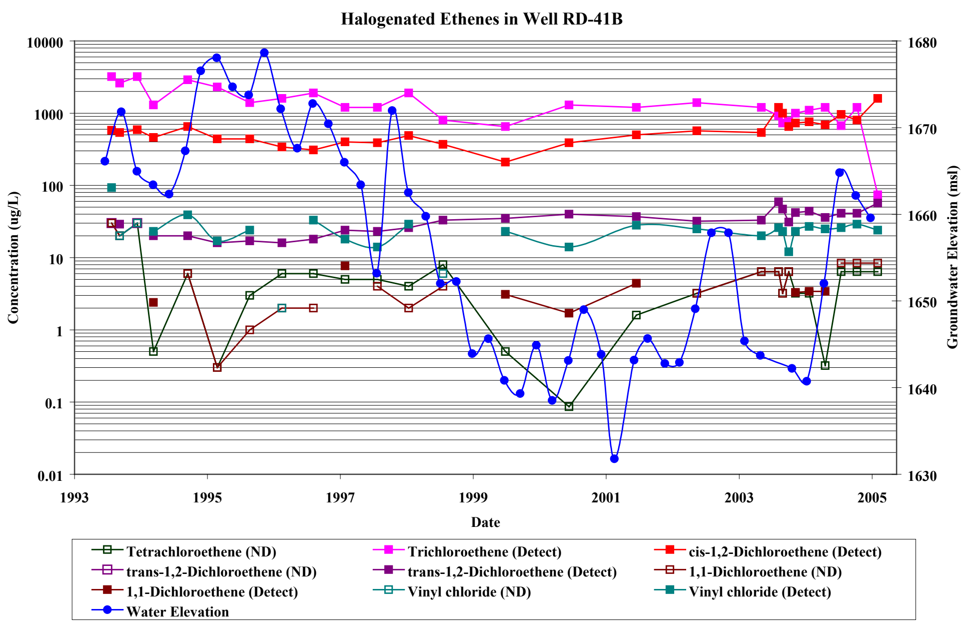
MWH

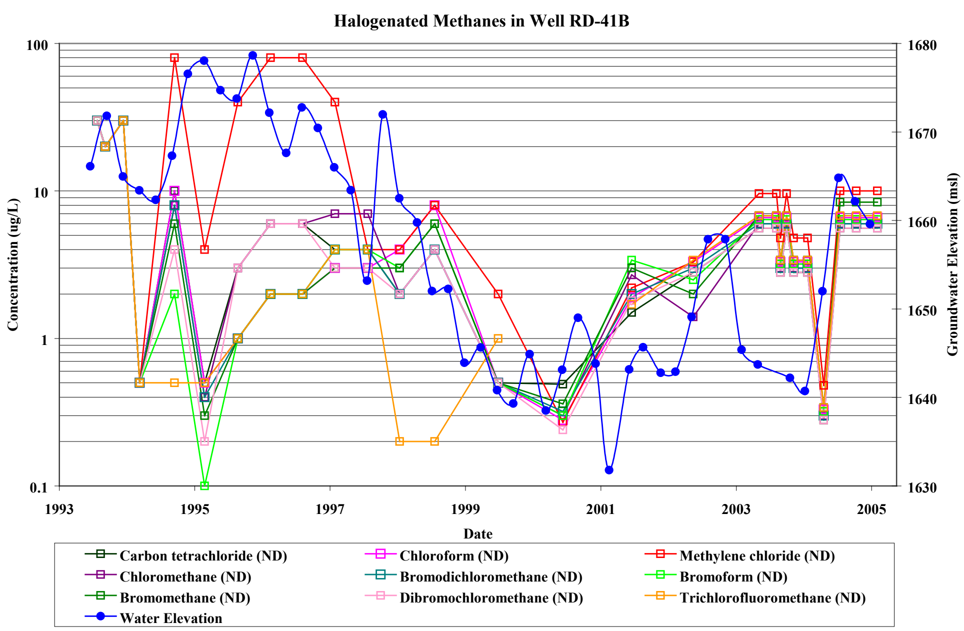
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

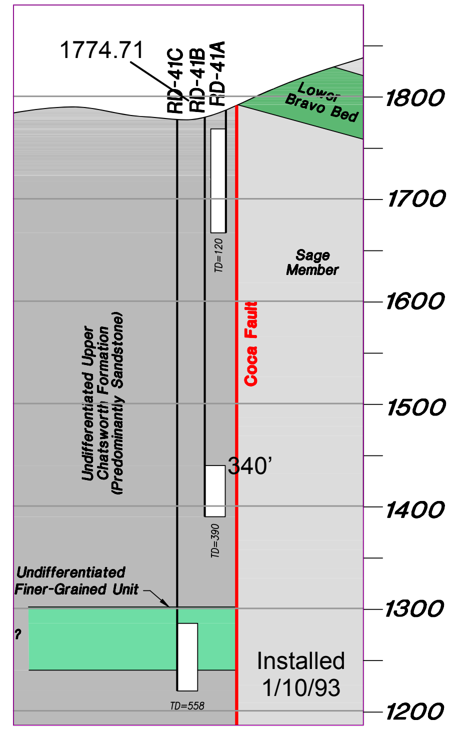
RD-41A

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 41 A B C









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.2 (Avg)	mg/L
Sulfate:	120	mg/L
Chloride:	69	mg/L
$^{18}O/^{2}H$:	-7.1/-42.26	permil
^{3}H:	1.94 ± 0.09	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
Tritium (^{3}H) sampled 6/94

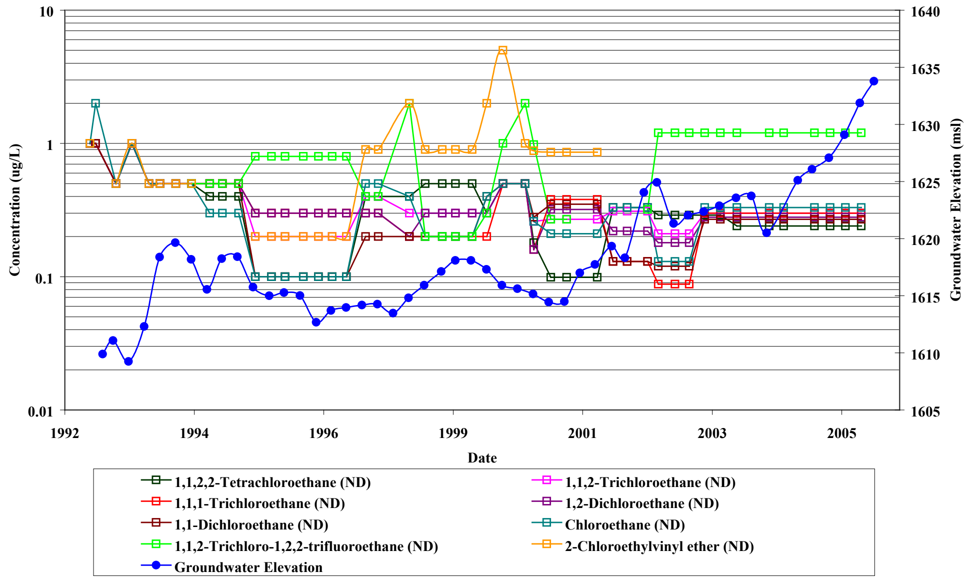
Grid Location D4

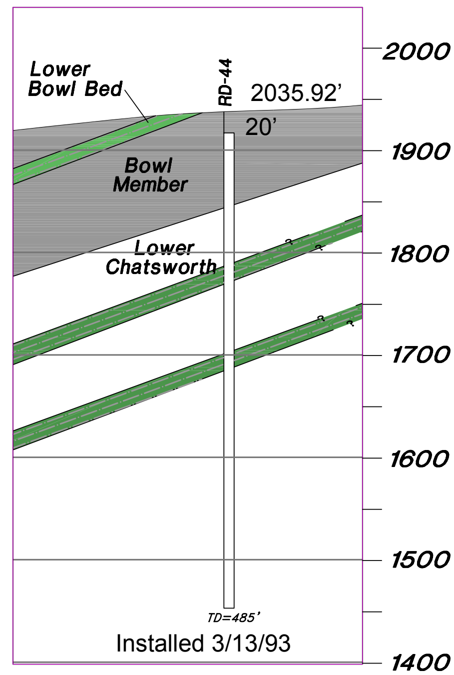
MWH
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-41B

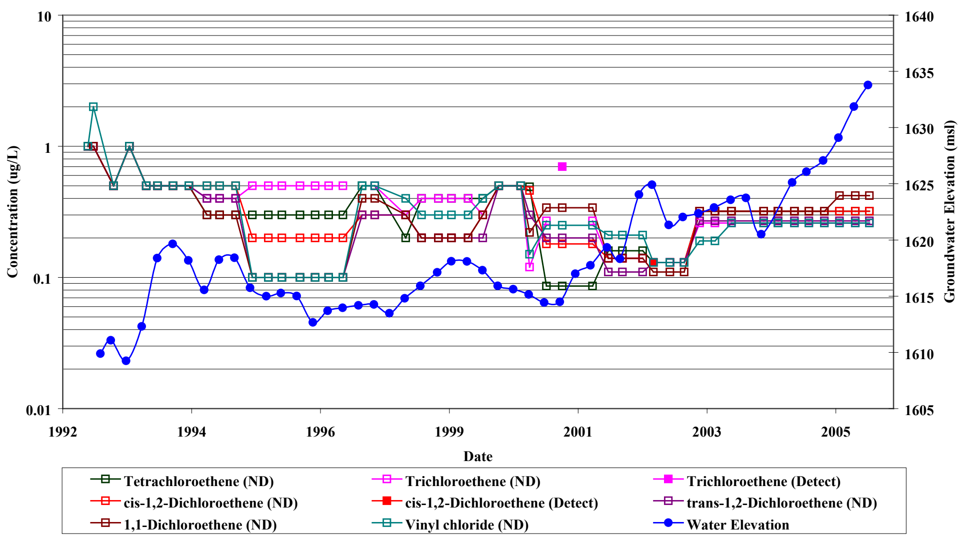
FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 44

Halogenated Ethanes in Well RD-44





Halogenated Ethenes in Well RD-44

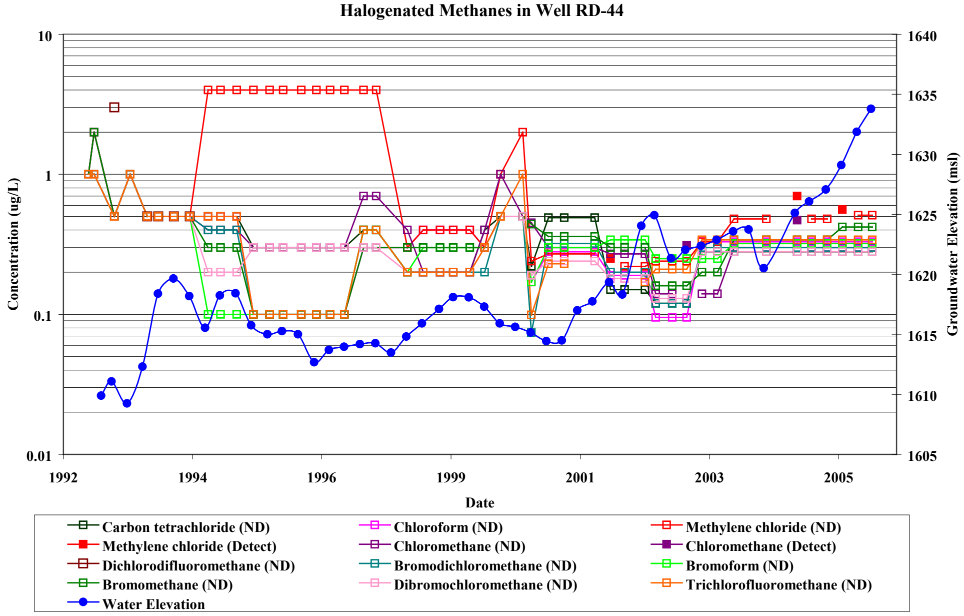


Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.2 (Avg)	mg/L
Sulfate:	255 (Avg)	mg/L
Chloride:	69 (Avg)	mg/L
$^{18}O/^{2}H$:	-6.83/-44.88	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Halogenated Methanes in Well RD-44



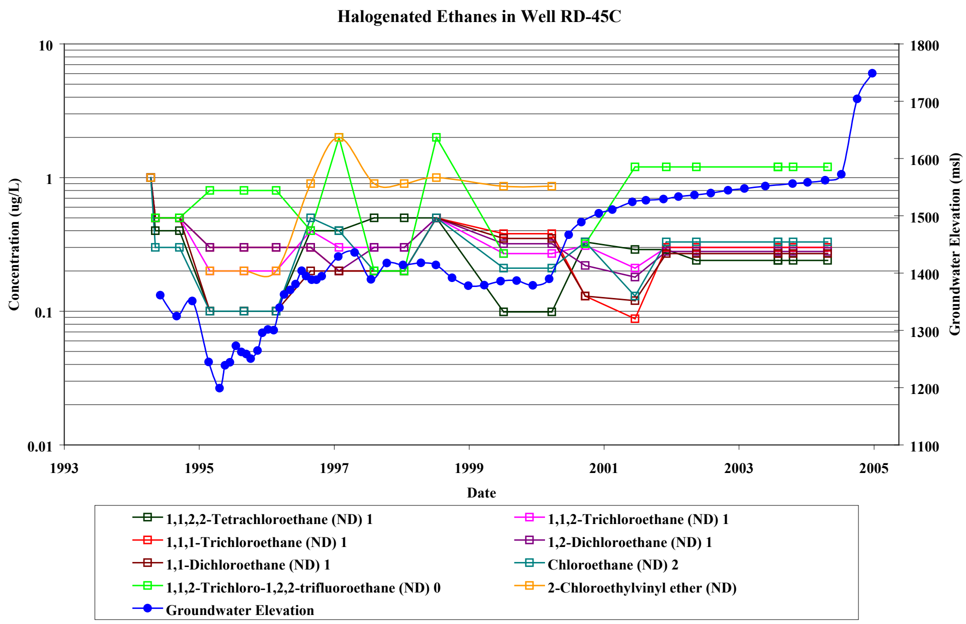
Grid Location D8

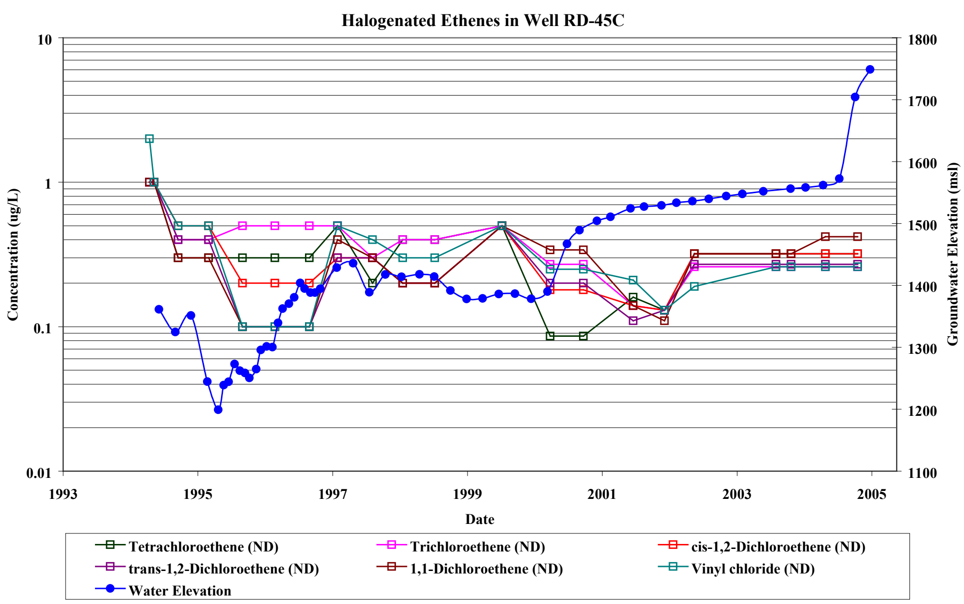
MWH

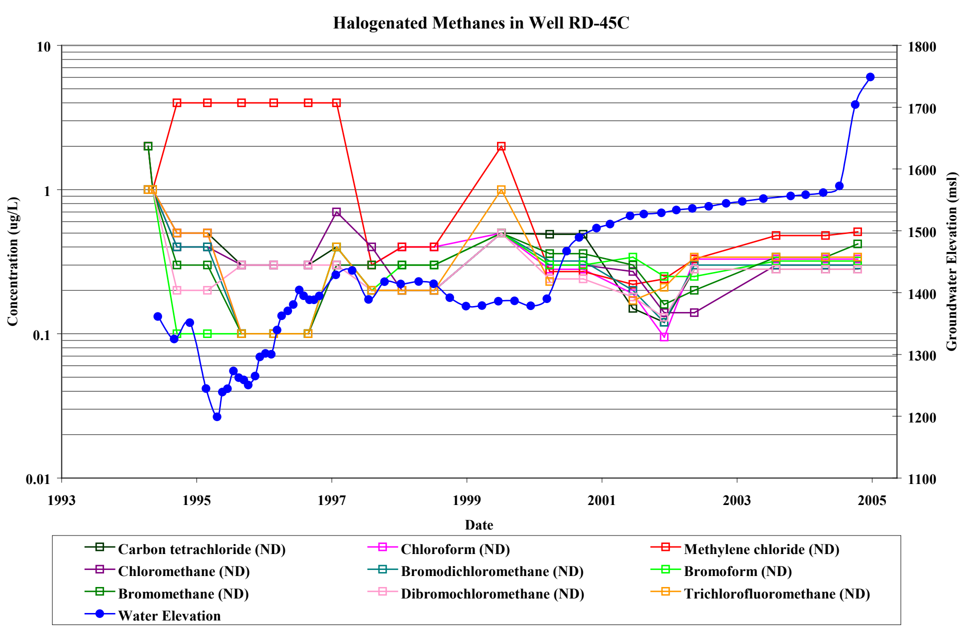
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

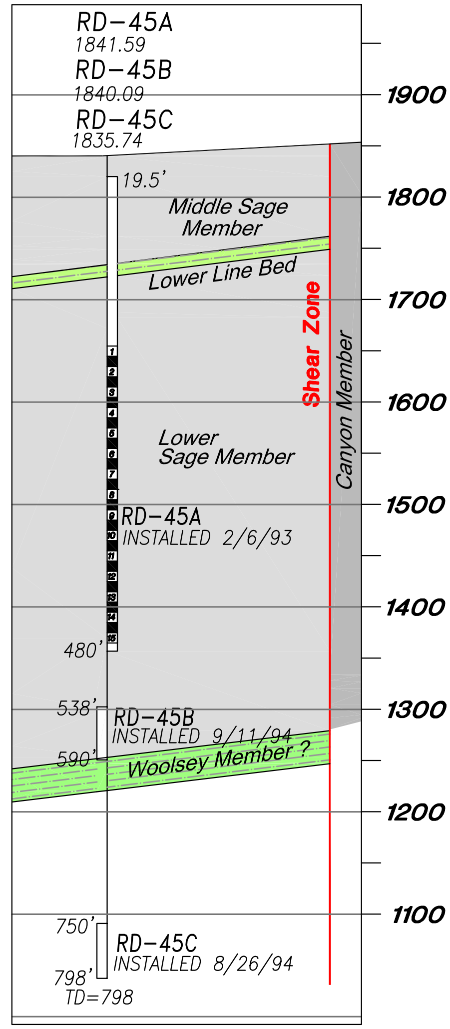
RD-44

JOB No.________________ FILE: ____









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.11 (Avg)	mg/L
Sulfate:	55.5 (Avg)	mg/L
Chloride:	26.3 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.15/-47.70	permil
^{3}H:	0.12 ± 0.09	TU

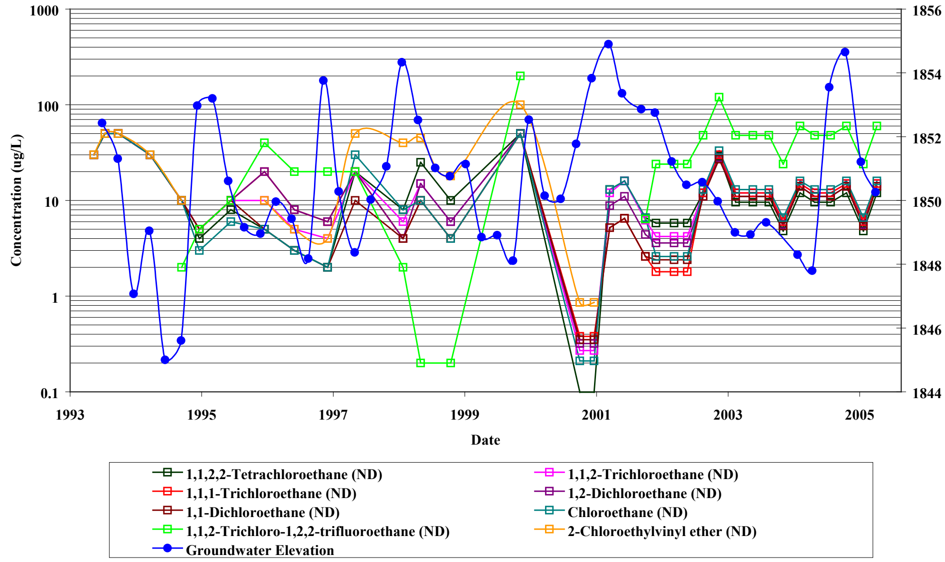
Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
Tritium (^{3}H) sampled 10/94

Grid Location C8

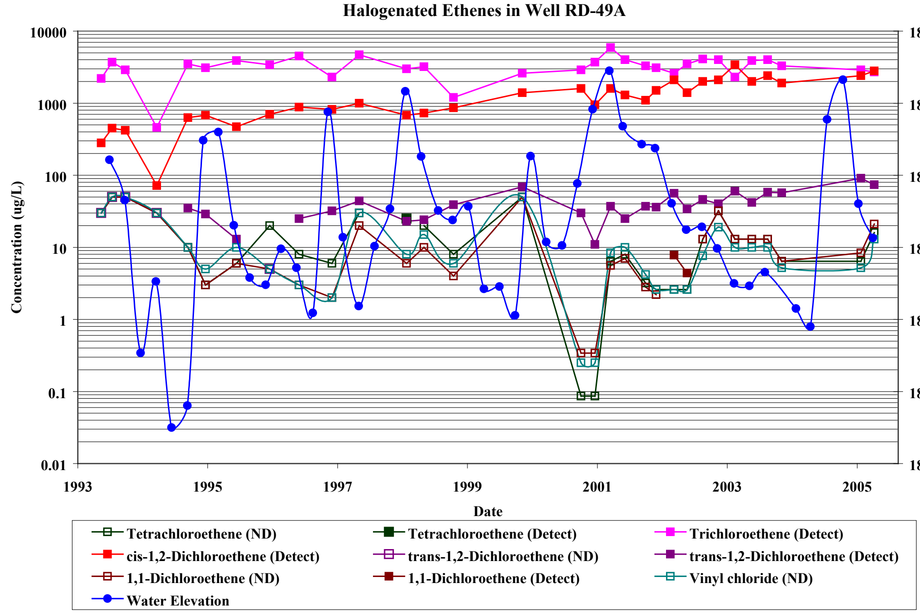
MWH
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-45C

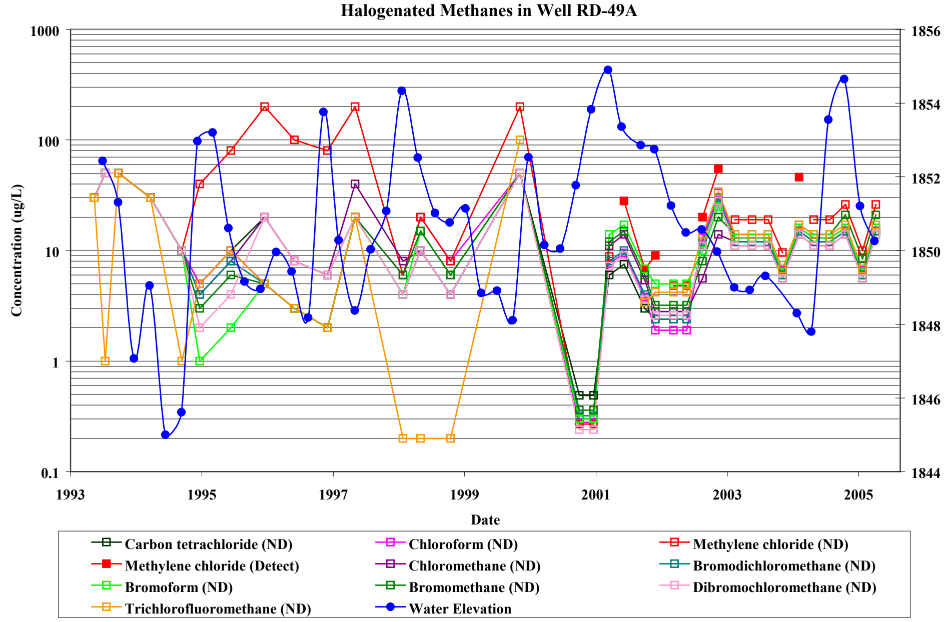
Halogenated Ethanes in Well RD-49A

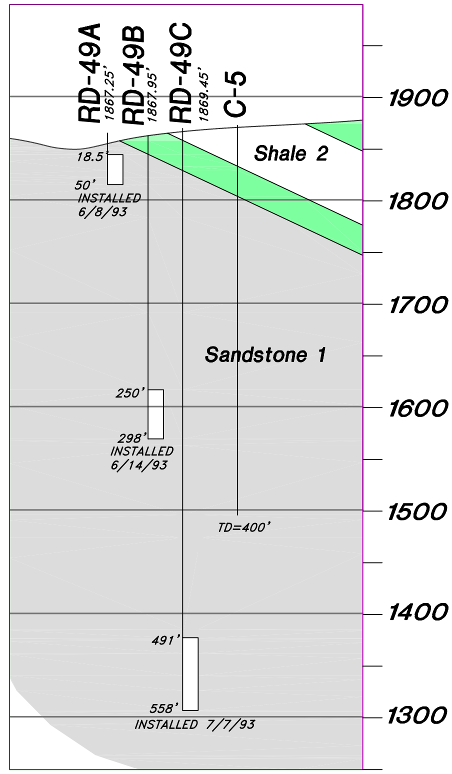


Halogenated Ethenes in Well RD-49A



Halogenated Methanes in Well RD-49A





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.6 (Avg)	mg/L
Sulfate:	620	mg/L
Chloride:	66	mg/L
$^{18}O/^{2}H$:	-7.31/-51.74	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration

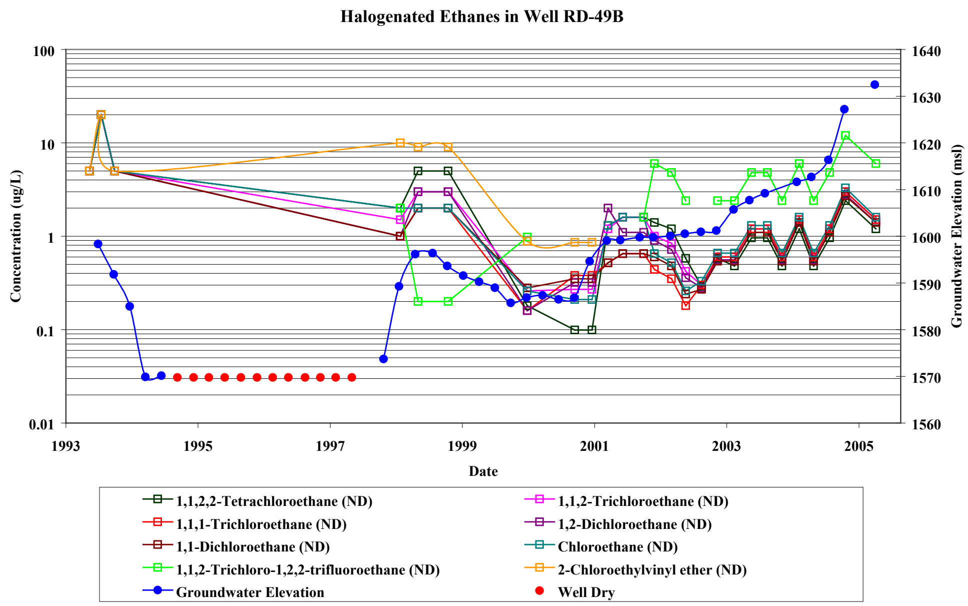
Grid Location B5

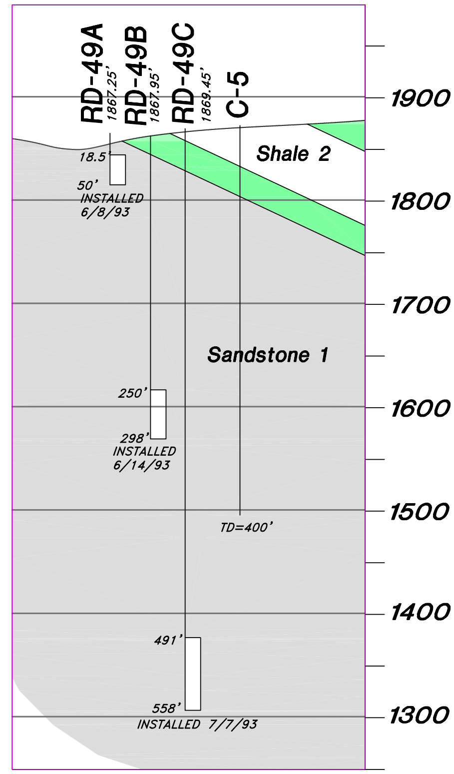
MWH

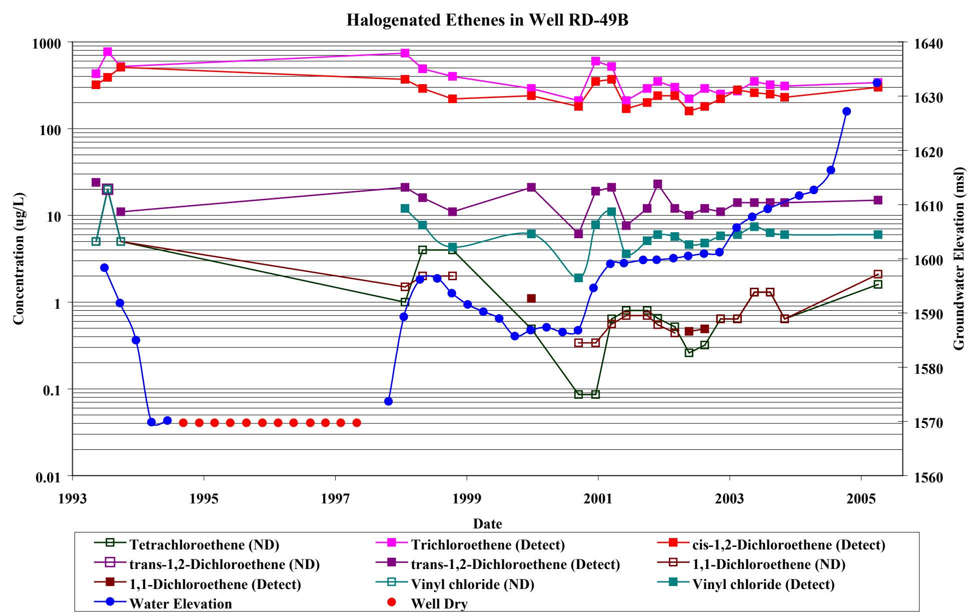
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-49A

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 49 ABC



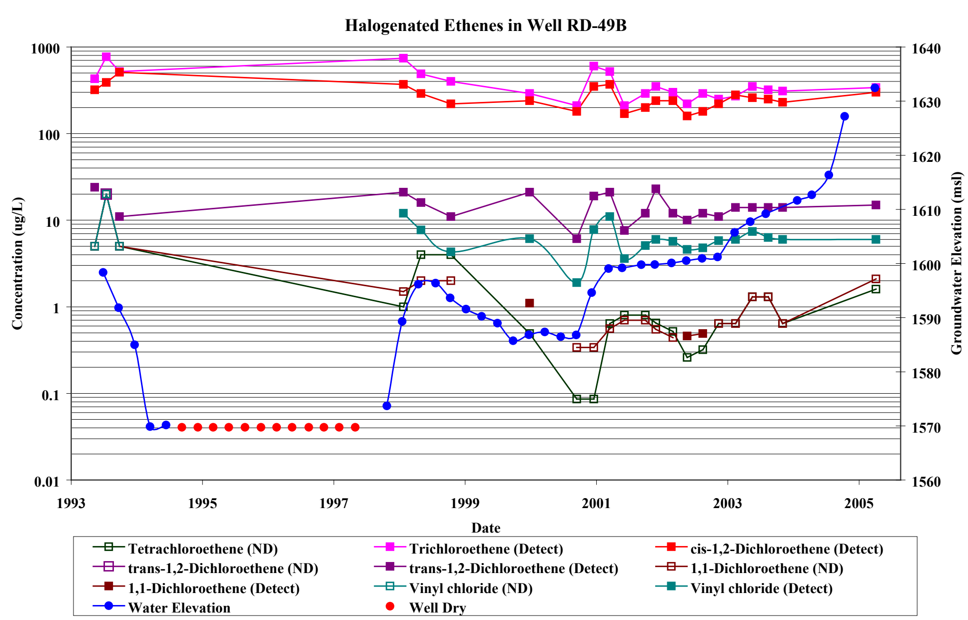




Other Data:	Value	Units
1,4-dioxane:	1.97 J (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.15 (Avg)	mg/L
Sulfate:	220	mg/L
Chloride:	44	mg/L
$^{18}O/^{2}H$:	-6.75/-43.45	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
J = estimated value

Grid Location B5

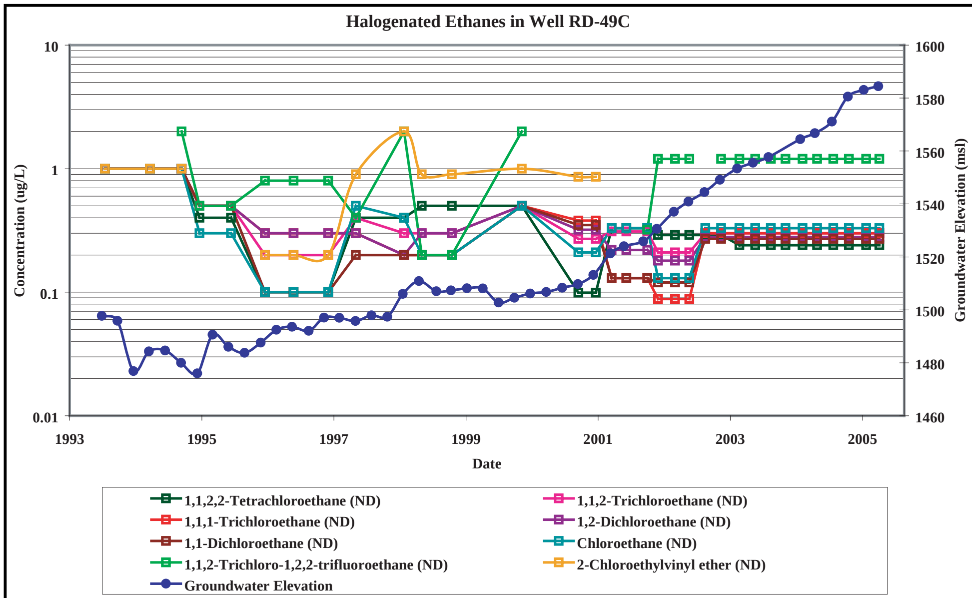


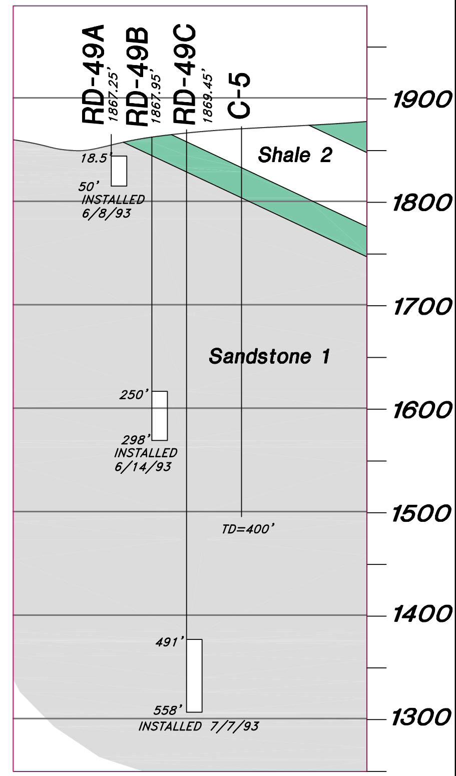
MWH

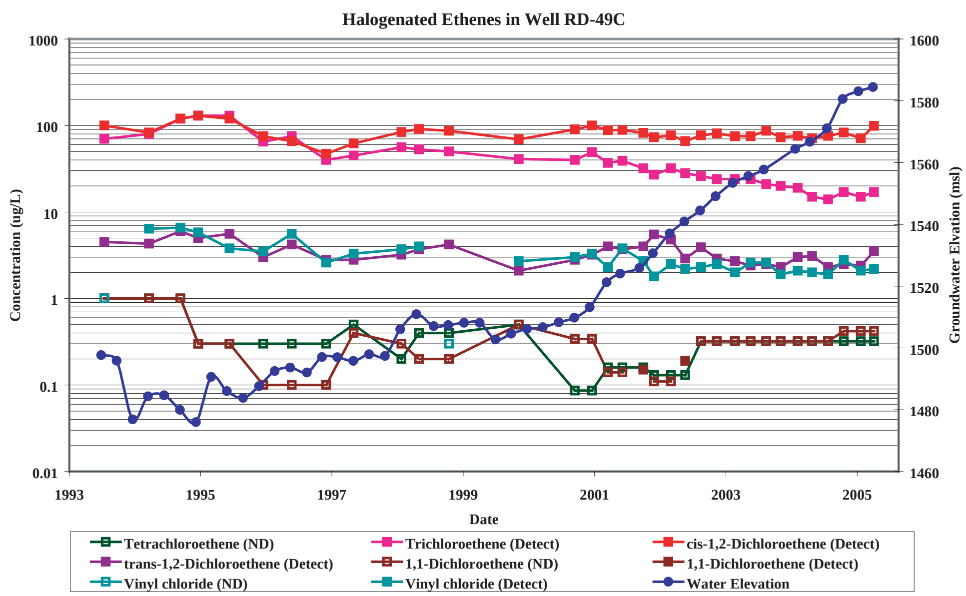
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-49B

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 49 ABC

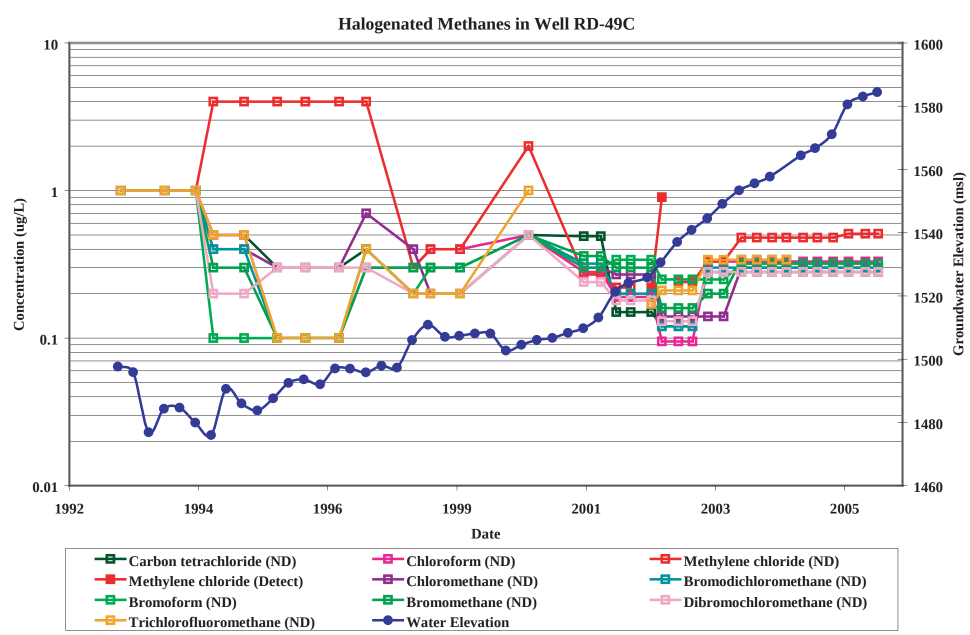






Other Data:	Value	Units
1,4-dioxane:	1.28 J (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	<0.11 (Avg)	mg/L
Sulfate:	120	mg/L
Chloride:	43	mg/L
$^{18}O/^{2}H$:	6.89/-43.15	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration
J = estimated value



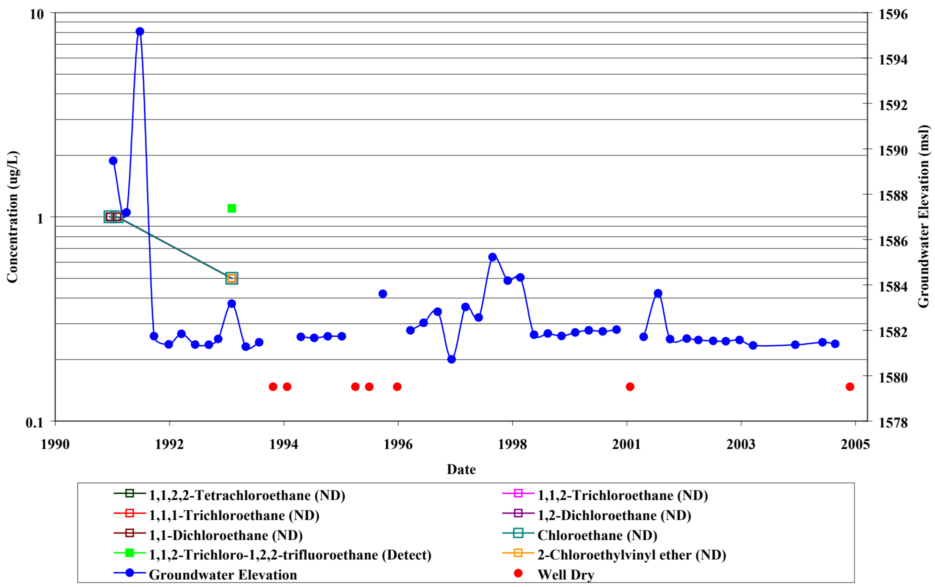
Grid Location B5

MWH

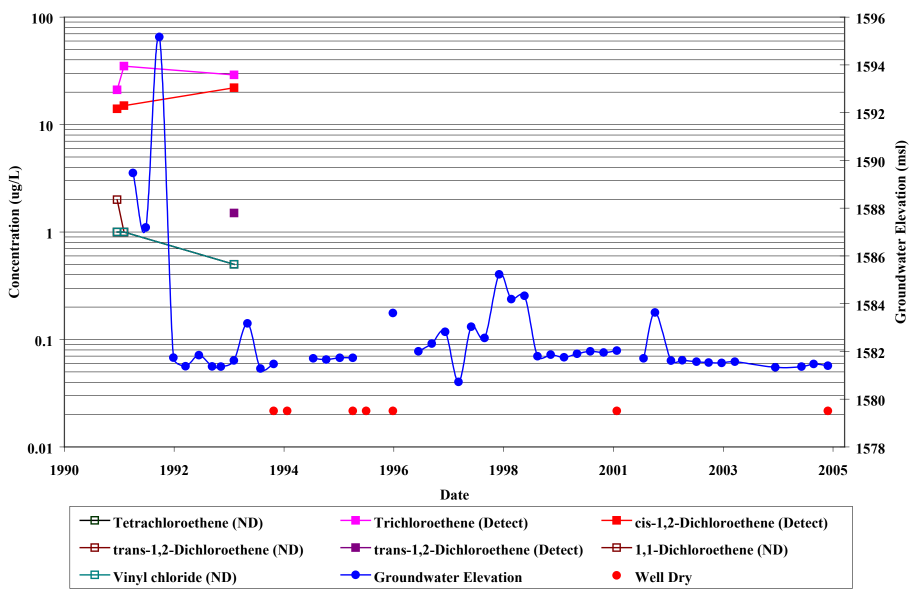
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-49C

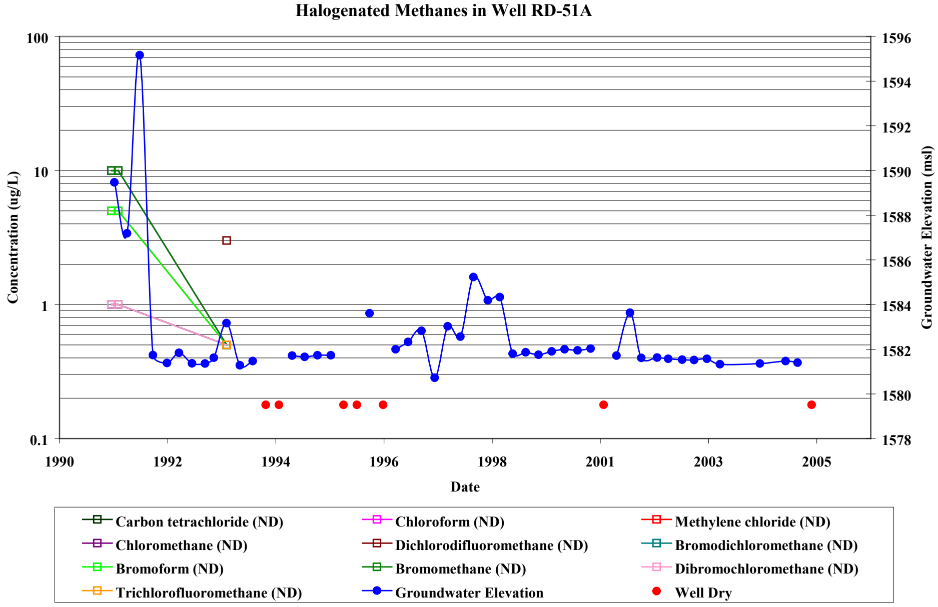
Halogenated Ethanes in Well RD-51A

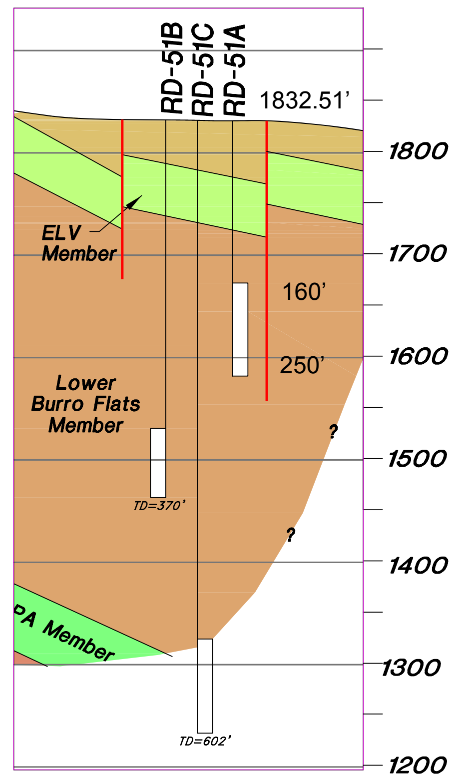


Halogenated Ethenes in Well RD-51A



Halogenated Methanes in Well RD-51A





Installed 7/11/91

Other Data:	Value	Units
1,4-dioxane:	NA	ug/L
Perchlorate:	NA	ug/L
Nitrate as NO_3:	NA	mg/L
Sulfate:	NA	mg/L
Chloride:	NA	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

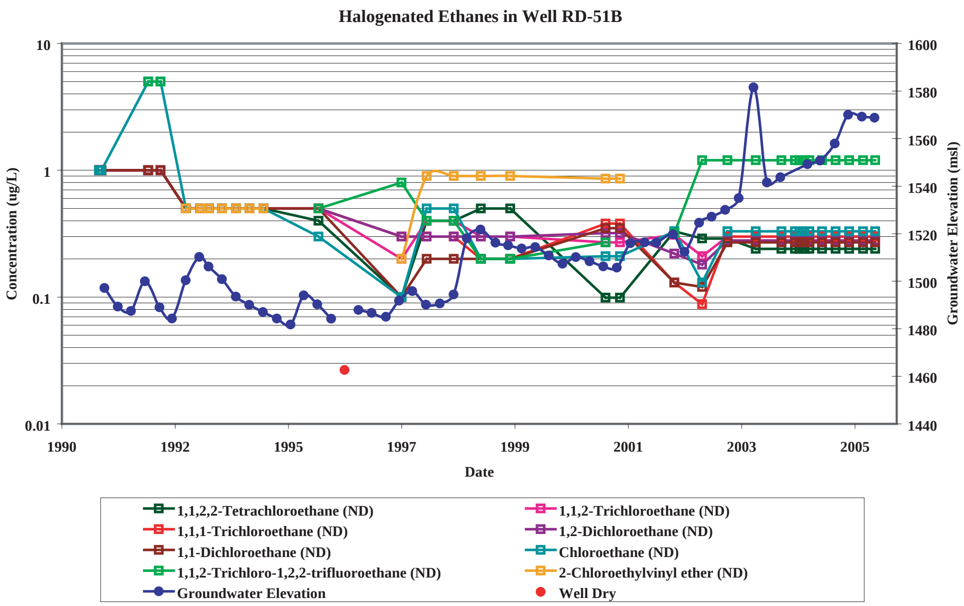
Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration

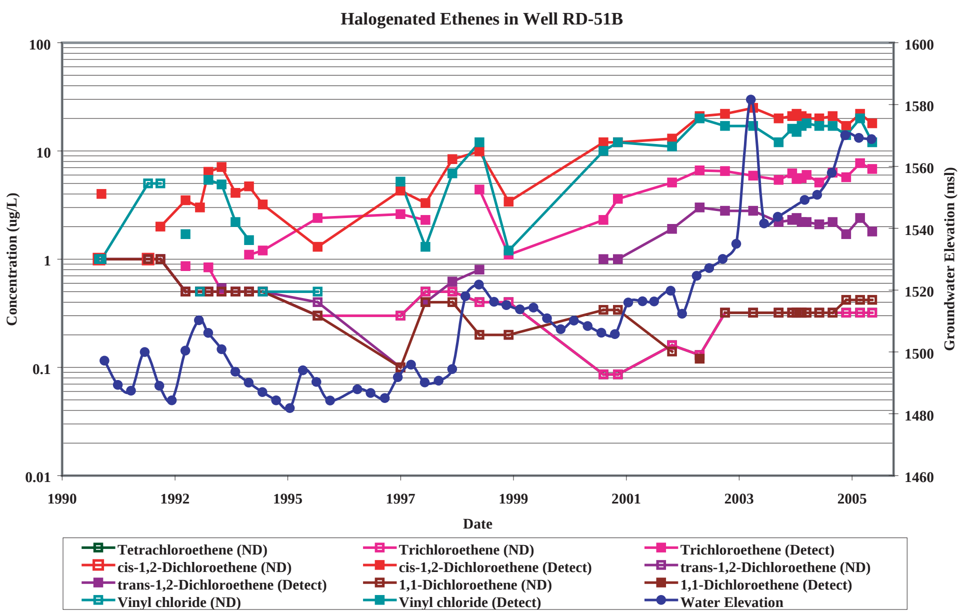
MWH

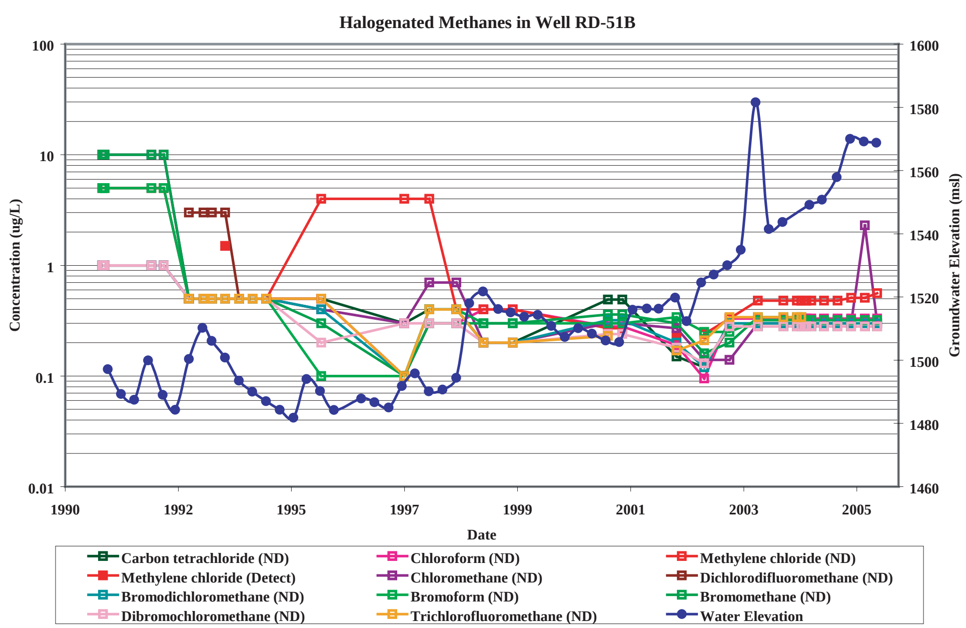
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

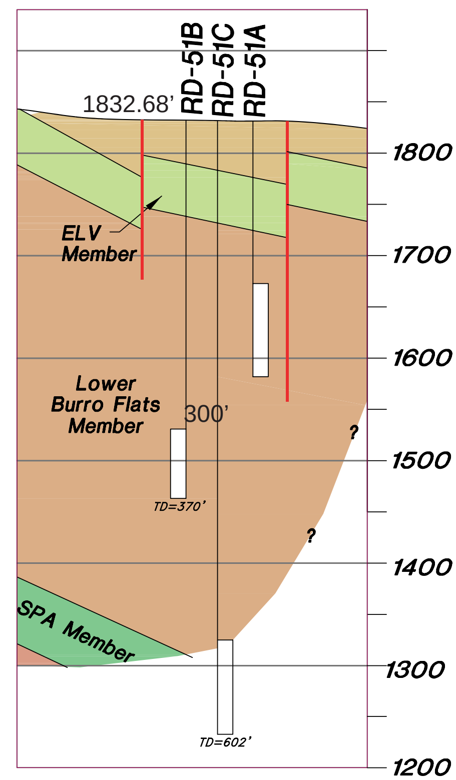
RD-51A

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 51B









Installed 7/11/91

Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.13 (Avg)	mg/L
Sulfate:	160.7 (Avg)	mg/L
Chloride:	49 (Avg)	mg/L
$^{18}O/^{2}H$:	-6.94/-42.55	permil
^{3}H:	1.17 ± 0.09	TU

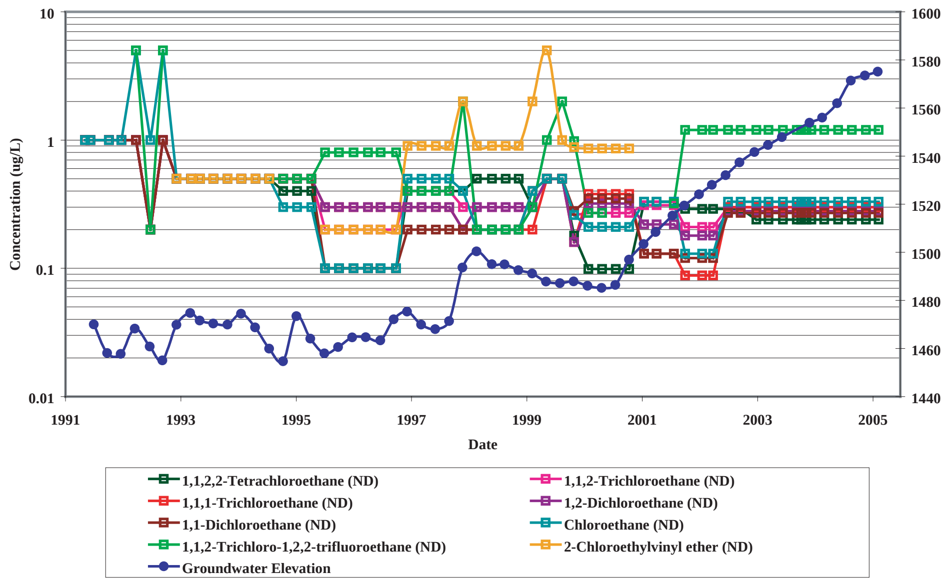
Notes: NA-not analyzed ND-not detected
Avg - multiple results, average concentration

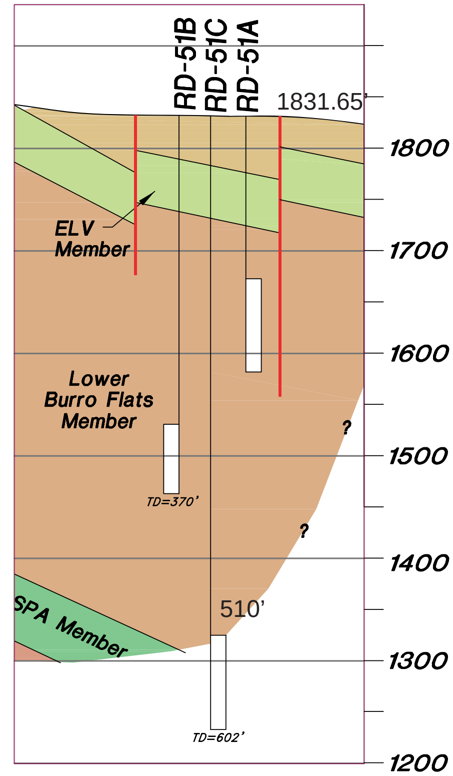
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-51B

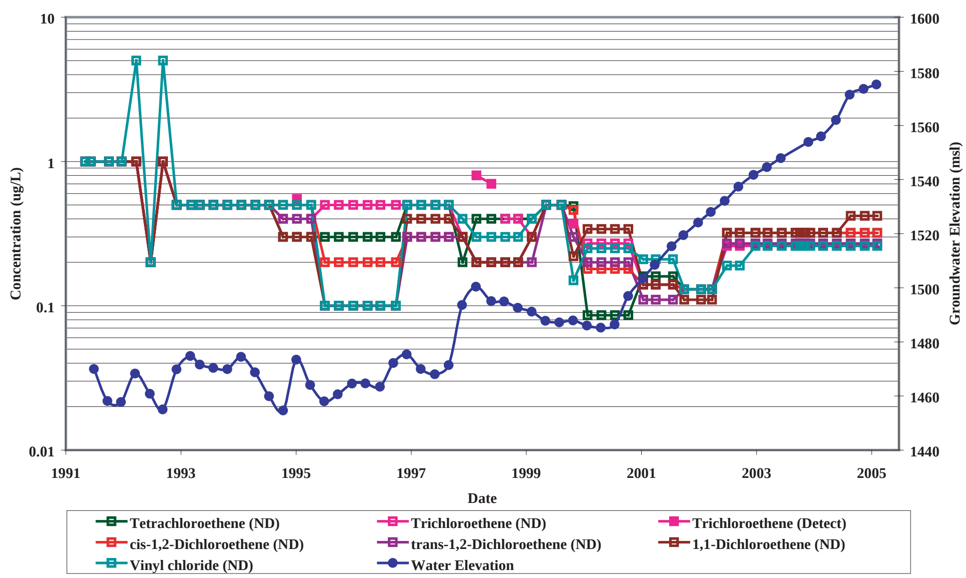
Halogenated Ethanes in Well RD-51C





Installed 7/9/91

Halogenated Ethenes in Well RD-51C

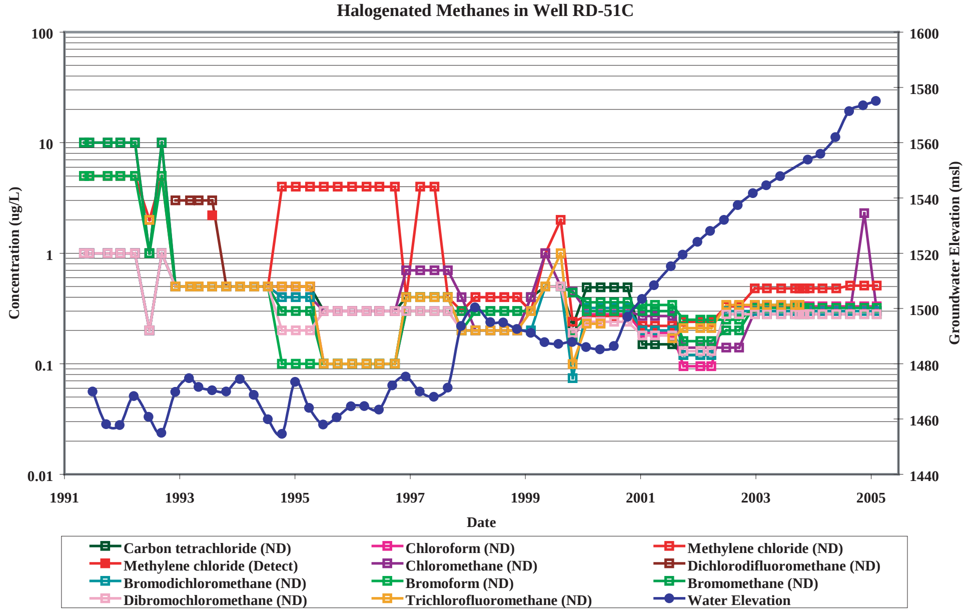


Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.12 (Avg)	mg/L
Sulfate:	152.2 (Avg)	mg/L
Chloride:	42.8 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.02/-41.76	permil
^{3}H:	0.39r ± 0.09	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Halogenated Methanes in Well RD-51C

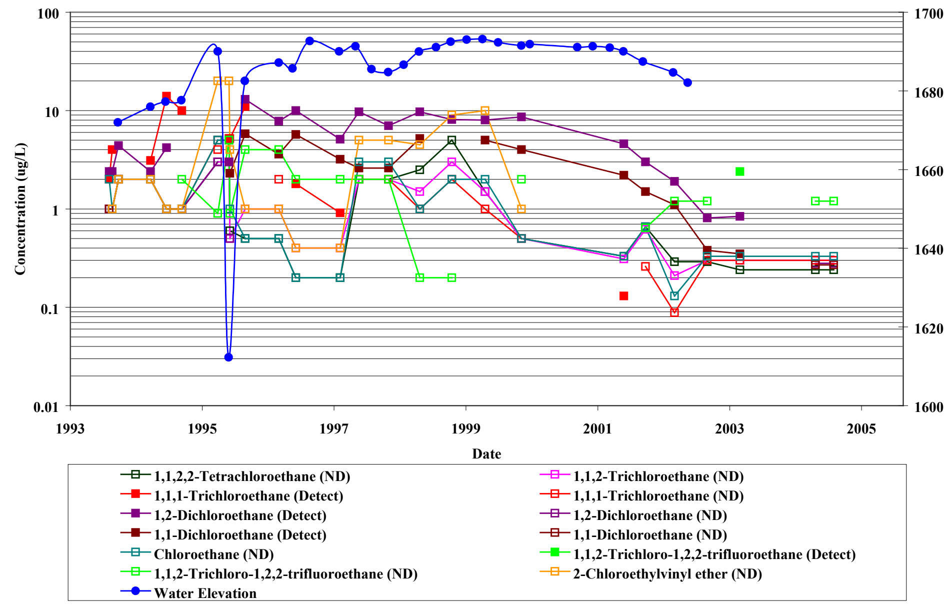


MWH

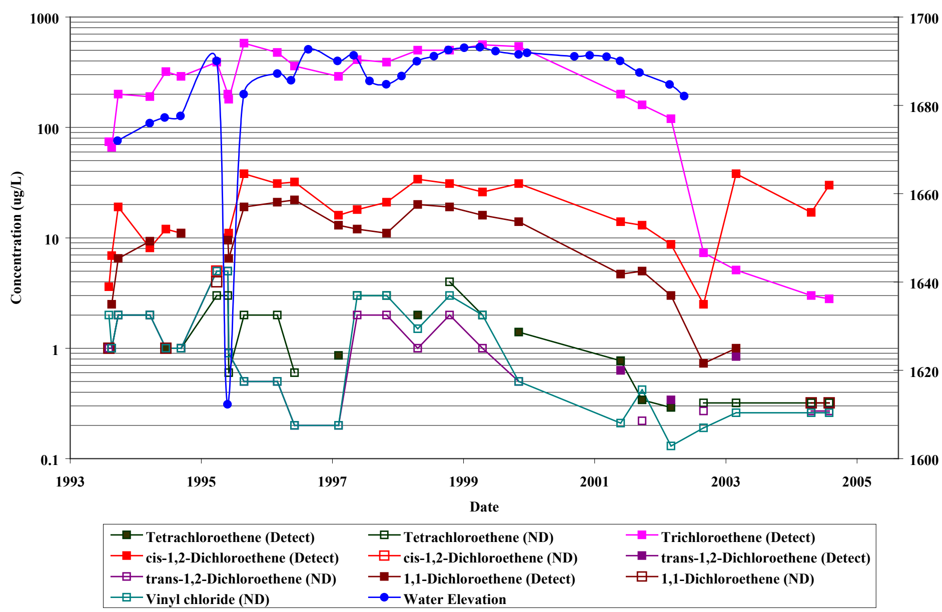
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-51C

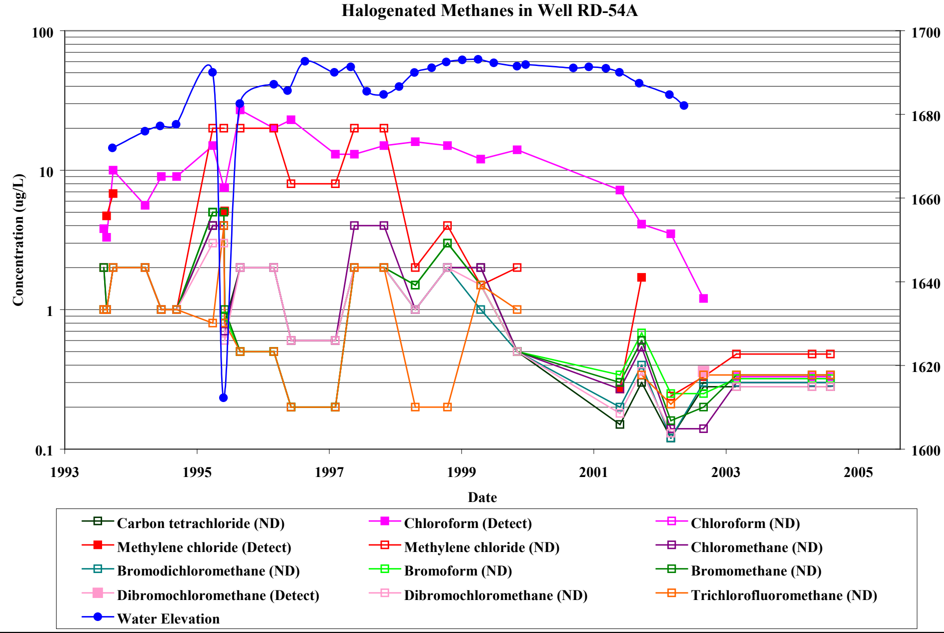
Halogenated Ethanes in Well RD-54A

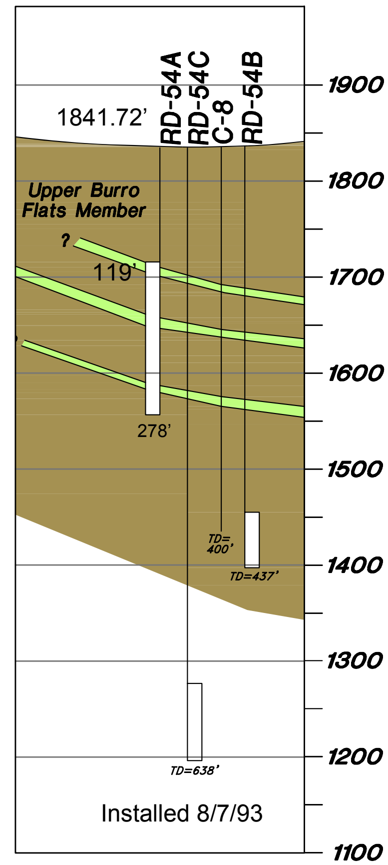


Halogenated Ethenes in Well RD-54A



Halogenated Methanes in Well RD-54A





Other Data:	Value	Units
1,4-dioxane:	2.64 B (Avg)	ug/L
Perchlorate:	14.63 (Avg)	ug/L
Nitrate as NO_3:	6.7	mg/L
Sulfate:	110	mg/L
Chloride:	68	mg/L
$^{18}O/^{2}H$: (port 2 of multi-level)	-6.69/-43.96	permil

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Multi-level installed 1/2003

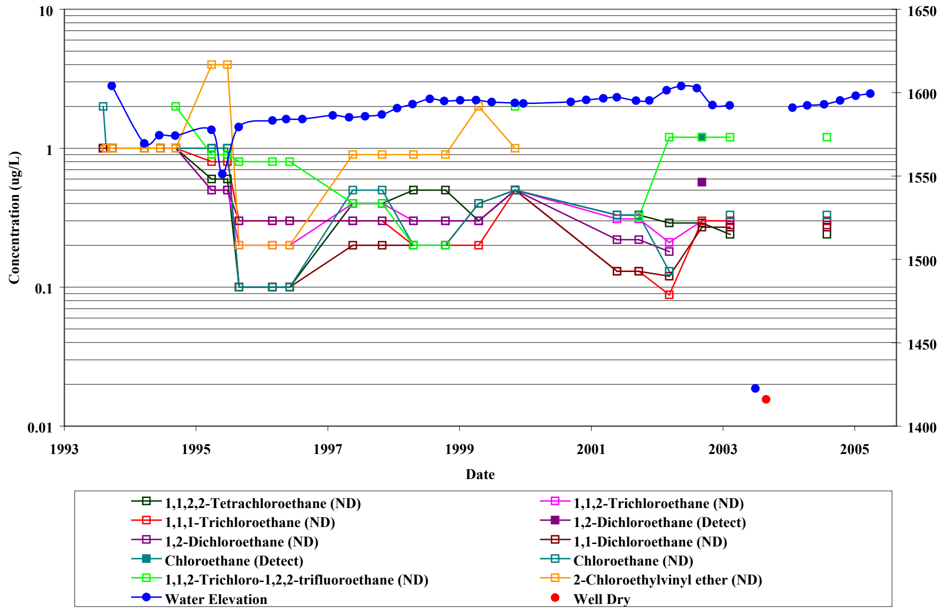
Grid Location C2

MWH

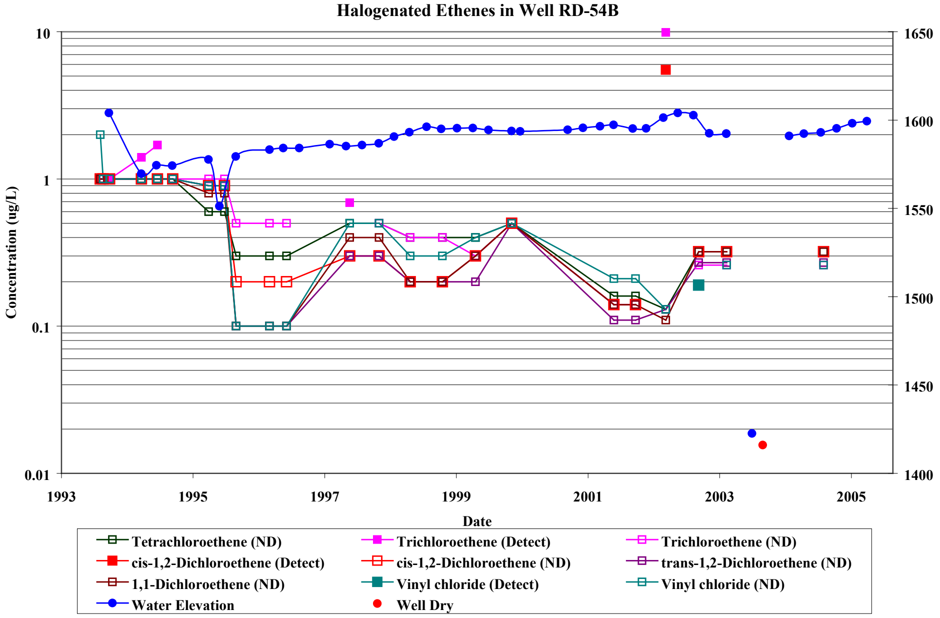
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-54A

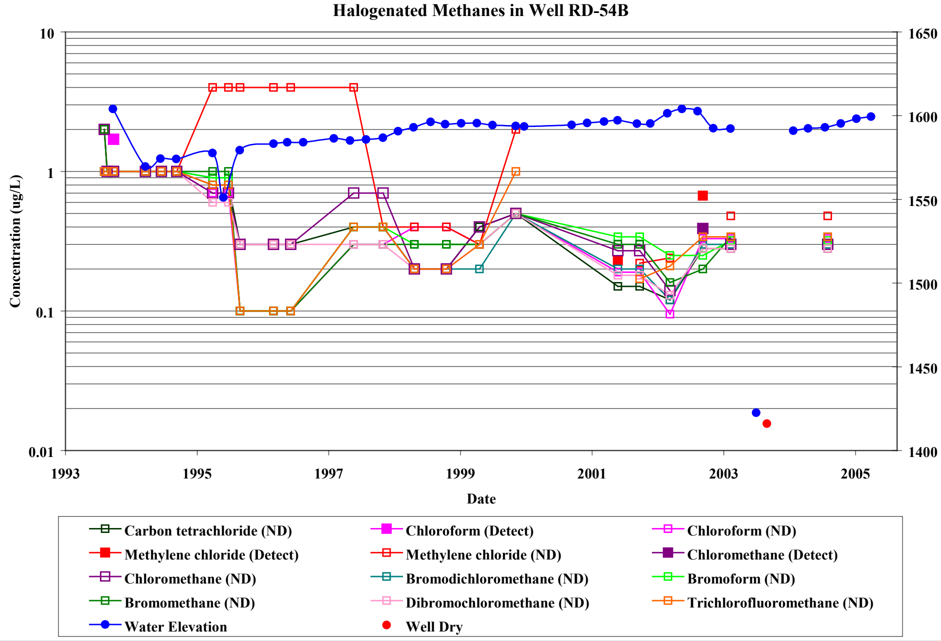
Halogenated Ethanes in Well RD-54B

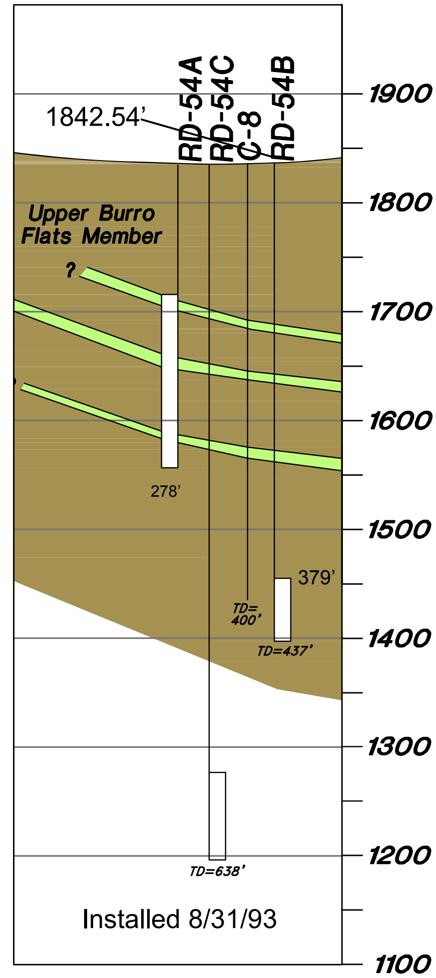


Halogenated Ethenes in Well RD-54B



Halogenated Methanes in Well RD-54B





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.54	mg/L
Sulfate:	250	mg/L
Chloride:	52	mg/L
$^{18}O/^{2}H$:	NA	permil

Notes: NA-not analyzed ND-not detected

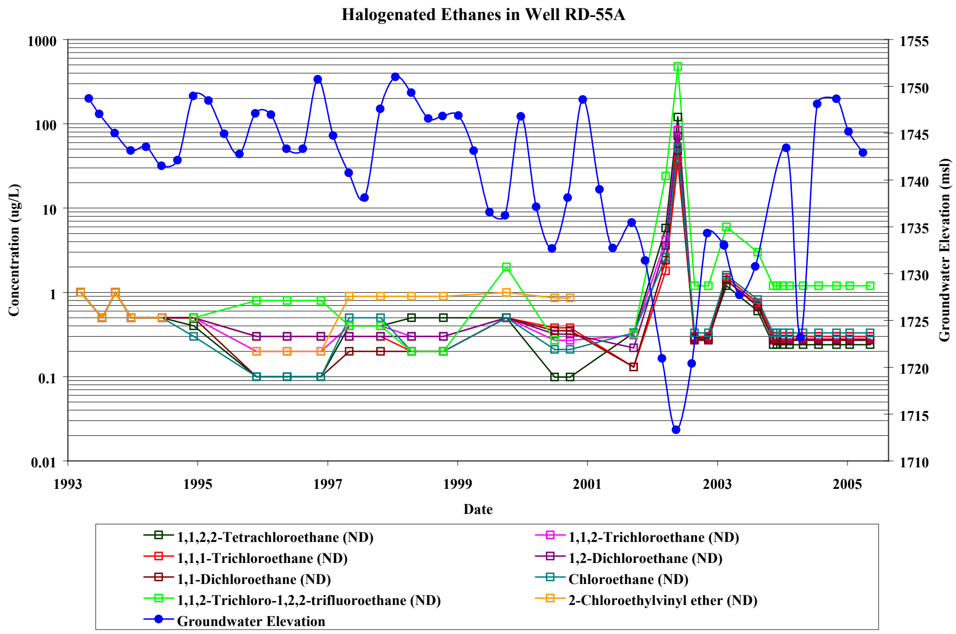
Avg - multiple results, average concentration

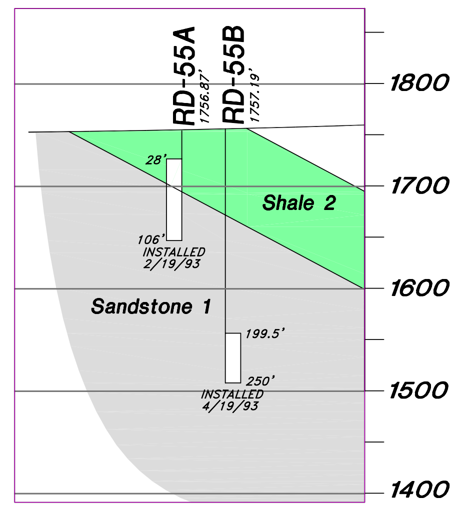
Grid Location C2

MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-54B



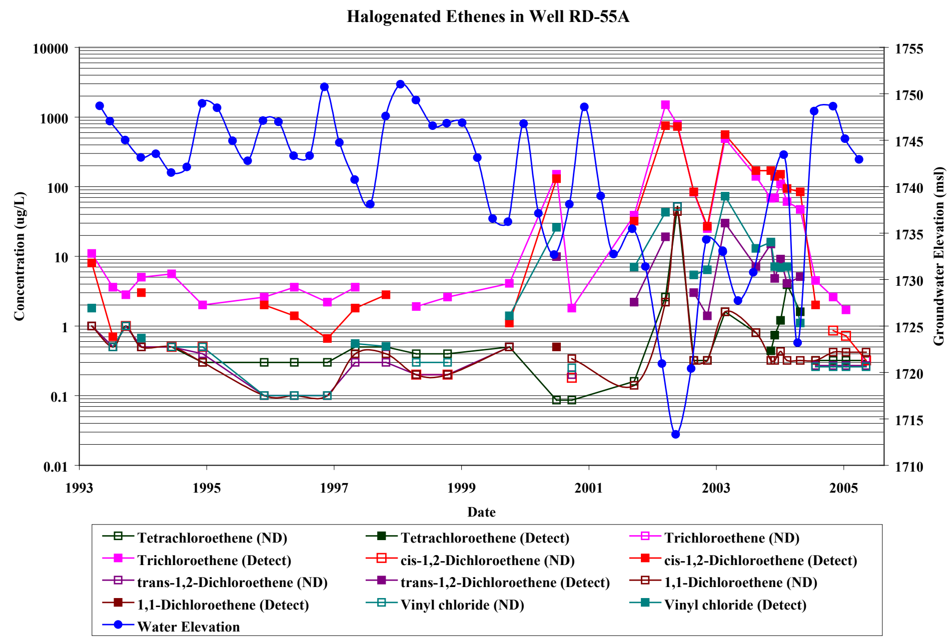


Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	12.28 (Avg)	mg/L
Sulfate:	60	mg/L
Chloride:	36	mg/L
$^{18}O/^{2}H$:	-6.75/-43.19	permil
^{3}H:	4.99 ± 0.16	TU

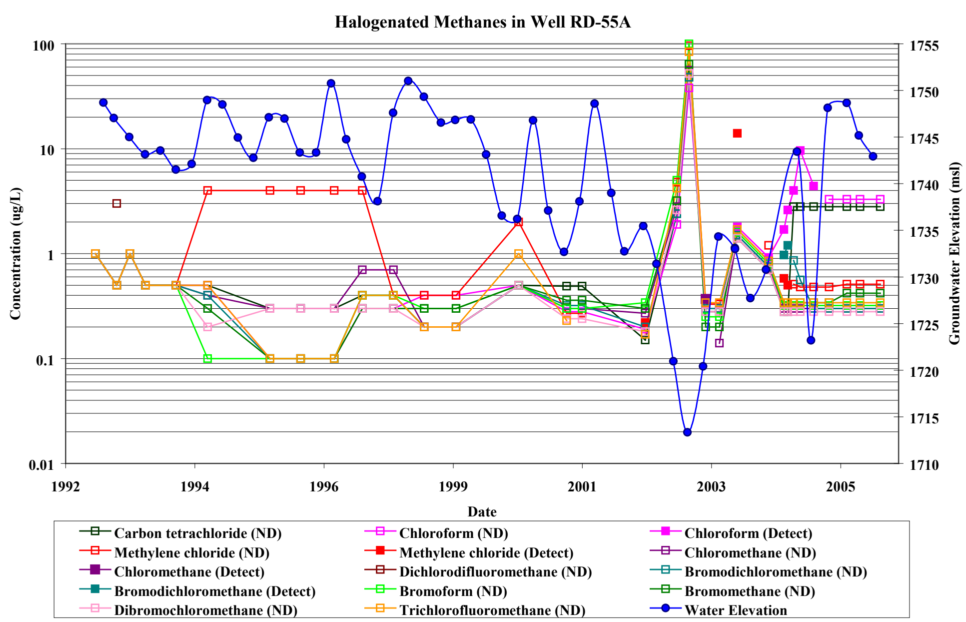
Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Tritium (^{3}H) sampled 4/93



Grid Location C3

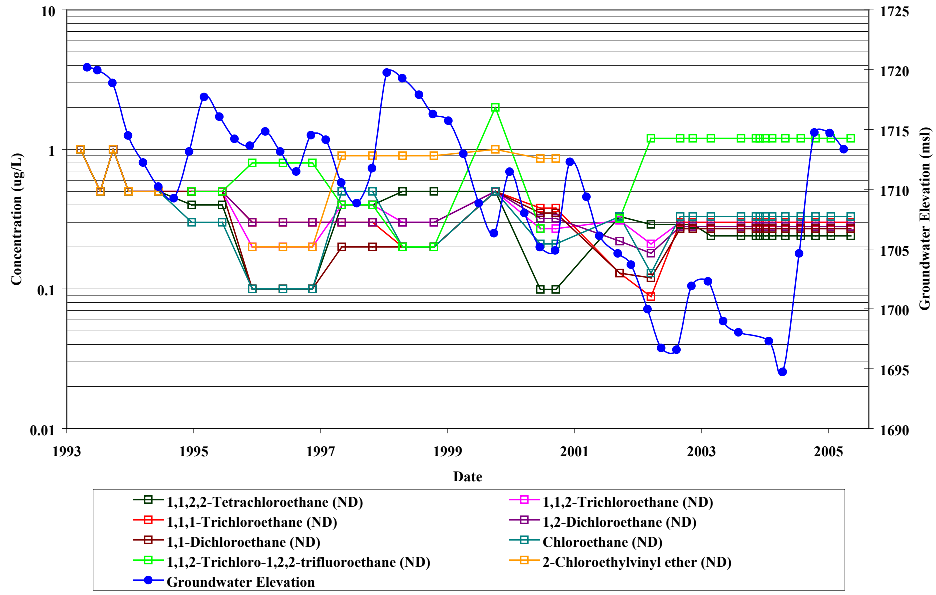


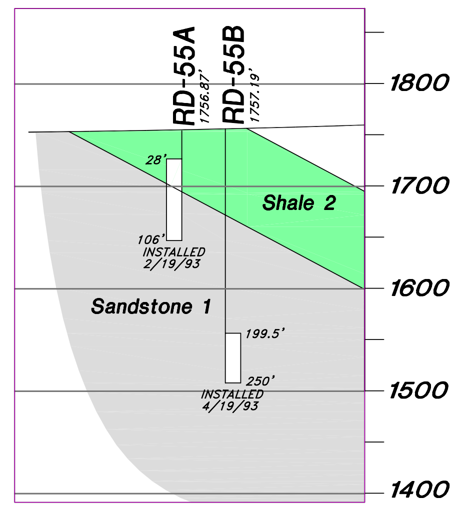
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

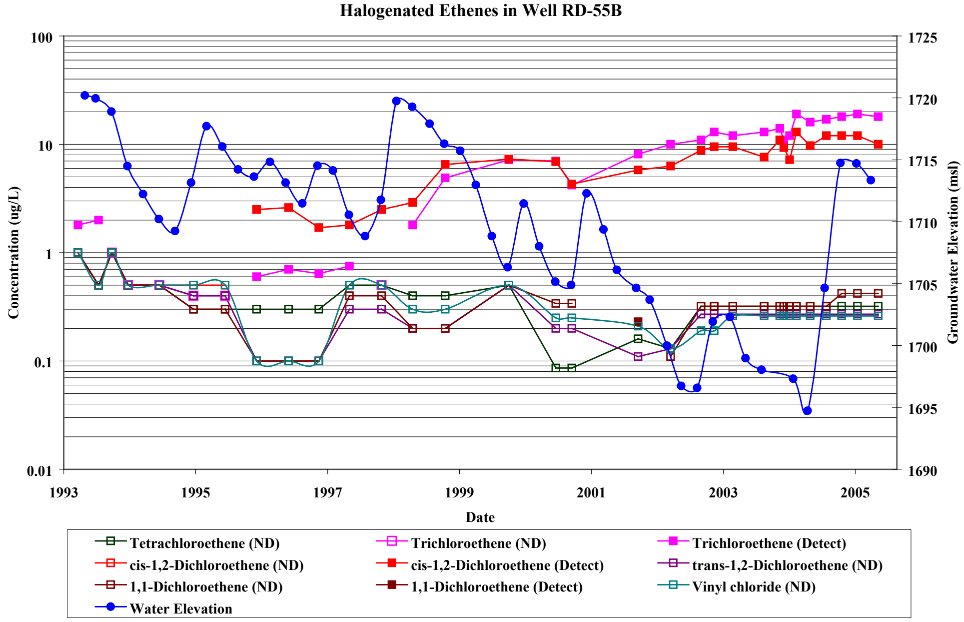
RD-55A

Halogenated Ethanes in Well RD-55B





Halogenated Ethenes in Well RD-55B



Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.15 (Avg)	mg/L
Sulfate:	15	mg/L
Chloride:	17	mg/L
$^{18}O/^{2}H$:	-6.9/-43.11	permil
^{3}H:	0.69 ± 0.09	TU

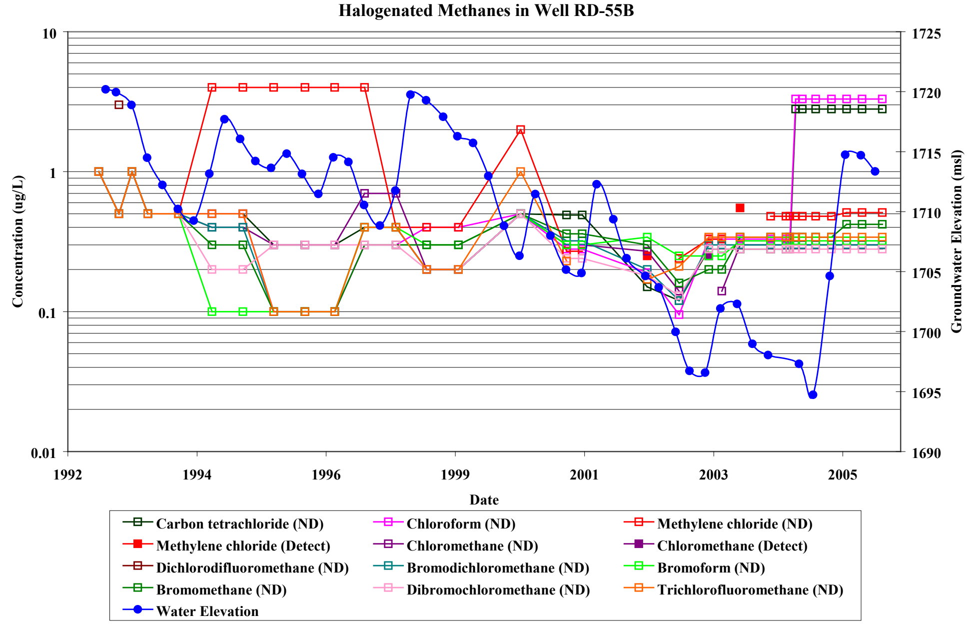
Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Tritium (^{3}H) sampled 8/93

Grid Location C3

Halogenated Methanes in Well RD-55B



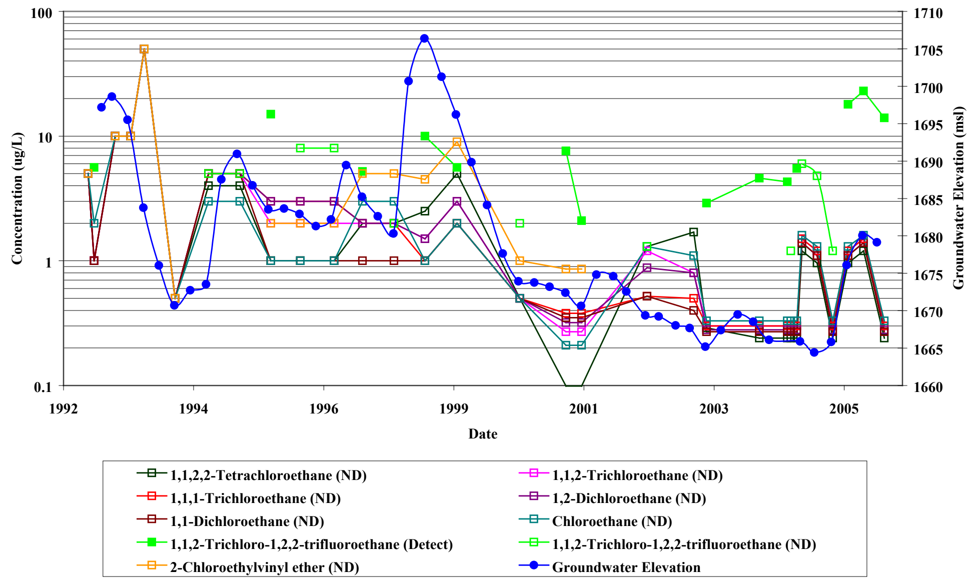
MWH

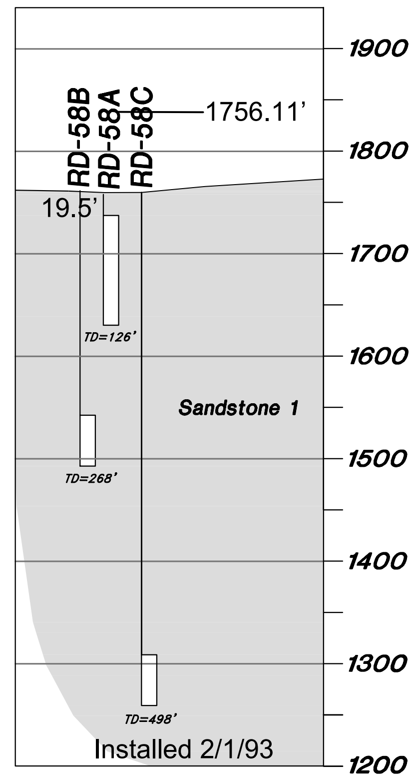
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-55B

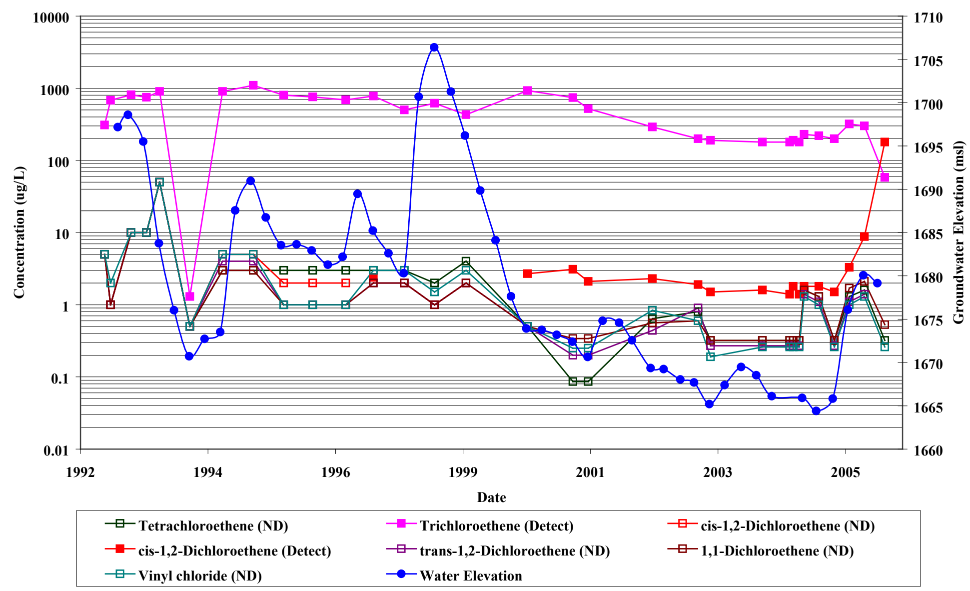
JOB No.________________ FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK\RD 58 A B C

Halogenated Ethanes in Well RD-58A





Halogenated Ethenes in Well RD-58A



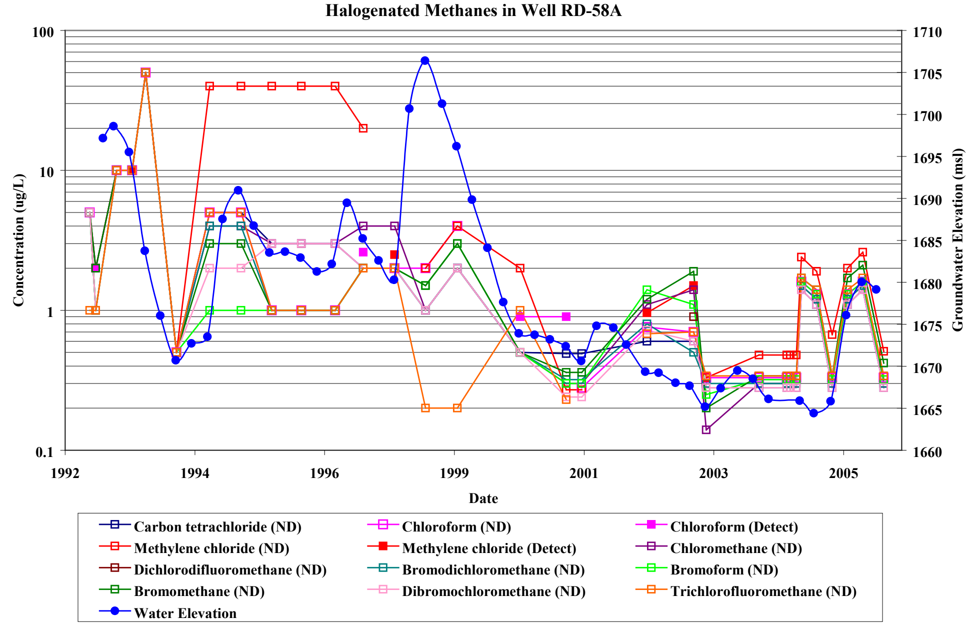
Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	17.09 (Avg)	mg/L
Sulfate:	255 (Avg)	mg/L
Chloride:	103 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.44/-45.46	permil
^{3}H:	8.83 ± 0.09	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Tritium (^{3}H) sampled 8/93

Halogenated Methanes in Well RD-58A

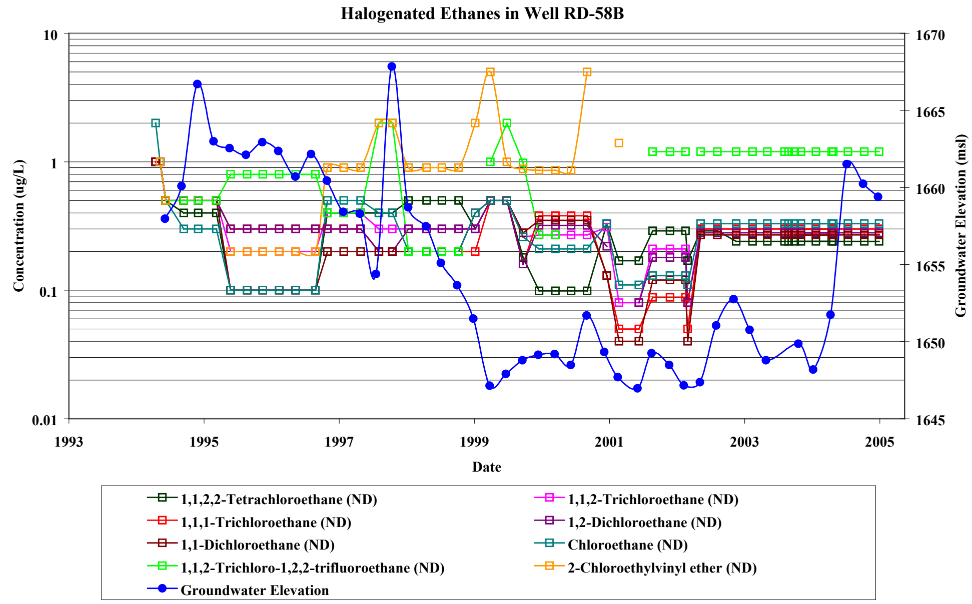


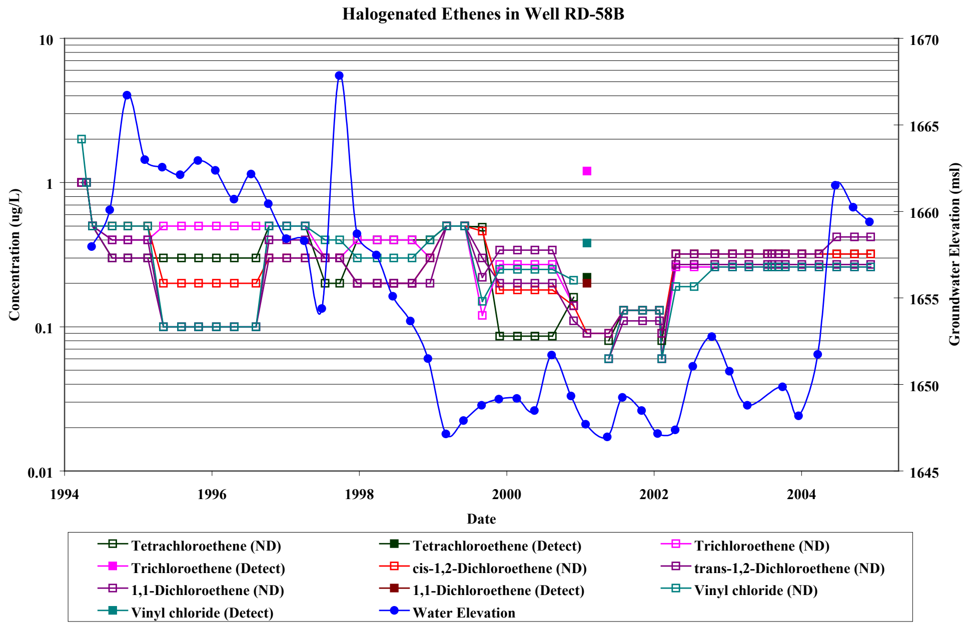
Grid Location D3

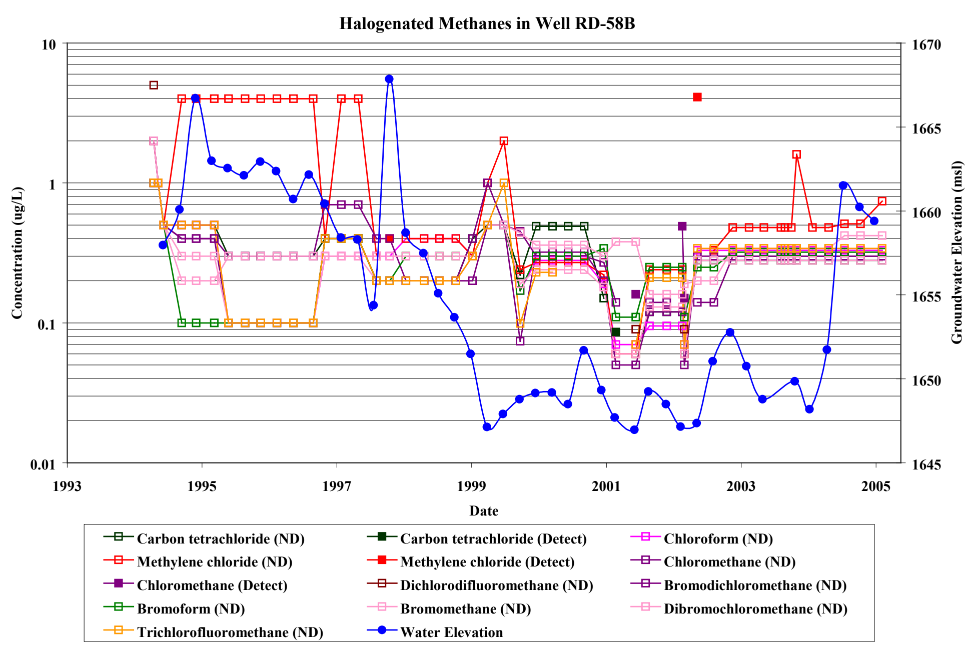
MWH

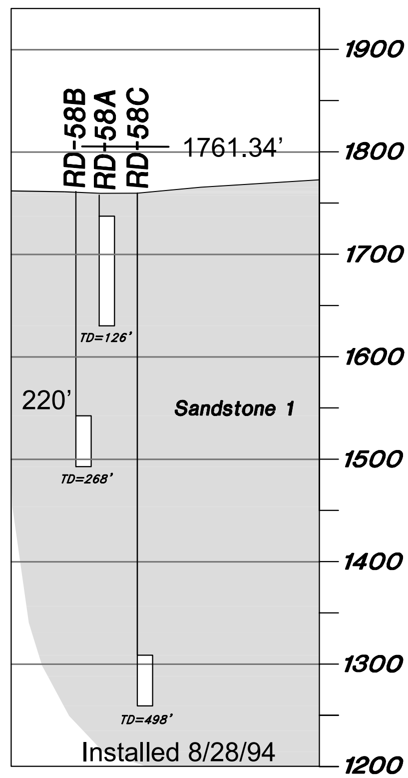
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

RD-58A









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.2 (Avg)	mg/L
Sulfate:	150	mg/L
Chloride:	31	mg/L
$^{18}O/^{2}H$:	-7.02/-42.20	permil
^{3}H:	6.65 ± 0.22	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Tritium (^{3}H) sampled 10/94

Grid Location D3

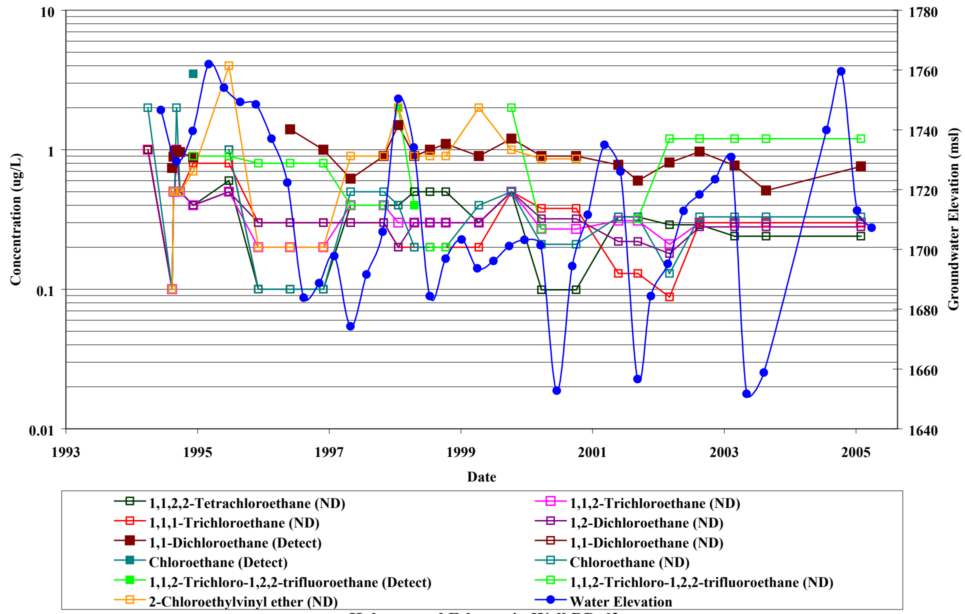
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

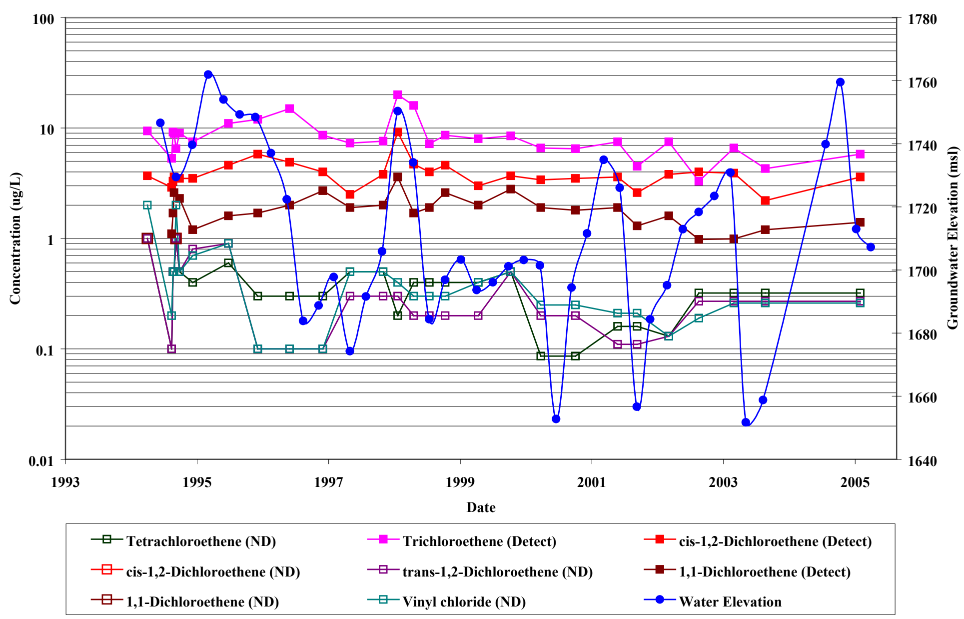
RD-58B

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 63

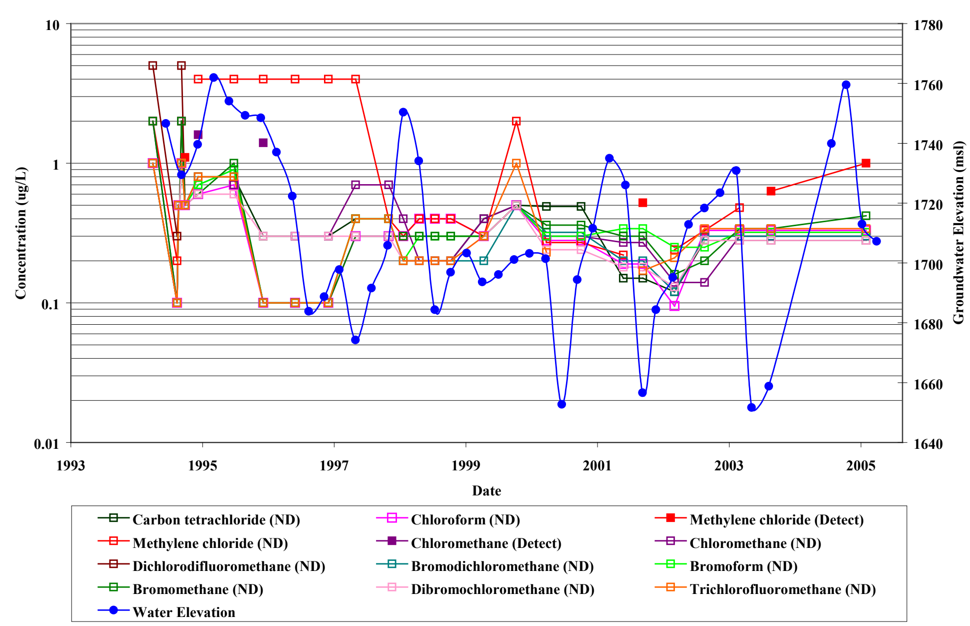
Halogenated Ethanes in Well RD-63

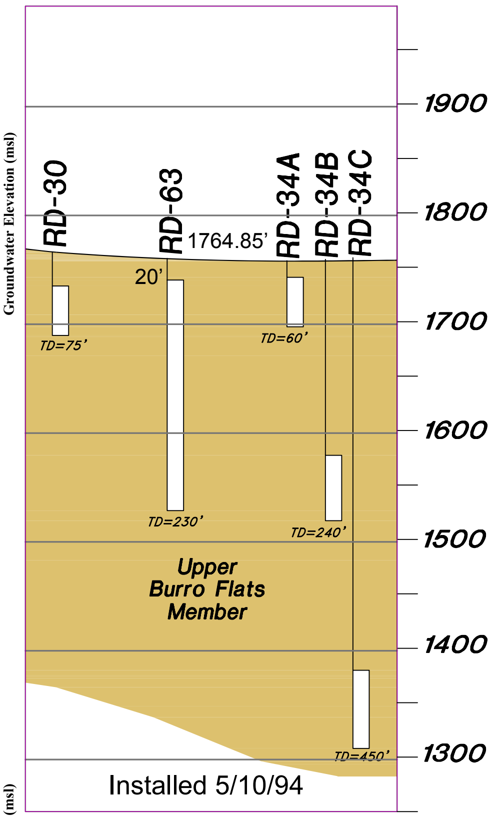


Halogenated Ethenes in Well RD-63



Halogenated Methanes in Well RD-63





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	ND	mg/L
Sulfate:	140	mg/L
Chloride:	50	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Used as interim measures extraction well

Grid Location B3

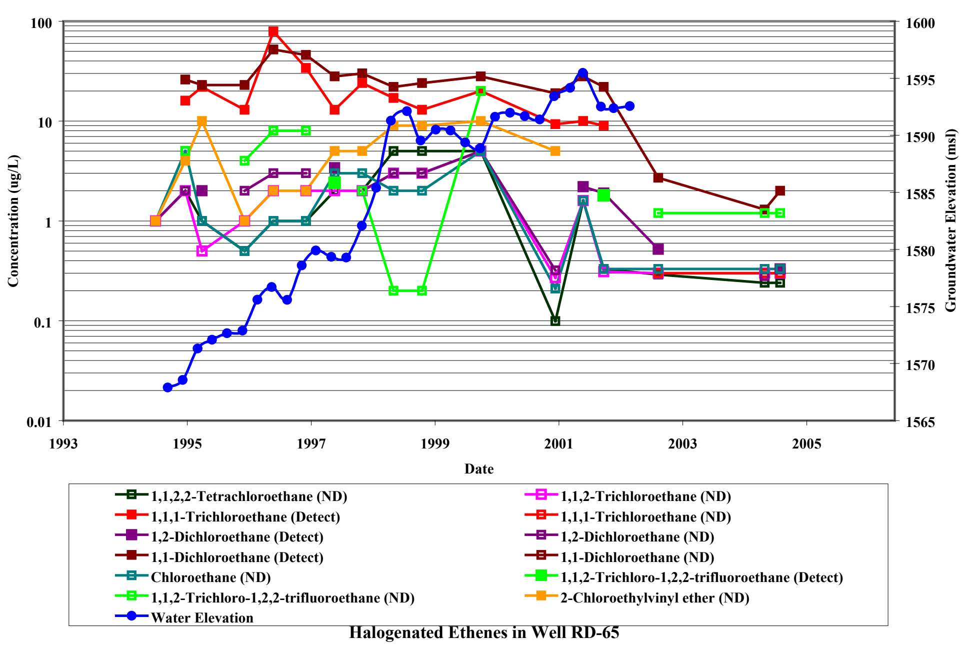
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

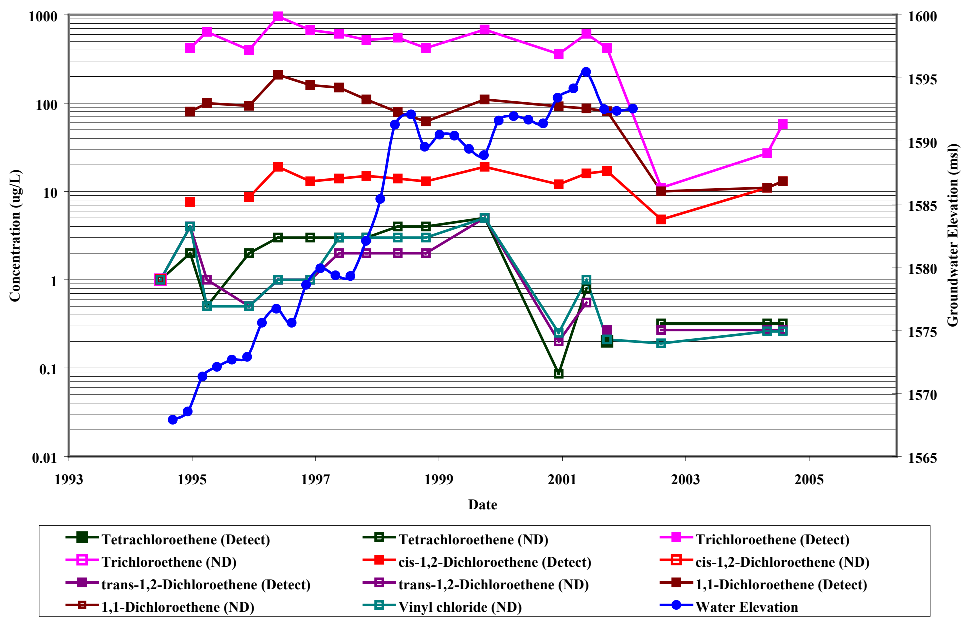
RD-63

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\RD 65

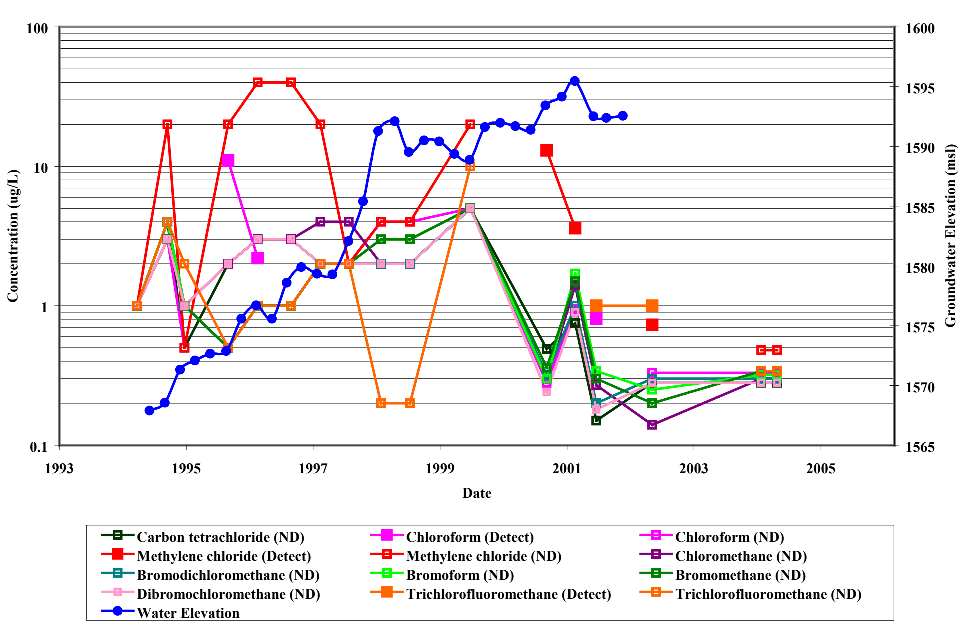
Halogenated Ethanes in Well RD-65

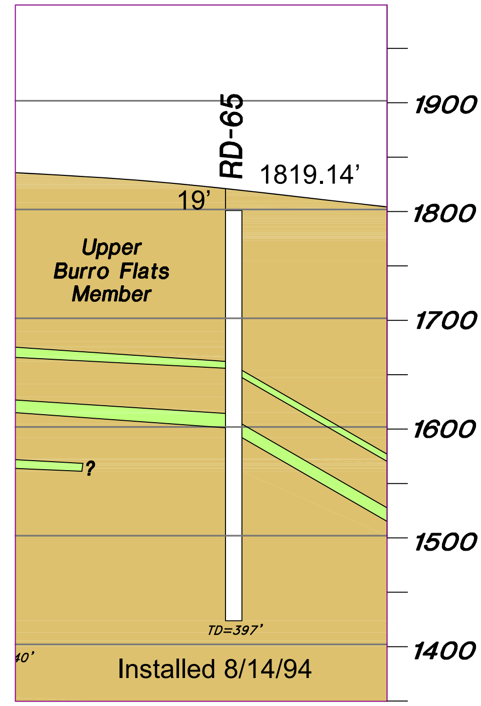


Halogenated Ethenes in Well RD-65



Halogenated Methanes in Well RD-65





Other Data:	Value	Units
1,4-dioxane:	6.5 (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	NA	mg/L
Sulfate:	45	mg/L
Chloride:	35	mg/L
$^{18}O/^{2}H$:	-7.15/-44.70	permil

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Multi-level installed 10/2002

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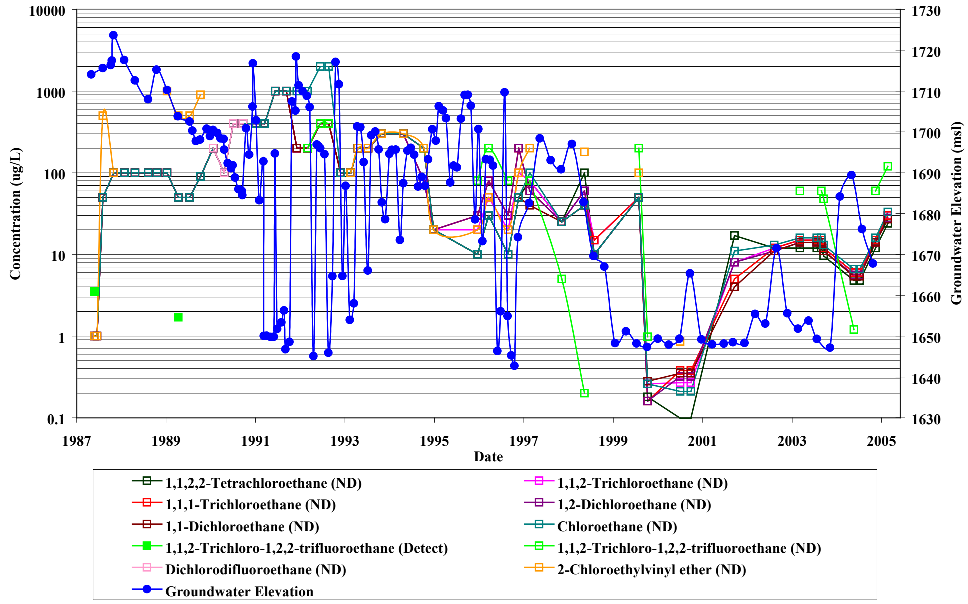
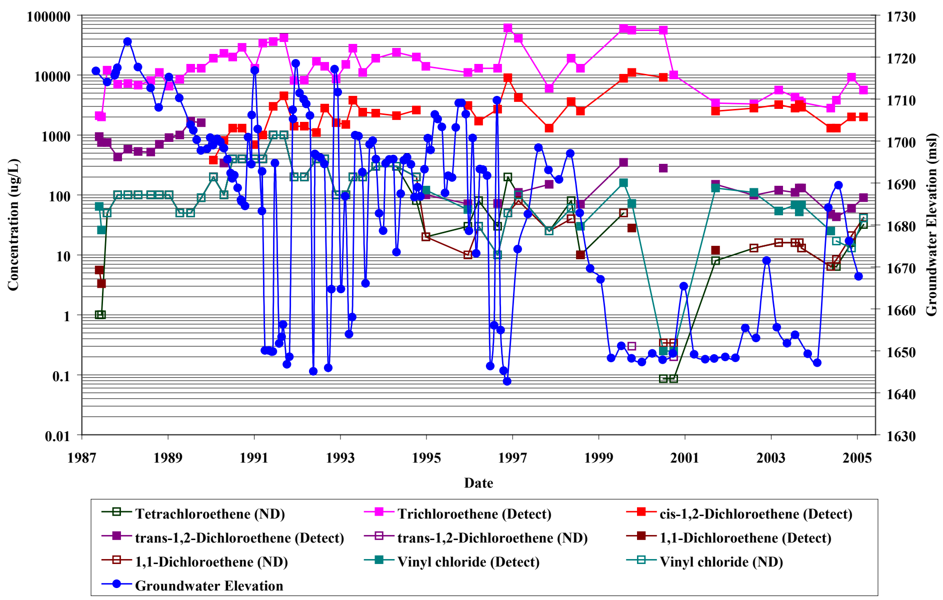
VENTURA COUNTY, CALIFORNIA

RD-65

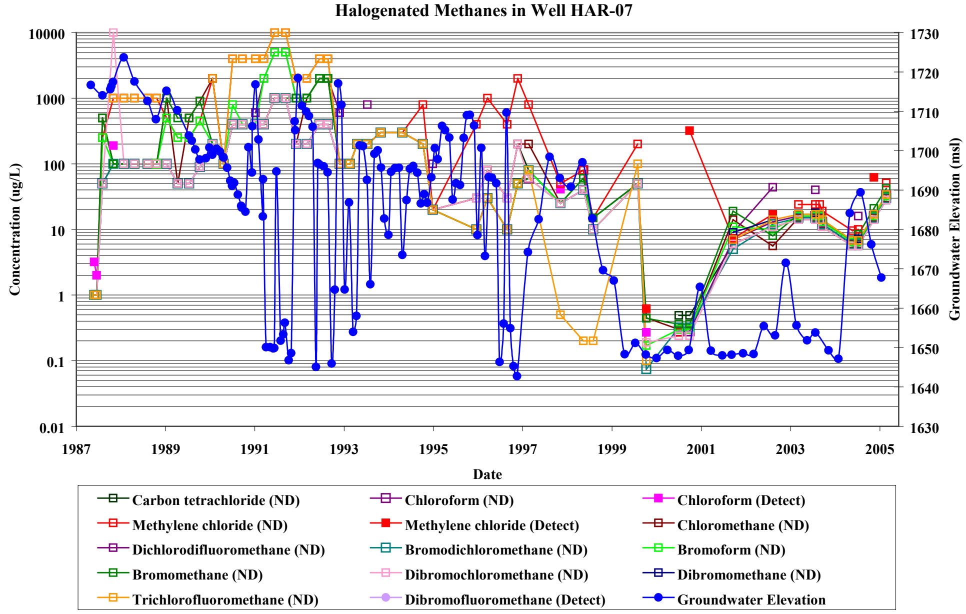
Halogenated Ethanes in Well HAR-07

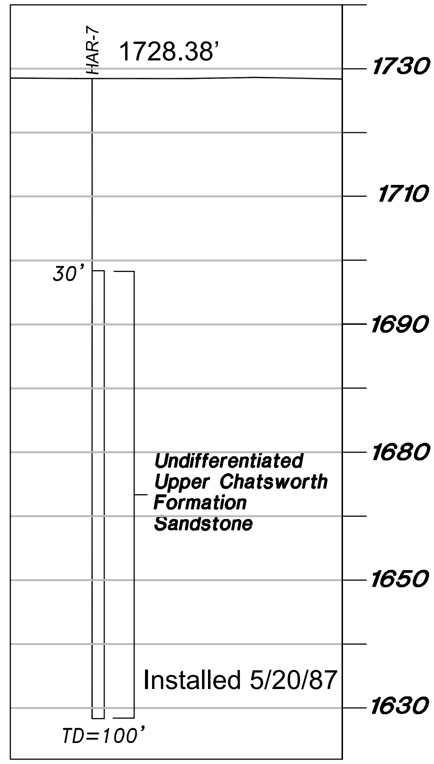


Halogenated Ethenes in Well HAR-07



Halogenated Methanes in Well HAR-07





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	5.08 (Avg)	mg/L
Sulfate:	78	mg/L
Chloride:	38.6	mg/L
$^{18}O/^{2}H$:	-7.00/-46.57	permil
^{3}H:	NA	TU

Notes: Extraction Well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Grid Location D4

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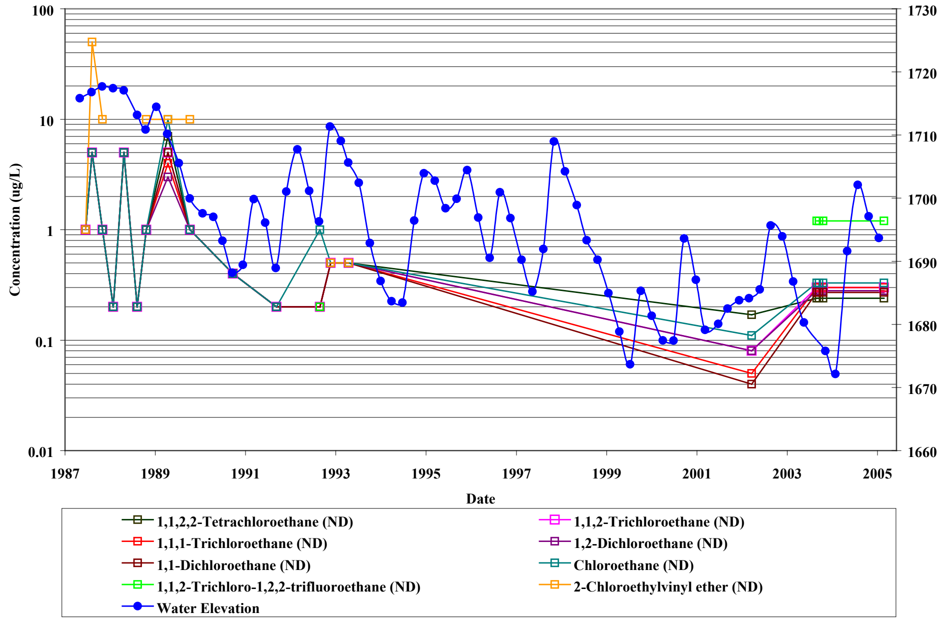
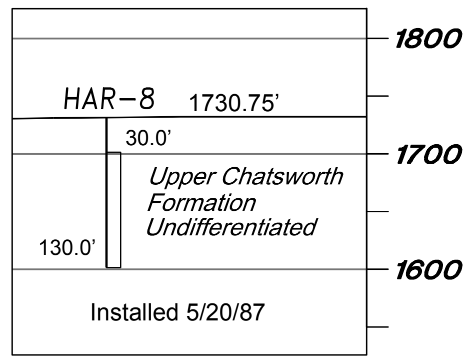
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

HAR-07

JOB No.________________ FILE: SANTA SUSANA\WELL BOOKS\HAR 8

Halogenated Ethanes in Well HAR-08





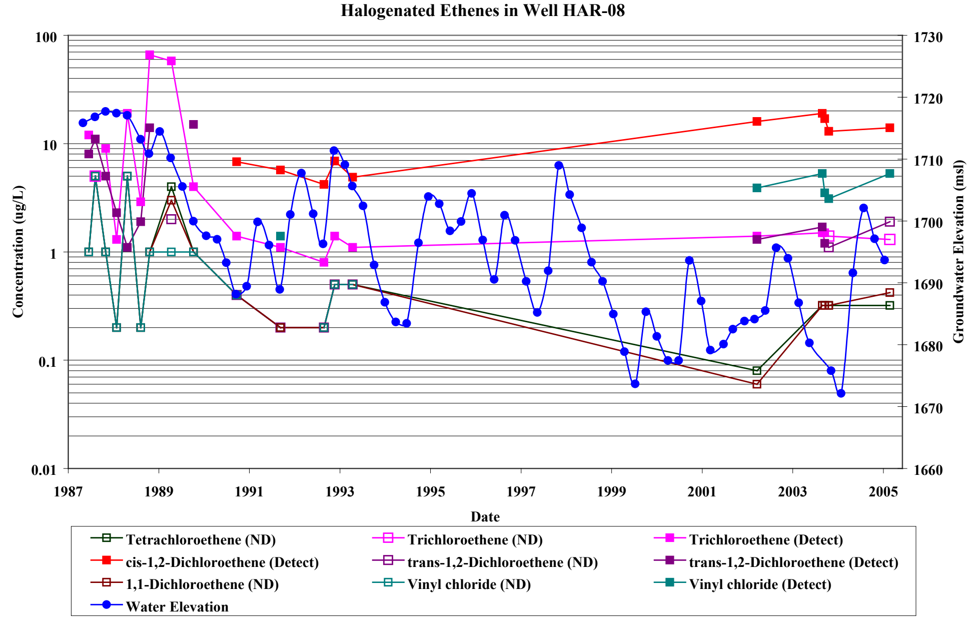
Other Data:	Value	Units
1,4-dioxane:	ND	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	<0.4	mg/L
Sulfate:	150	mg/L
Chloride:	67.3	mg/L
$^{18}O/^{2}H$:	-7.04/-46.34	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

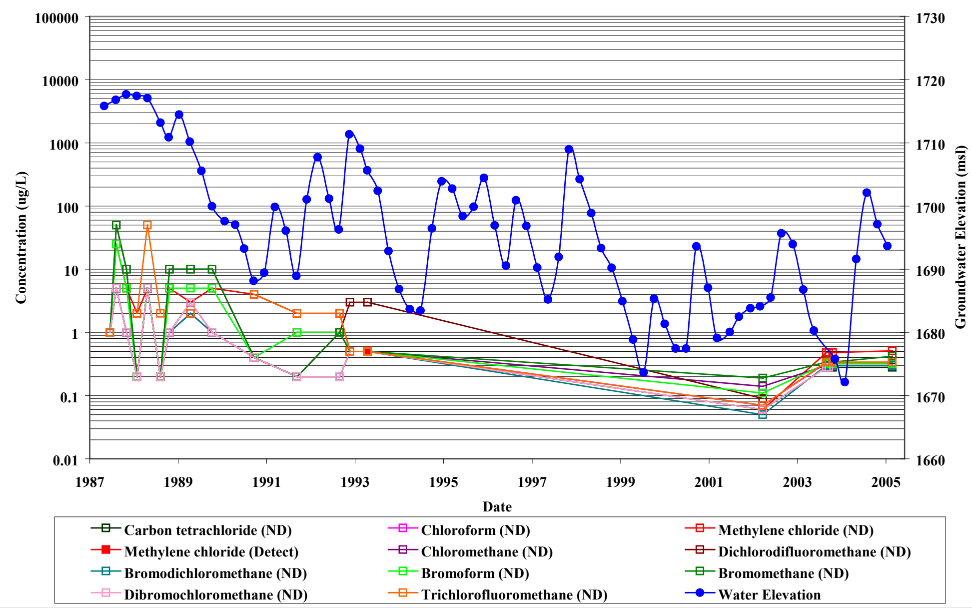
Avg - multiple results, average concentration

Grid Location D4

Halogenated Ethenes in Well HAR-08



Halogenated Methanes in Well HAR-08



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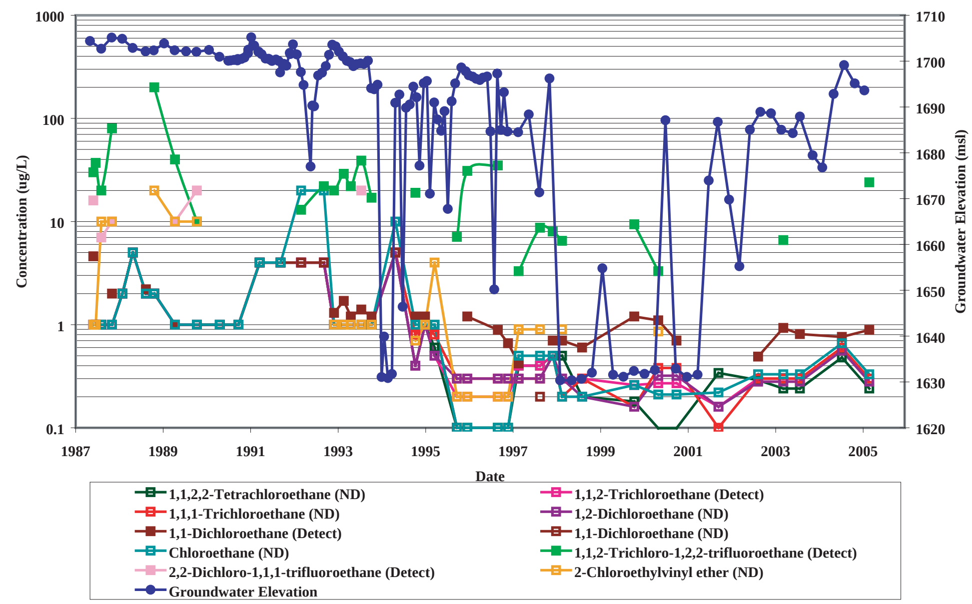
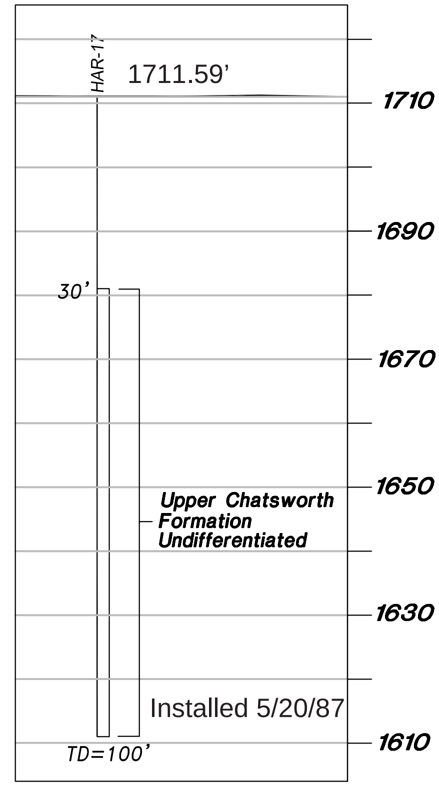
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

HAR-8

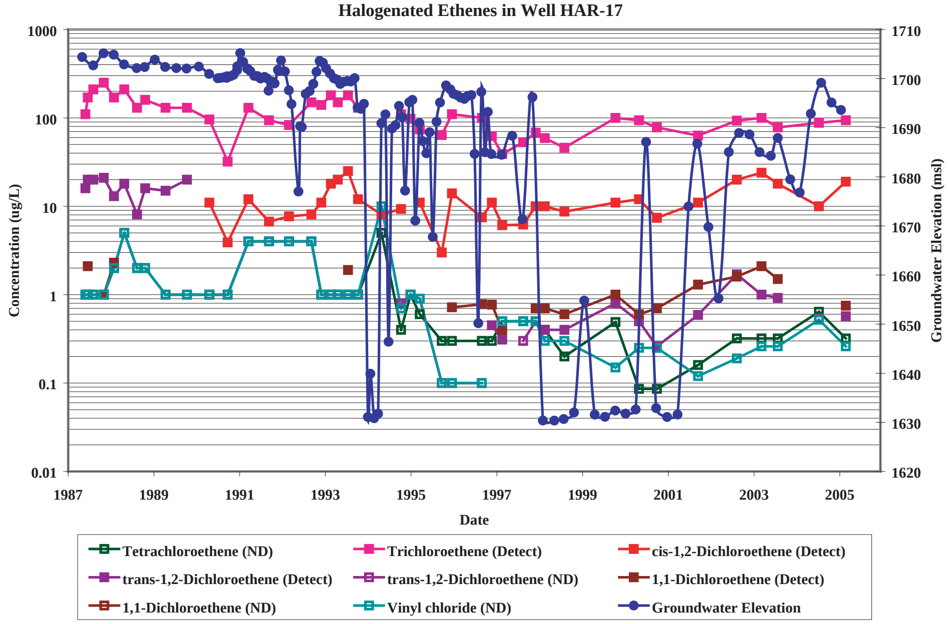
JOB No.________________ FILE: SANTA SUSANA\WELL BOOKS\HAR 17

Halogenated Ethanes in Well HAR-17





Halogenated Ethenes in Well HAR-17



Other Data:	Value	Units
1,4-dioxane:	4.4 (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	3.86 (Avg)	mg/L
Sulfate:	190	mg/L
Chloride:	107	mg/L
$^{18}O/^{2}H$:	-6.81/-48.44	permil
^{3}H:	NA	TU

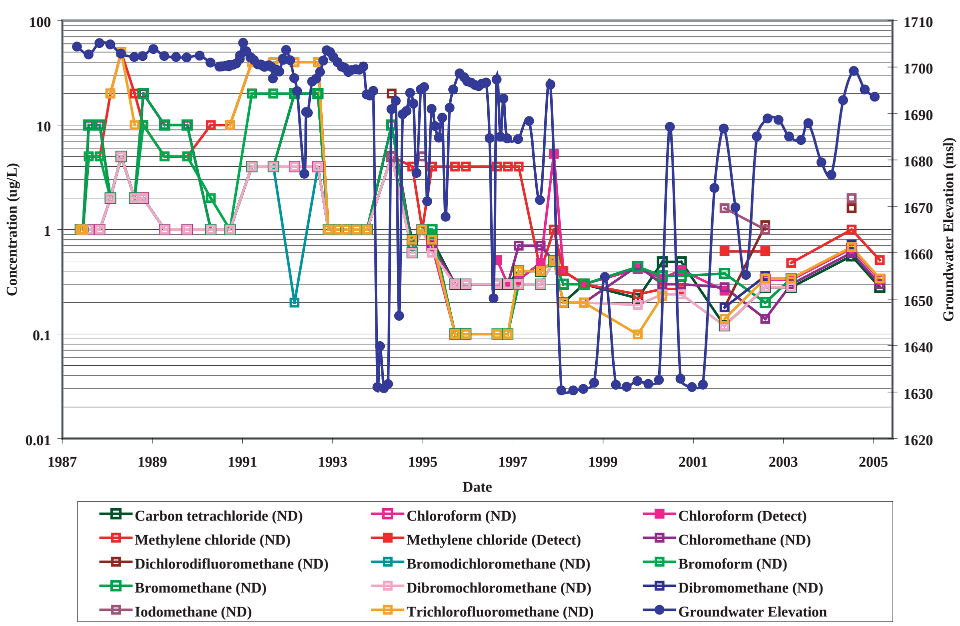
Notes: Extraction Well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

1,4-dioxane: 21 analyses/2 detections

Halogenated Methanes in Well HAR-17



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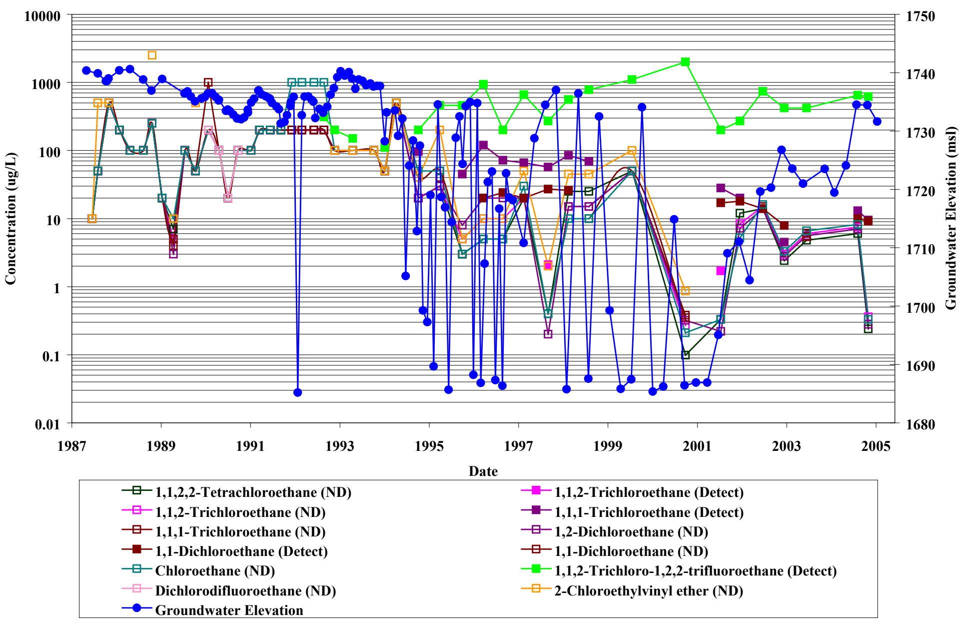
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

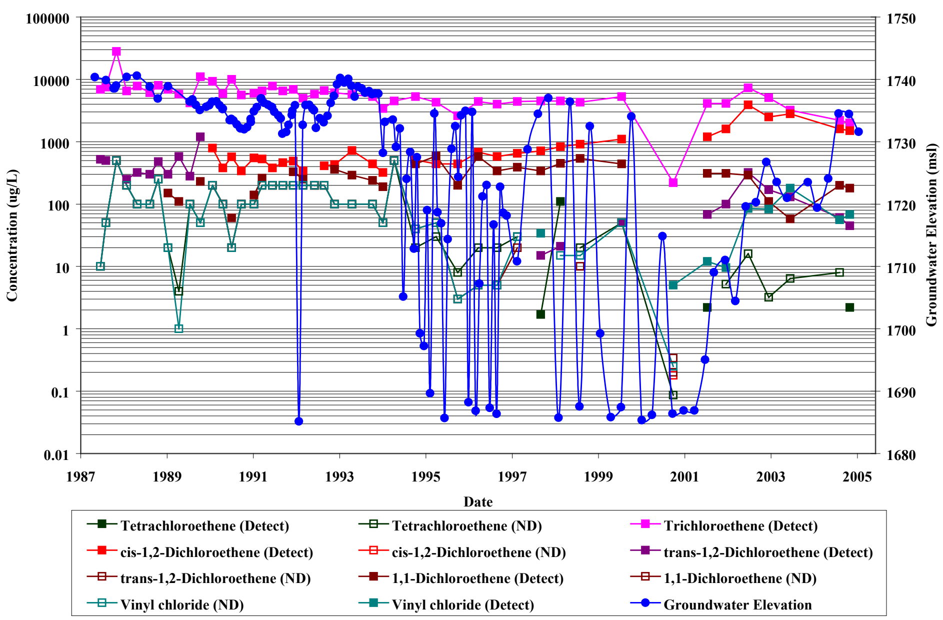
HAR-17

FILE: CADMLUEBKE\BOEING\SANTA SUSANA\WELL BOOK FIGS\HAR 18

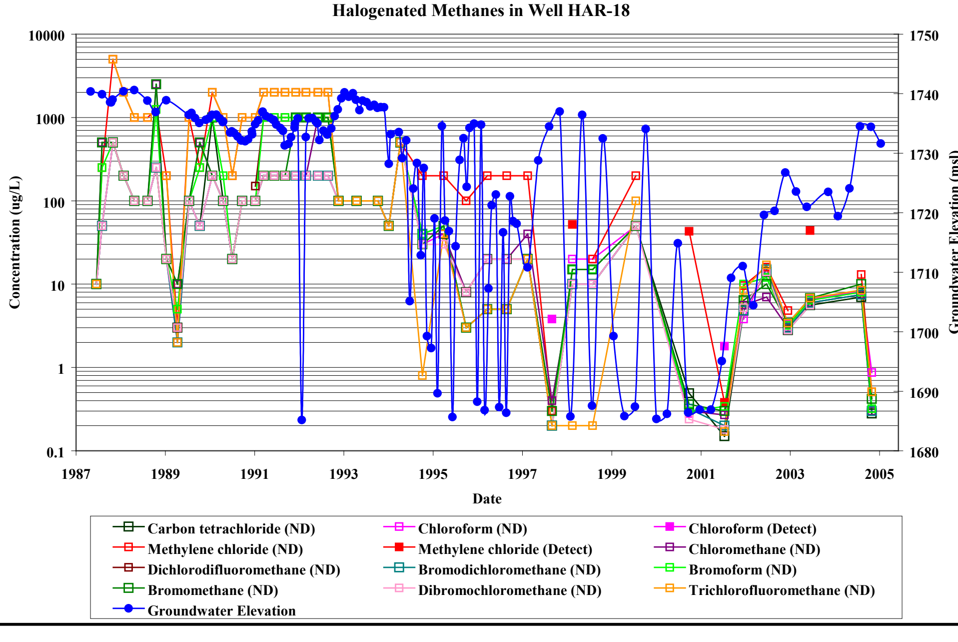
Halogenated Ethanes in Well HAR-18

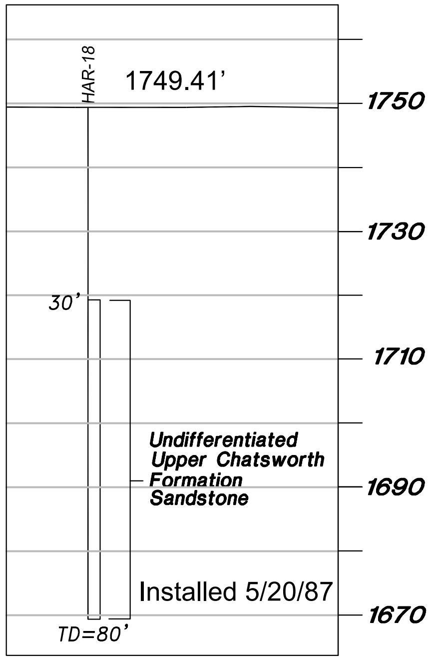


Halogenated Ethenes in Well HAR-18



Halogenated Methanes in Well HAR-18





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	57.6	mg/L
Sulfate:	148	mg/L
Chloride:	61.6	mg/L
$^{18}O/^{2}H$:	-7.04/-50.02	permil
^{3}H:	NA	TU

Notes: Extraction Well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

Grid Location C3

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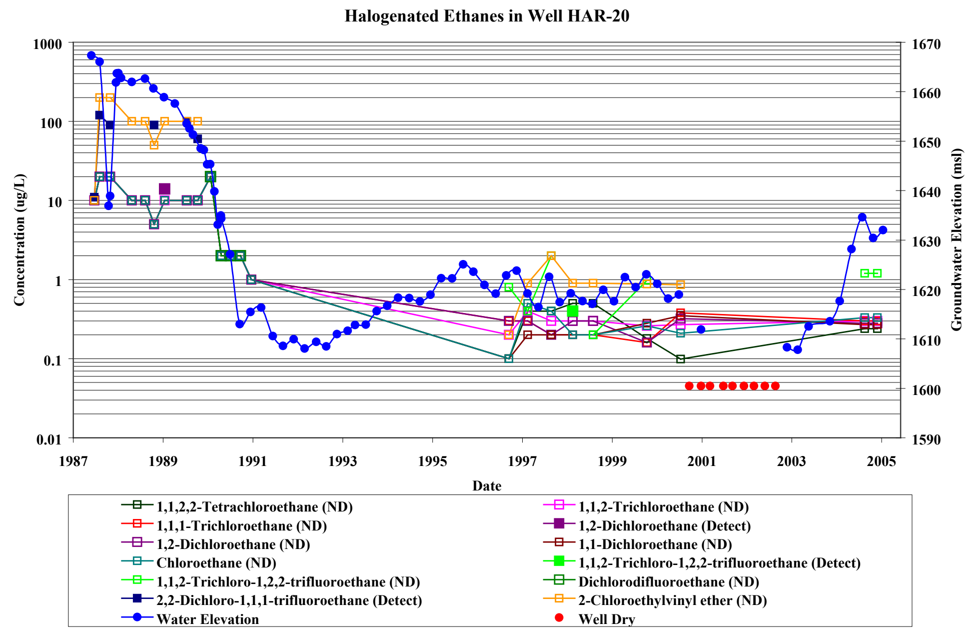
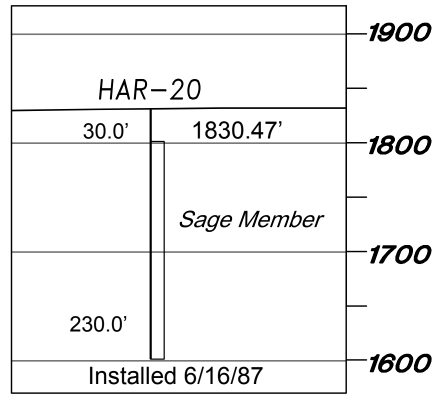
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

HAR-18

JOB No.________________ FILE: SANTA SUSANA\WELL BOOKS\HAR 20

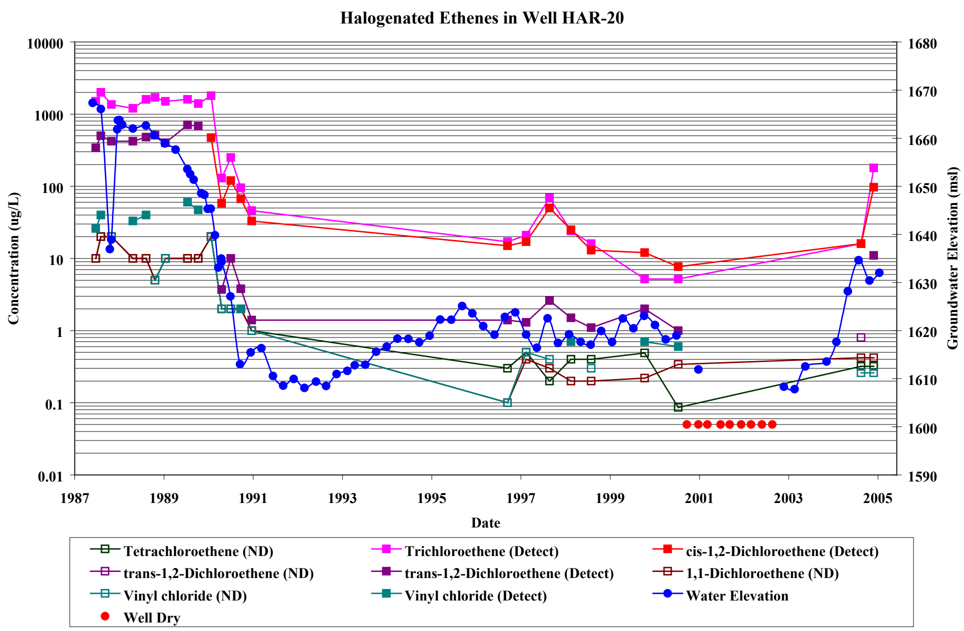




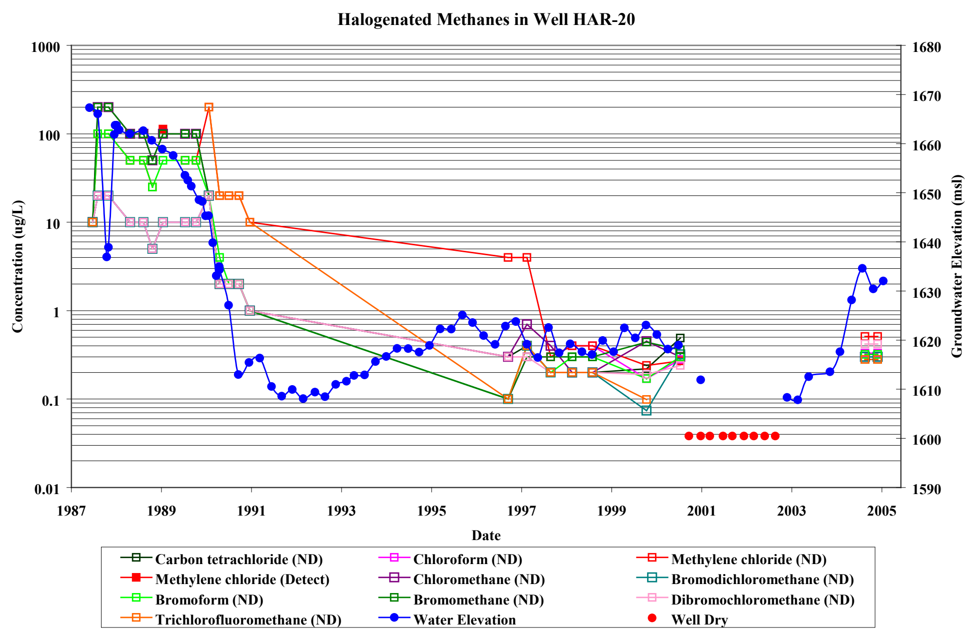
Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	ND	mg/L
Sulfate:	158	mg/L
Chloride:	65.1	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

Avg - multiple results, average concentration



Grid Location C5



MWH

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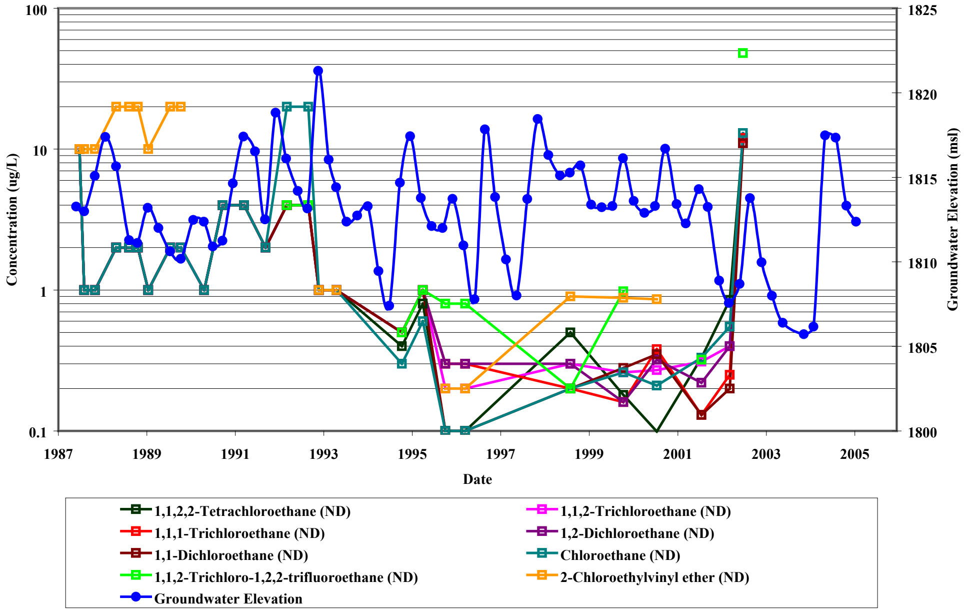
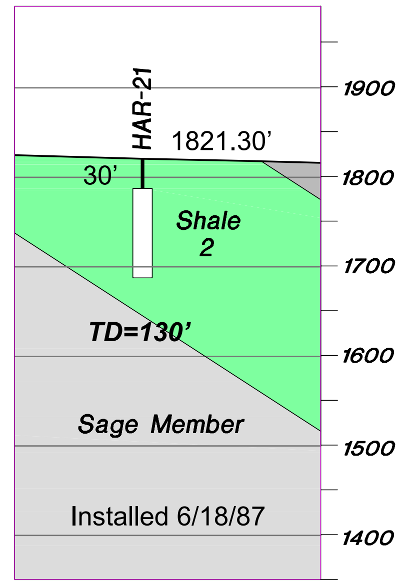
VENTURA COUNTY, CALIFORNIA

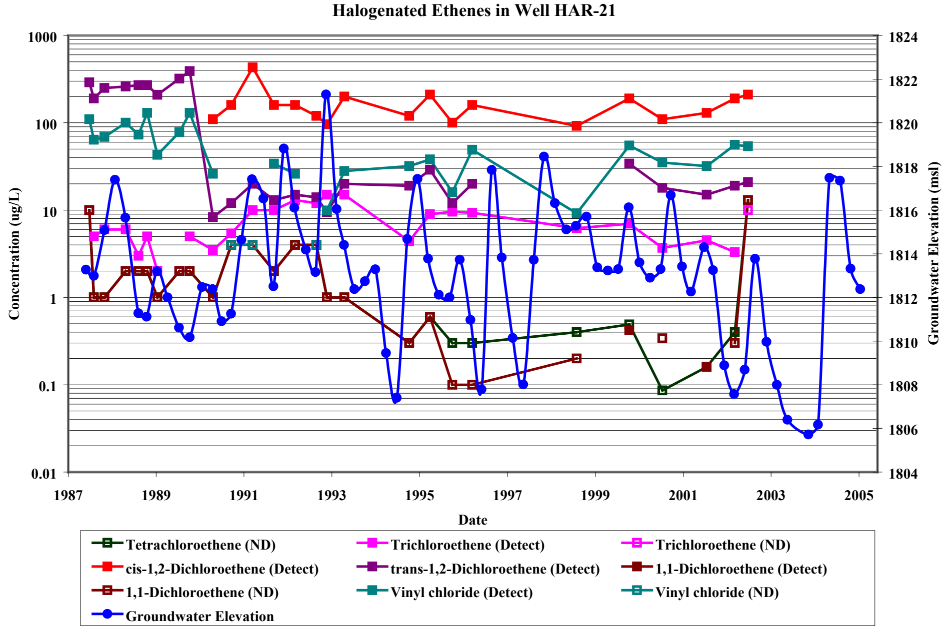
HAR-20

Halogenated Ethanes in Well HAR-21





Halogenated Ethenes in Well HAR-21

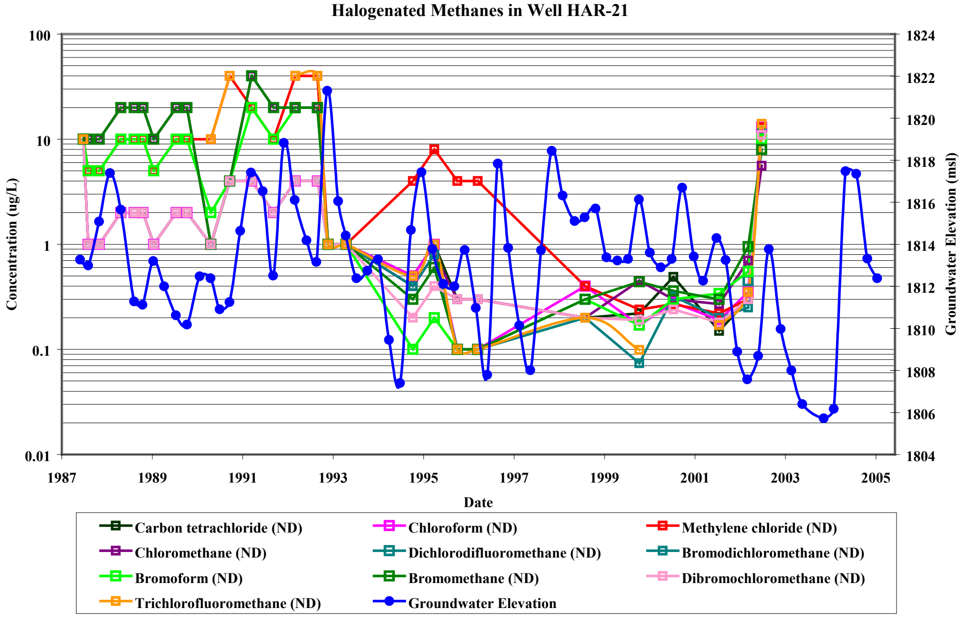


Other Data:	Value	Units
1,4-dioxane:	3.23	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	NA	mg/L
Sulfate:	255	mg/L
Chloride:	89.9	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: NA-not analyzed ND-not detected

1,4-dioxane: 4 analyses/1 detection

Halogenated Methanes in Well HAR-21



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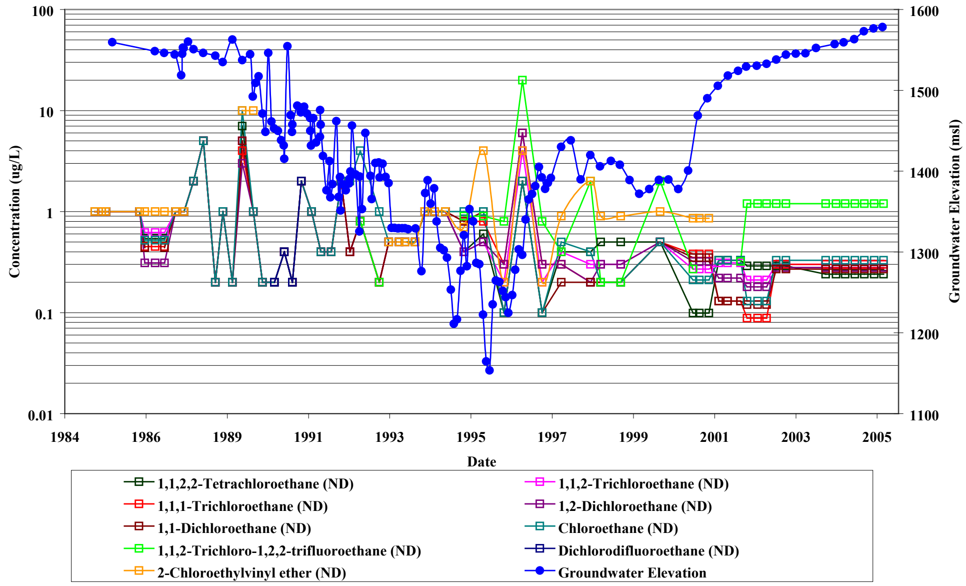
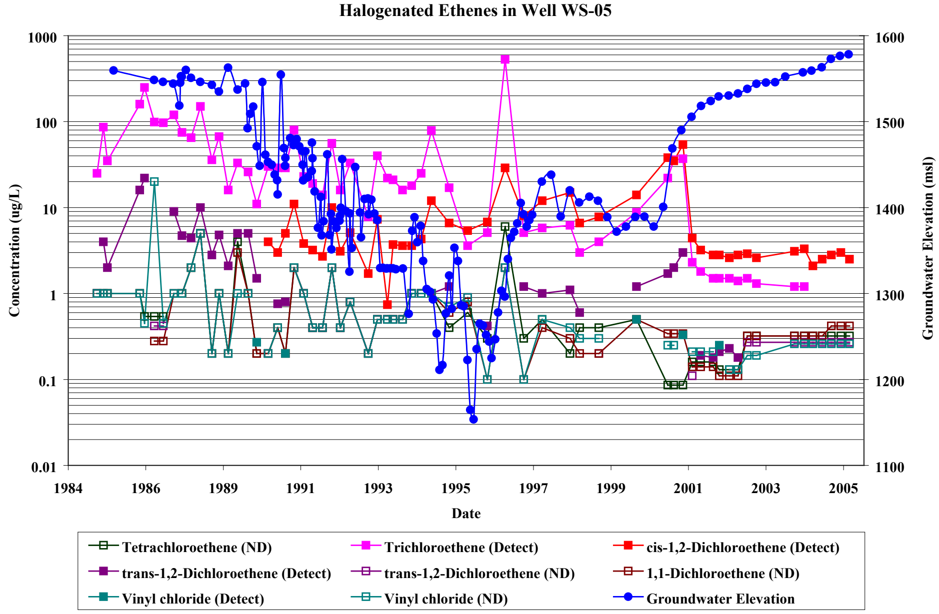
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

HAR-21

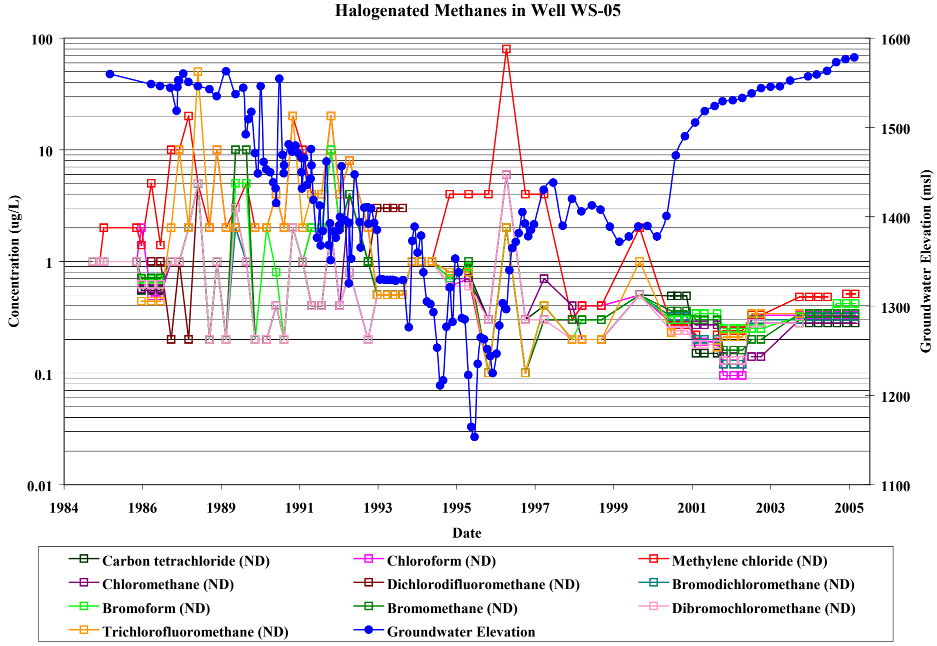
Halogenated Ethanes in Well WS-05

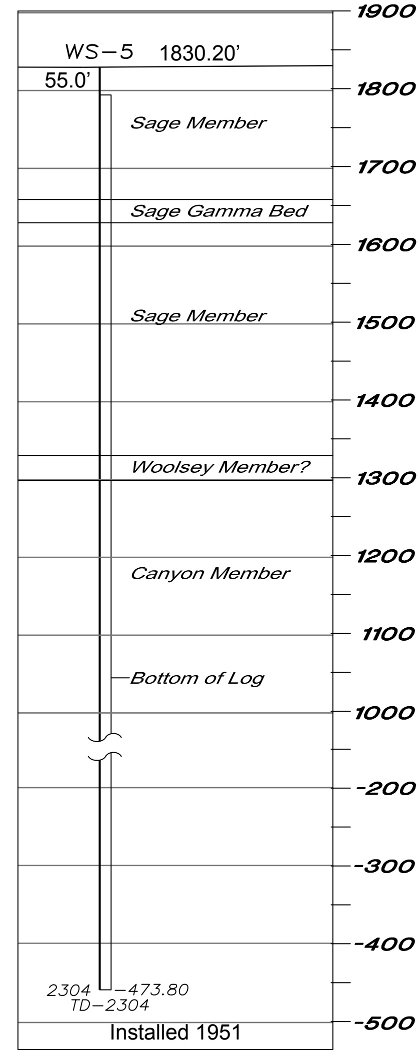


Halogenated Ethenes in Well WS-05



Halogenated Methanes in Well WS-05





Other Data:	Value	Units
1,4-dioxane:	3.2 (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	0.13 (Avg)	mg/L
Sulfate:	128.5 (Avg)	mg/L
Chloride:	34.5 (Avg)	mg/L
$^{18}O/^{2}H$:	-7.32/-47.92	permil
^{3}H:	12.7 ± 8.37	TU

Notes: Periodically used as an extraction well

NA-not analyzed   ND-not detected

Avg - multiple results, average concentration

1,4-dioxane: 2 analyses/1 detection

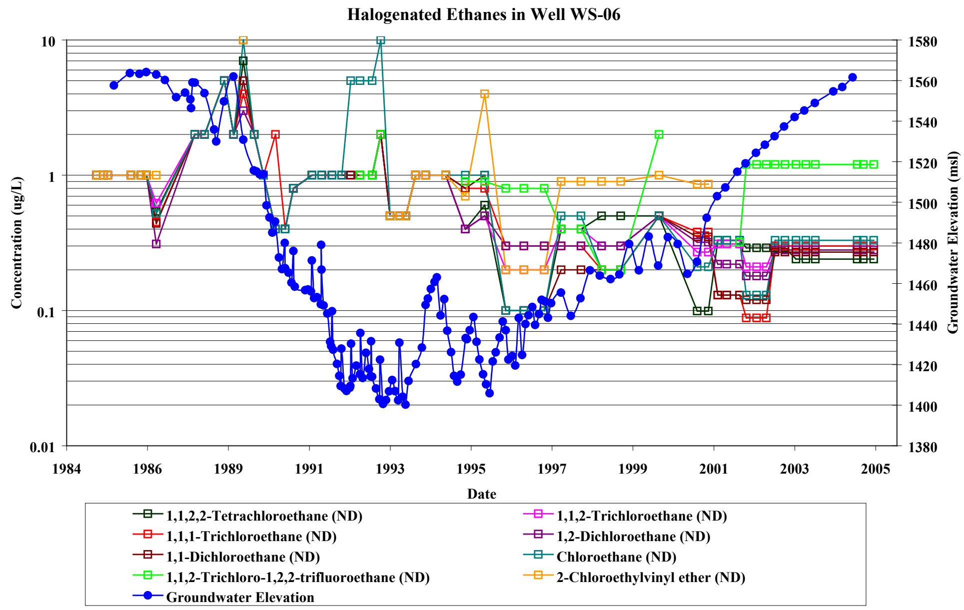
Tritium (^{3}H) sampled 9/87

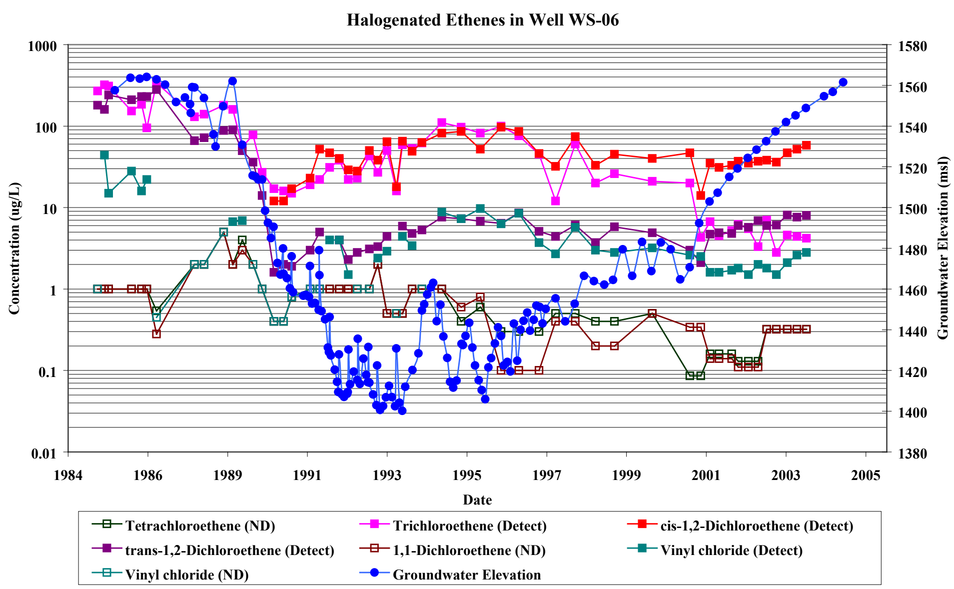
Grid Location C7

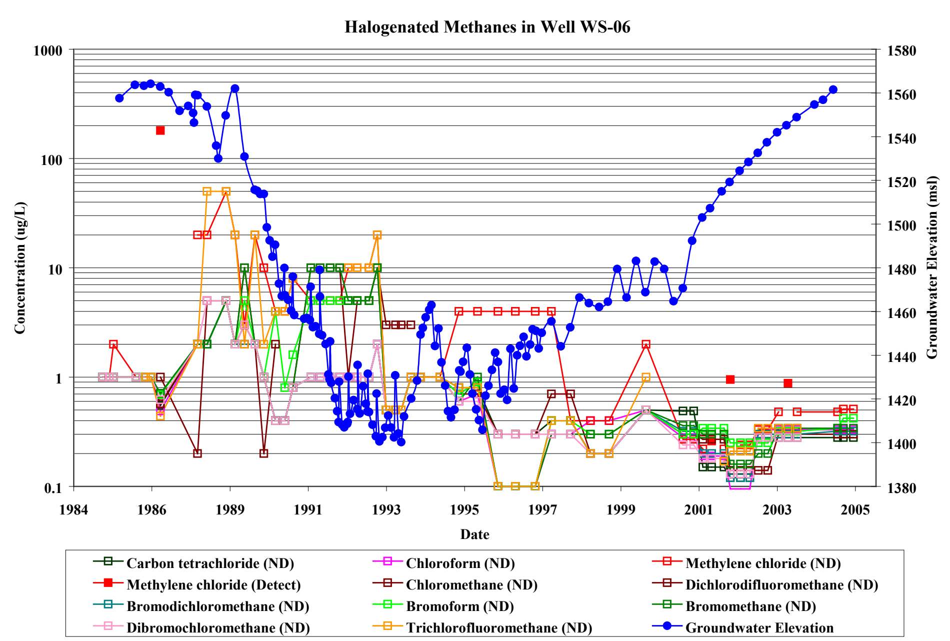
MWH

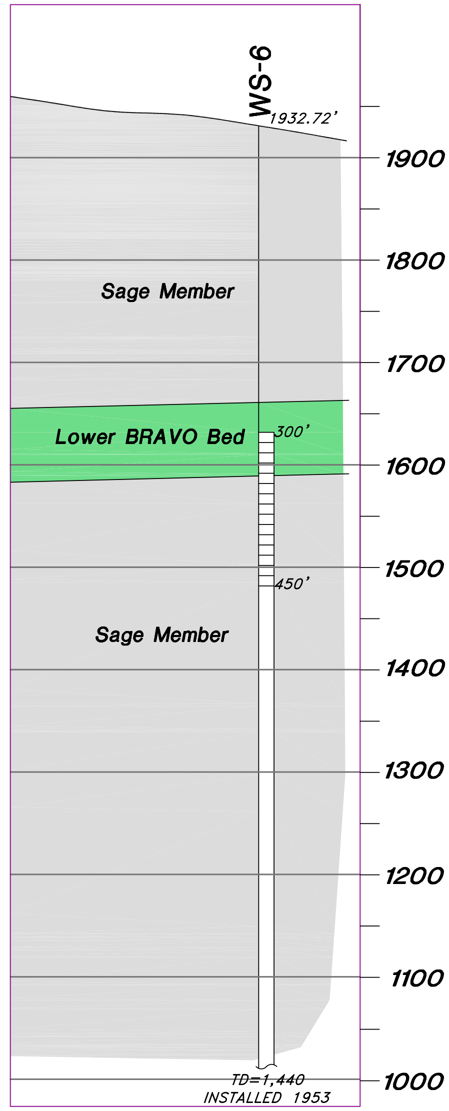
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

WS 5









Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	<0.2 (Avg)	mg/L
Sulfate:	145.2 (Avg)	mg/L
Chloride:	40.9 (Avg)	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

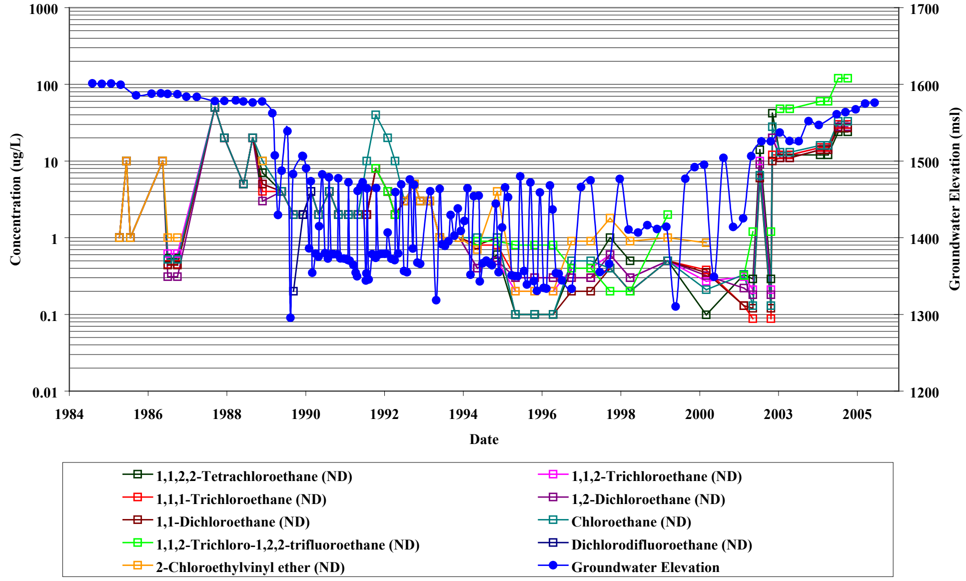
Grid Location C6

MWH

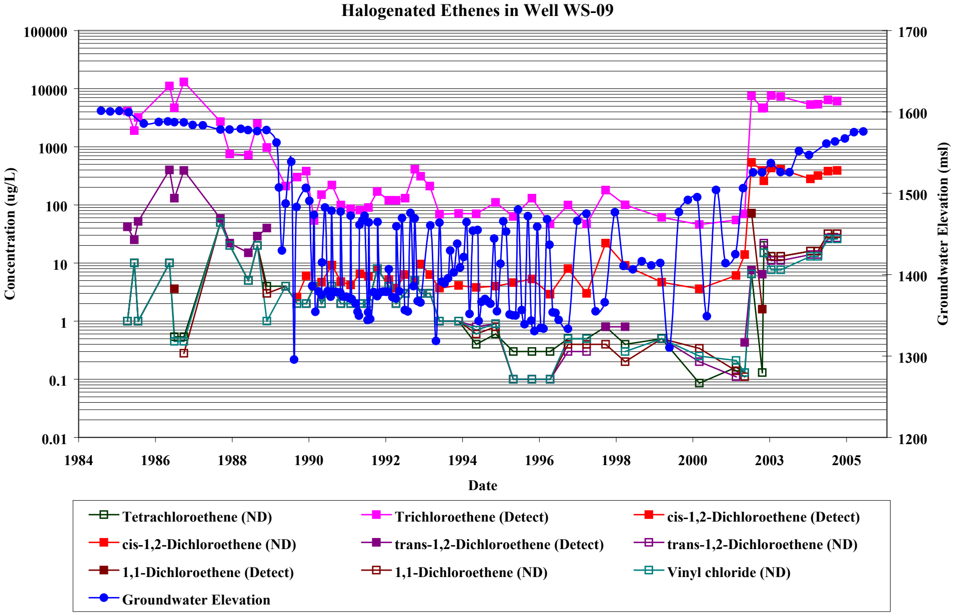
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

WS-6

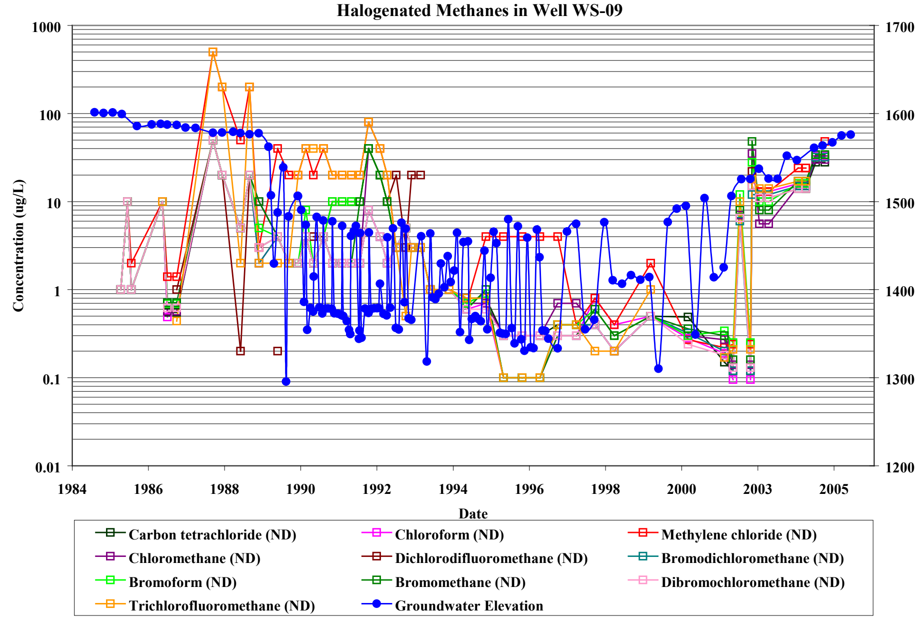
Halogenated Ethanes in Well WS-09

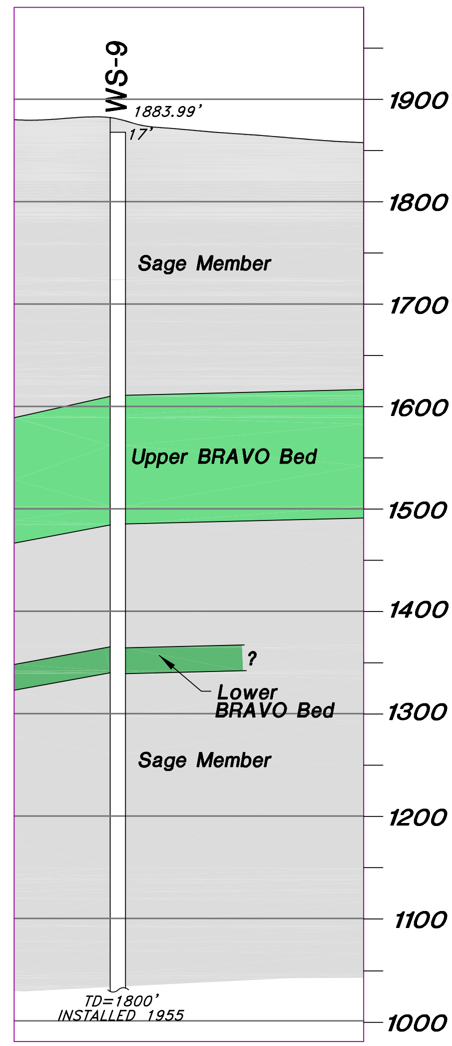


Halogenated Ethenes in Well WS-09



Halogenated Methanes in Well WS-09





Other Data:	Value	Units
1,4-dioxane:	2.1 (Avg)	ug/L
Perchlorate:	ND	ug/L
Nitrate as NO_3:	ND (Avg)	mg/L
Sulfate:	190 (Avg)	mg/L
Chloride:	31.2 (Avg)	mg/L
$^{18}O/^{2}H$:	NA	permil
^{3}H:	NA	TU

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

1,4-dioxane: 17 analyses/5 detections

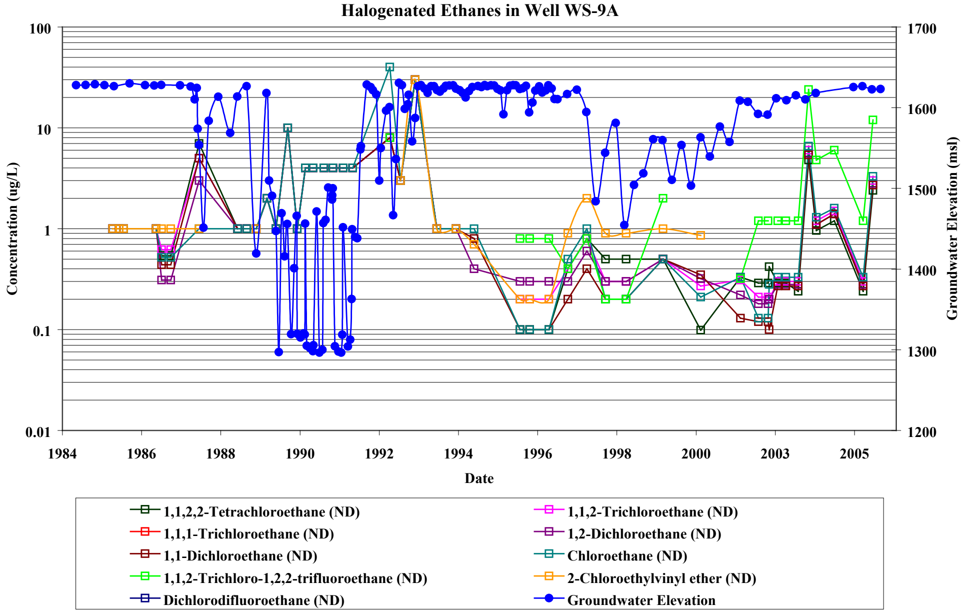
Grid Location C5

MWH

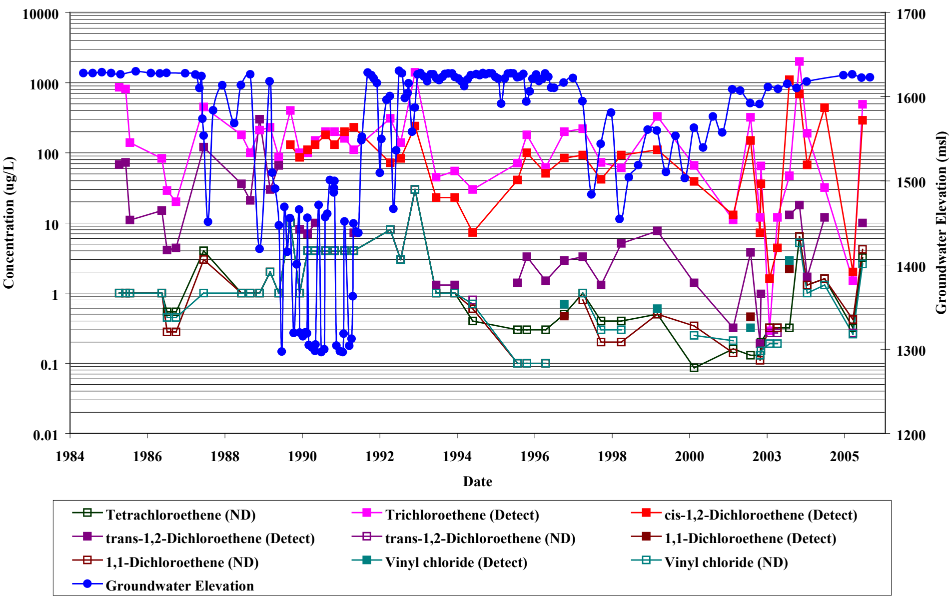
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

WS-9

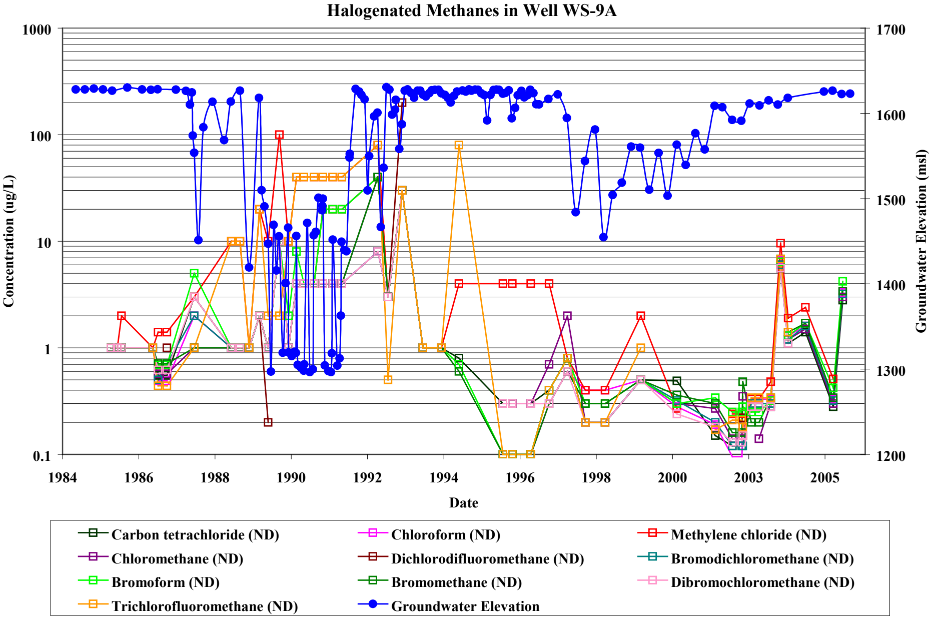
Halogenated Ethanes in Well WS-9A

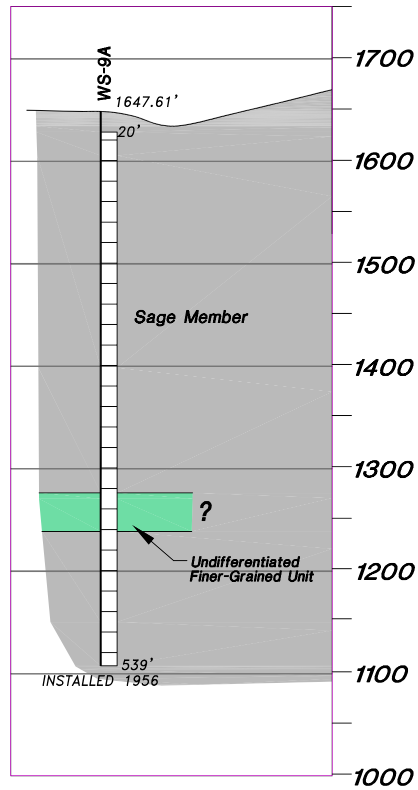


Halogenated Ethenes in Well WS-9A



Halogenated Methanes in Well WS-9A





Other Data:	Value	Units
1,4-dioxane:	ND (Avg)	ug/L
Perchlorate:	ND (Avg)	ug/L
Nitrate as NO_3:	ND (Avg)	mg/L
Sulfate:	168.7 (Avg)	mg/L
Chloride:	44.6 (Avg)	mg/L
$^{18}O/^{2}H$:	-5.05/-39.68	permil
	-6.91/-44.91	permil

Notes: Periodically used as an extraction well

NA-not analyzed ND-not detected

Avg - multiple results, average concentration

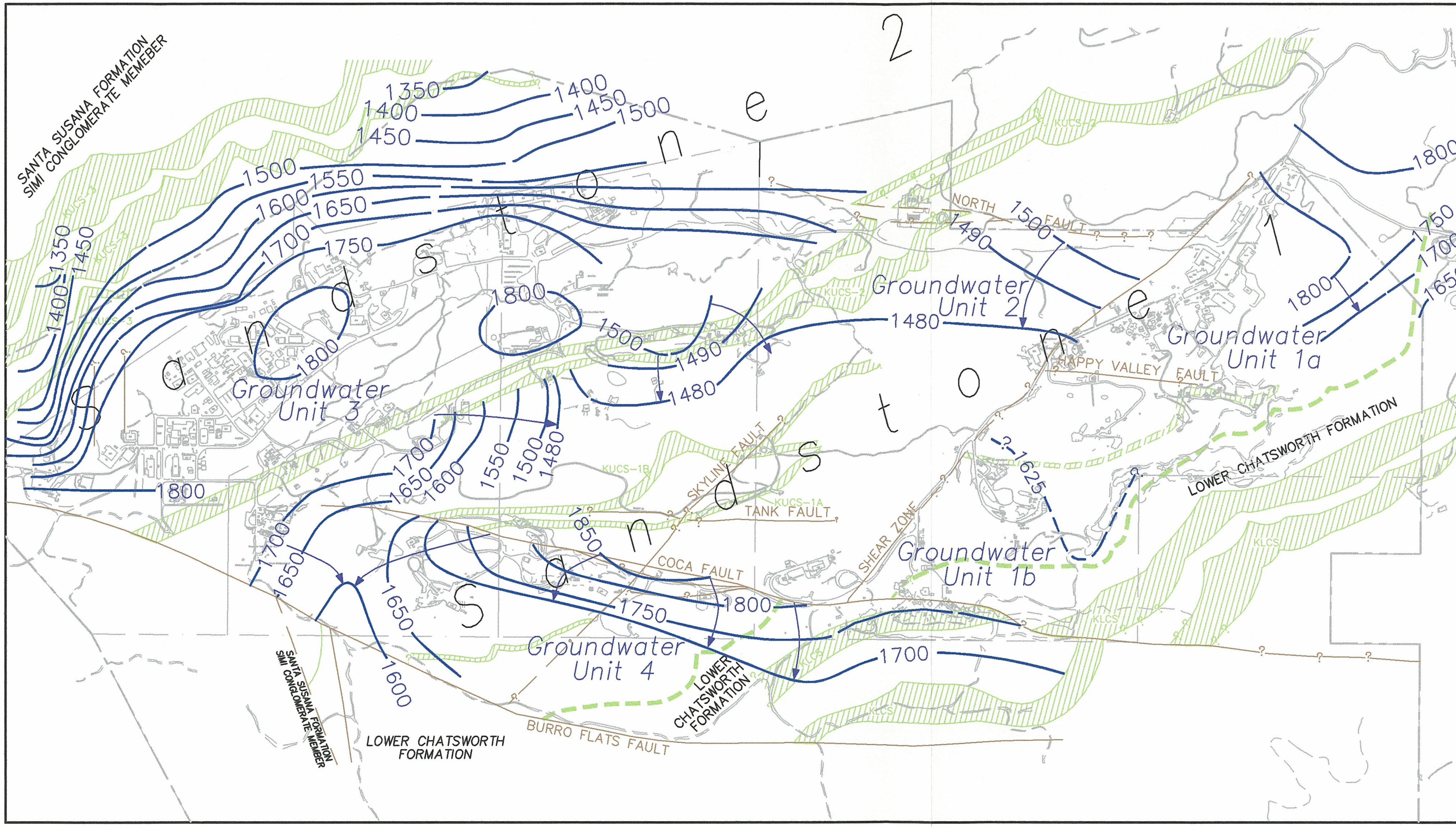
Grid Location D4

MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

WS-9A

APPENDIX B



0 1500 3000
SCALE IN FEET

HALEY & ALDRICH
UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

THE BOEING COMPANY
ROCKETDYNE PROPULSION AND POWER
SANTA SUSANA FIELD LABORATORY

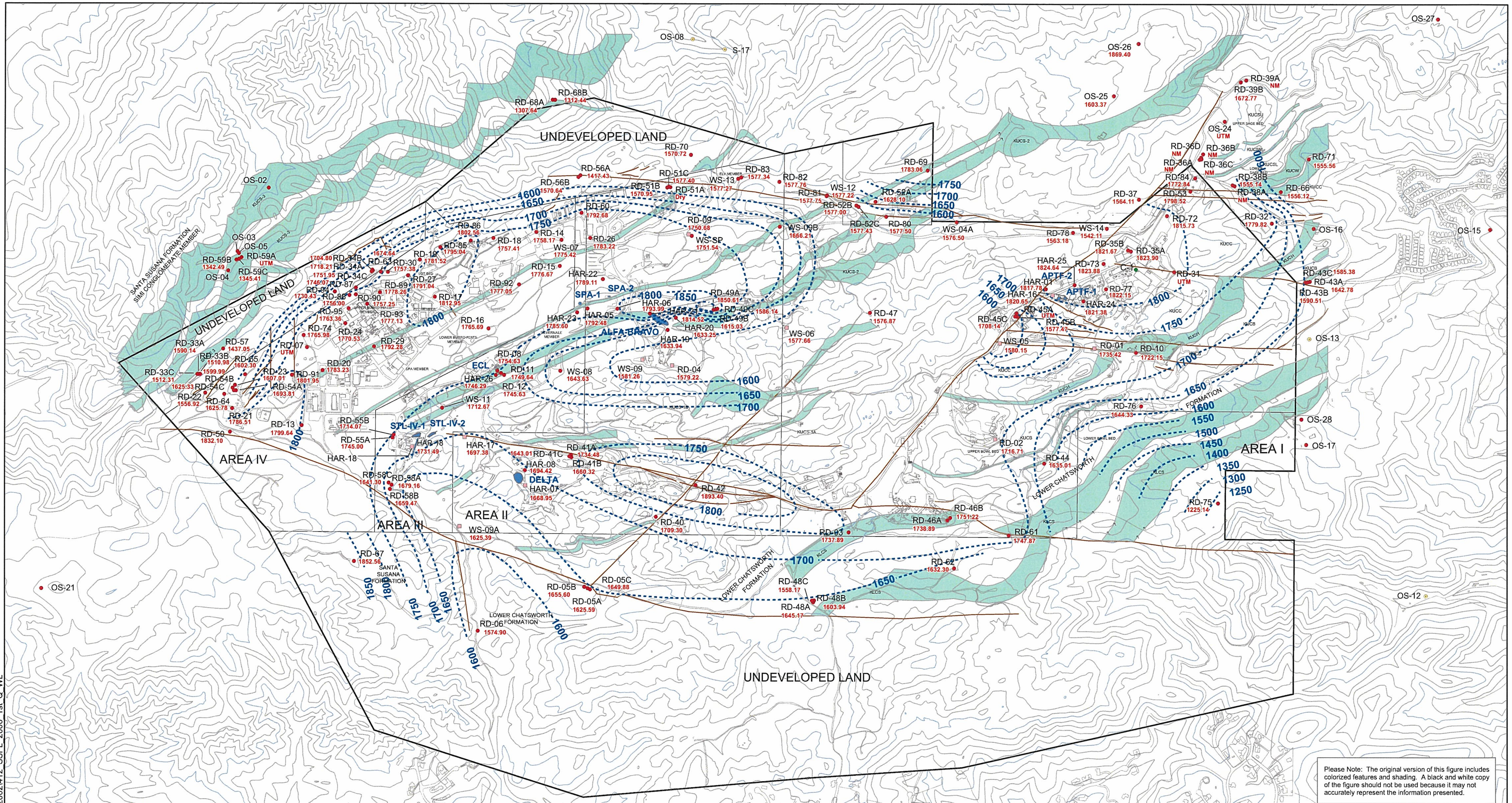
WATER LEVEL ELEVATION CONTOUR MAP – MAY 2000
CHATSWORTH FORMATION
GROUNDWATER SYSTEM

SCALE: AS SHOWN

AUGUST 2000

FIGURE 2

26472-203 B02



Legend

- Chatsworth Formation Monitoring Well
- Chatsworth Formation Extraction Well
- C-1 Corehole
- Springs
- Fault and/or Shear Zone
- Property Boundary Line

1600 - - -	Approximate Contour of Equal Water Level Elevation, in feet above Mean Sea Level. Contour interval 50 feet.
1802.07	Water Level Elevation, in feet above Mean Sea Level
UTM	Unable to Measure
NM	Not Measured

Legend for geology: Refer to Figure 4, Geologic Map, in Haley & Aldrich's "Report on the Annual Groundwater Monitoring, 2004, Santa Susana Field Laboratory, Ventura County, California," February 28, 2006.

- KUCC — Geologic Unit
- Marker Bed
- KLCS — Geologic Unit

Geology provided by Montgomery Watson Harza. "Geologic Characterization of the Eastern Portion of SSFL, Technical Memorandum," February 22, 2002.

Water level elevations are provided for illustrative purposes only and are not intended to infer groundwater flow conditions. The lateral direction of groundwater movement cannot be ascertained from the contour lines because of stratigraphic and structural properties of the bedrock.

Contours are based on measured water levels in conventional wells. Actual water levels in the subsurface will vary from those shown.

N / W / E / S

0 700 1400 2800
SCALE IN FEET

FIRST QUARTER 2006 GROUNDWATER MONITORING REPORT

HALEY & ALDRICH

THE BOEING COMPANY
SANTA SUSANA FIELD LABORATORY

CHATSWORTH FORMATION
WATER LEVEL ELEVATION
CONTOUR MAP - FEBRUARY 2006

SCALE: AS SHOWN
MAY 2006

FIGURE 3

G:\Graphics\Projects\26472-ROC\ROC_GIS_2002\412_SSFL_2006_1st_Q_WL

APPENDIX C

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	3
Location	Date	Port	Sample Type	Screening Values and Results in ug/L
C-8	28-Feb-03	5	Primary	1.7 UJ
C-8	28-Feb-03	6	Primary	1 UJ
C-8	28-Feb-03	7	Primary	1.4 UJ
C-8	28-Feb-03	8	Primary	1.3 UJ
C-8	28-Feb-03	9	Primary	1 UJ
C-8	24-Mar-03	5	Primary	1 UJ
C-8	24-Mar-03	6	Primary	1 UJ
C-8	24-Mar-03	7	Primary	1 UJ
C-8	24-Mar-03	8	Primary	1 UJ
C-8	24-Mar-03	9	Primary	0.3 U
C-8	24-Mar-03	10	Primary	1.3 UJ
OS-03	21-Aug-96	--	Primary	500 U
OS-03	22-Aug-97	--	Primary	20 U
OS-04	21-Aug-96	--	Primary	500 U
OS-04	22-Aug-97	--	Primary	20 U
OS-04	17-Feb-01	--	Primary	20 U
OS-04	17-Feb-01	--	Duplicate	20 U
OS-05	21-Aug-96	--	Primary	500 U
OS-05	22-Aug-97	--	Primary	20 U
RD-07	07-Feb-96	--	Primary	500 U
RD-07	18-Aug-96	--	Primary	500 U
RD-07	18-Aug-96	--	Duplicate	500 U
RD-07	25-Feb-97	--	Primary	500 U
RD-07	25-Aug-97	--	Primary	20 U
RD-07	05-Feb-98	--	Primary	20 U
RD-07	19-Aug-99	--	Primary	1000 U
RD-07	19-Aug-99	--	Duplicate	1000 U
RD-07	10-Aug-00	--	Primary	20 U
RD-07	10-Aug-00	--	Duplicate	20 U
RD-07	23-Feb-01	--	Primary	20 U
RD-07	10-Feb-03	3	Primary	1 UJ
RD-07	10-Feb-03	4	Primary	0.3 U
RD-07	10-Feb-03	5	Primary	1 UJ
RD-07	10-Feb-03	6	Primary	1 UJ
RD-07	10-Feb-03	7	Primary	0.3 U
RD-07	10-Feb-03	8	Primary	1 UJ
RD-07	10-Feb-03	9	Primary	0.3 U
RD-07	10-Feb-03	10	Primary	0.3 U
RD-07	10-Feb-03	11	Primary	1 UJ
RD-07	10-Feb-03	12	Primary	0.3 U
RD-07	10-Feb-03	13	Primary	0.71 JB
RD-21	05-Nov-95	--	Primary	5000 U
RD-21	16-Feb-96	--	Primary	5000 U
RD-21	18-Aug-96	--	Primary	3000 U
RD-21	06-Feb-97	--	Primary	3000 U
RD-21	02-Aug-97	--	Primary	80 U

See table C-37 for footnotes.

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	3
Location	Date	Port	Sample Type	Screening Values and Results in ug/L
RD-21	16-Feb-99	--	Split	200 U
RD-21	05-Aug-99	--	Primary	1000 U
RD-21	12-Feb-03	2	Primary	1 UJ
RD-21	12-Feb-03	3	Primary	1 UJ
RD-21	12-Feb-03	4	Primary	1 UJ
RD-21	12-Feb-03	5	Primary	1 UJ
RD-21	12-Feb-03	5	Duplicate	1 UJ
RD-22	16-Feb-96	--	Primary	500 U
RD-22	18-Aug-96	--	Primary	500 U
RD-22	26-Feb-97	--	Primary	500 U
RD-22	24-Aug-97	--	Primary	20 U
RD-22	12-Aug-99	--	Primary	1000 U
RD-22	10-Aug-00	--	Primary	20 U
RD-22	09-Nov-00	--	Primary	20 U
RD-22	09-Nov-00	--	Duplicate	20 U
RD-22	16-Feb-01	--	Primary	20 U
RD-22	09-May-01	--	Primary	20 U
RD-22	24-Feb-03	2	Primary	0.3 U
RD-22	24-Feb-03	3	Primary	0.3 U
RD-22	24-Feb-03	3	Duplicate	0.3 U
RD-22	24-Feb-03	4	Primary	0.3 U
RD-22	24-Feb-03	5	Primary	0.3 U
RD-22	24-Feb-03	6	Primary	0.3 U
RD-22	24-Feb-03	7	Primary	0.3 U
RD-23	05-Nov-95	--	Primary	3000 U
RD-23	16-Feb-96	--	Primary	1000 U
RD-23	18-Aug-96	--	Primary	1000 U
RD-23	27-Feb-97	--	Primary	3000 U
RD-23	22-Aug-97	--	Primary	40 U
RD-23	07-Feb-98	--	Primary	80 U
RD-23	07-Feb-98	--	Duplicate	80 U
RD-23	18-Aug-99	--	Primary	1000 U
RD-23	26-Feb-03	1	Primary	1.7 UJ
RD-23	26-Feb-03	2	Primary	1.4 UJ
RD-23	26-Feb-03	3	Primary	1.4 UJ
RD-23	26-Feb-03	5	Primary	1.5 UJ
RD-23	26-Feb-03	6	Primary	1.2 UJ
RD-23	26-Feb-03	7	Primary	1.5 UJ
RD-23	26-Feb-03	8	Primary	1.6 UJ
RD-23	26-Feb-03	9	Primary	1.5 UJ
RD-33A	19-Feb-96	--	Primary	500 U
RD-33A	23-Aug-96	--	Primary	500 U
RD-33A	25-Feb-97	--	Primary	500 U
RD-33A	27-Aug-97	--	Primary	20 U
RD-33A	11-Aug-99	--	Split	5.7 U
RD-33A	11-Aug-99	--	Primary	1000 U

See table C-37 for footnotes.

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	3
Location	Date	Port	Sample Type	Screening Values and Results in ug/L
RD-33A	09-Aug-00	--	Primary	20 U
RD-33A	14-May-01	--	Primary	20 U
RD-33A	20-Feb-03	1	Primary	0.3 U
RD-33A	20-Feb-03	1	Duplicate	0.3 U
RD-33A	20-Feb-03	2	Primary	0.3 U
RD-33A	20-Feb-03	3	Primary	1.1 UJ
RD-33A	20-Feb-03	4	Primary	2.6 UJ
RD-33A	20-Feb-03	5	Primary	2.9 UJ
RD-33A	20-Feb-03	6	Primary	3.1 UJ
RD-33B	19-Feb-96	--	Primary	500 U
RD-33B	23-Aug-96	--	Primary	500 U
RD-33B	25-Feb-97	--	Primary	500 U
RD-33B	22-Aug-97	--	Primary	20 U
RD-33B	11-Aug-99	--	Primary	1000 U
RD-33B	09-Aug-00	--	Primary	20 U
RD-33B	06-Nov-00	--	Primary	20 U
RD-33B	17-Feb-01	--	Primary	20 U
RD-33B	14-May-01	--	Primary	20 U
RD-33C	19-Feb-96	--	Primary	500 U
RD-33C	22-Aug-96	--	Primary	500 U
RD-33C	25-Feb-97	--	Primary	500 U
RD-33C	21-Aug-97	--	Primary	20 U
RD-33C	11-Aug-99	--	Primary	1000 U
RD-33C	11-Aug-99	--	Duplicate	1000 U
RD-33C	09-Aug-00	--	Primary	20 U
RD-33C	04-Nov-00	--	Primary	20 U
RD-33C	17-Feb-01	--	Primary	20 U
RD-33C	11-May-01	--	Primary	20 U
RD-50	07-Nov-95	--	Primary	500 U
RD-50	14-May-96	--	Primary	500 U
RD-50	11-Nov-96	--	Primary	500 U
RD-50	05-May-97	--	Primary	500 U
RD-50	05-May-97	--	Duplicate	500 U
RD-50	05-Nov-97	--	Primary	20 U
RD-50	28-May-98	--	Split	5000 U
RD-50	06-Aug-99	--	Primary	1000 U
RD-50	05-Aug-00	--	Primary	20 U
RD-50	04-May-01	--	Primary	20 U
RD-50	17-Feb-03	2	Primary	0.3 U
RD-50	17-Feb-03	3	Primary	0.3 U
RD-50	17-Feb-03	4	Primary	0.3 U
RD-50	17-Feb-03	5	Primary	0.3 U
RD-54A	05-Nov-94	--	Primary	500 U
RD-54A	05-Nov-95	--	Primary	3000 U
RD-54A	16-May-96	--	Primary	3000 U
RD-54A	23-Aug-96	--	Primary	1000 U

See table C-37 for footnotes.

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	3
Location	**Date**	**Port**	**Sample Type**	**Screening Values and Results in ug/L**
RD-54A	05-May-97	--	Primary	1000 U
RD-54A	04-Aug-97	--	Primary	40 U
RD-54A	22-Aug-97	--	Primary	80 U
RD-54A	08-Feb-98	--	Primary	80 U
RD-54A	18-Aug-99	--	Primary	5000 U
RD-54A	18-Feb-03	2	Primary	1.9 UJ
RD-54A	18-Feb-03	3	Primary	2.2 J
RD-54A	18-Feb-03	4	Primary	2.8 B
RD-54A	18-Feb-03	5	Primary	2.9 B
RD-54A	18-Feb-03	6	Primary	2.5 B
RD-54A	18-Feb-03	7	Primary	**3.3 B**
RD-54A	18-Feb-03	--	Duplicate	2.9 B
RD-54B	05-Nov-94	--	Split	500 U
RD-54B	05-Nov-94	--	Primary	500 U
RD-54B	05-Nov-95	--	Primary	500 U
RD-54B	16-May-96	--	Primary	500 U
RD-54B	23-Aug-96	--	Primary	500 U
RD-54B	22-Aug-97	--	Primary	20 U
RD-54B	08-Feb-98	--	Primary	20 U
RD-54B	18-Aug-99	--	Primary	1000 U
RD-54C	05-Nov-94	--	Primary	500 U
RD-54C	05-Nov-94	--	Duplicate	500 U
RD-54C	05-Nov-95	--	Primary	500 U
RD-54C	05-Nov-95	--	Duplicate	500 U
RD-54C	16-May-96	--	Primary	500 U
RD-54C	23-Aug-96	--	Primary	500 U
RD-54C	05-May-97	--	Primary	500 U
RD-54C	24-Aug-97	--	Primary	20 U
RD-54C	08-Feb-98	--	Primary	20 U
RD-54C	18-Aug-99	--	Primary	1000 U
RD-57	08-Nov-94	--	Primary	500 U
RD-57	19-Feb-96	--	Primary	500 U
RD-57	22-Aug-96	--	Primary	500 U
RD-57	27-Feb-97	--	Primary	500 U
RD-57	27-Aug-97	--	Primary	20 U
RD-57	11-Aug-99	--	Primary	1000 U
RD-57	08-Aug-00	--	Primary	20 U
RD-57	01-Dec-00	--	Primary	20 U
RD-57	11-May-01	--	Primary	20 U
RD-57	11-May-01	--	Duplicate	20 U
RD-57	21-Feb-03	7	Primary	0.3 U
RD-57	21-Feb-03	8	Primary	1 UJ
RD-57	21-Feb-03	9	Primary	0.3 U
RD-57	21-Feb-03	10	Primary	0.3 U
RD-59A	08-Nov-94	--	Primary	500 U
RD-59A	12-Mar-96	--	Primary	500 U

See table C-37 for footnotes.

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	**3**
Location	**Date**	**Port**	**Sample Type**	**Screening Values and Results in ug/L**
RD-59A	21-Aug-96	--	Primary	500 U
RD-59A	26-Feb-97	--	Primary	500 U
RD-59A	22-Aug-97	--	Primary	20 U
RD-59A	06-Aug-99	--	Primary	1000 U
RD-59A	10-Aug-00	--	Primary	20 U
RD-59A	03-Nov-00	--	Primary	20 U
RD-59A	16-May-01	--	Primary	20 U
RD-59B	08-Nov-94	--	Primary	500 U
RD-59B	08-Nov-94	--	Duplicate	500 U
RD-59B	12-Mar-96	--	Primary	500 U
RD-59B	21-Aug-96	--	Primary	500 U
RD-59B	16-Feb-97	--	Primary	500 U
RD-59B	22-Aug-97	--	Primary	20 U
RD-59B	06-Aug-99	--	Primary	1000 U
RD-59B	10-Aug-00	--	Primary	20 U
RD-59B	03-Nov-00	--	Primary	20 U
RD-59B	17-Feb-01	--	Primary	20 U
RD-59B	16-May-01	--	Primary	20 U
RD-59C	08-Nov-94	--	Primary	500 U
RD-59C	12-Mar-96	--	Primary	500 U
RD-59C	21-Aug-96	--	Primary	500 U
RD-59C	16-Feb-97	--	Primary	500 U
RD-59C	22-Aug-97	--	Primary	20 U
RD-59C	06-Aug-99	--	Primary	1000 U
RD-59C	10-Aug-00	--	Primary	20 U
RD-59C	03-Nov-00	--	Primary	20 U
RD-59C	17-Feb-01	--	Primary	20 U
RD-59C	16-May-01	--	Primary	20 U
RD-64	16-Feb-96	--	Primary	500 U
RD-64	11-Aug-96	--	Primary	500 U
RD-64	27-Feb-97	--	Primary	500 U
RD-64	22-Aug-97	--	Primary	20 U
RD-64	28-May-98	--	Split	5000 U
RD-64	10-May-01	--	Primary	20 U
RD-64	19-Feb-03	4	Primary	1 UJ
RD-64	19-Feb-03	6	Primary	**5.5**
RD-64	19-Feb-03	7	Primary	**5**
RD-64	19-Feb-03	8	Primary	**5**
RD-64	19-Feb-03	9	Primary	**5.1**
RD-64	19-Feb-03	10	Primary	**4.4**
RD-64	19-Feb-03	11	Primary	**5.1**
RD-64	19-Feb-03	12	Primary	**5.3**
RD-65	16-Feb-96	--	Primary	3000 U
RD-65	11-Aug-96	--	Primary	5000 U
RD-65	27-Feb-97	--	Primary	5000 U
RD-65	22-Aug-97	--	Primary	80 U

See table C-37 for footnotes.

TABLE C-11

Summary of Analytical Laboratory Results for 1,4-Dioxane in Chatsworth Formation Groundwater

FSDF Investigation Area

				1,4-Dioxane
			Screening Value	3
Location	Date	Port	Sample Type	Screening Values and Results in ug/L
RD-65	07-Feb-98	--	Primary	80 U
RD-65	07-May-01	--	Primary	20 U
RD-65	11-Feb-03	5	Primary	**13**
RD-65	11-Feb-03	5	Duplicate	**11**
RD-65	11-Feb-03	6	Primary	1 UJ
RD-65	11-Feb-03	7	Primary	**4.6**
RD-65	11-Feb-03	8	Primary	**5**
RD-65	17-Feb-03	9	Primary	**6**
RD-65	17-Feb-03	11	Primary	**5.2**
RD-65	19-Feb-03	10	Primary	**6.2**
RD-74	13-May-99	--	Split	5.7 U
RD-74	19-Aug-99	--	Primary	1000 U

See table C-37 for footnotes.

TABLE C-27

Summary of Analytical Laboratory Results for Perchlorate in Chatsworth Formation Groundwater

FSDF Investigation Area

				Perchlorate
			Screening Value	6
Location ID	Sample Date	Port	Sample Type	Results in (ug/L)
C-8	28-Feb-03	5	Primary	**6.2**
C-8	28-Feb-03	6	Primary	1.6 J
C-8	28-Feb-03	7	Primary	2.5 J
C-8	28-Feb-03	8	Primary	3.3 J
C-8	28-Feb-03	9	Primary	5.8
C-8	24-Mar-03	5	Primary	0.8 U
C-8	24-Mar-03	6	Primary	0.8 U
C-8	24-Mar-03	7	Primary	0.8 U
C-8	24-Mar-03	8	Primary	0.8 U
C-8	24-Mar-03	9	Primary	0.8 U
C-8	24-Mar-03	10	Primary	2.4 J
OS-03	16-Feb-99	--	Primary	4 U
OS-03	14-Mar-00	--	Primary	4 U
OS-03	17-Feb-01	--	Primary	1 U
OS-03	31-Jan-03	--	Primary	1 U
OS-03	09-Dec-03	--	Primary	0.8 U
OS-03	01-Mar-04	--	Primary	0.8 U
OS-04	16-Feb-99	--	Primary	4 U
OS-04	14-Mar-00	--	Primary	4 U
OS-04	17-Feb-01	--	Primary	1 U
OS-04	08-Aug-03	--	Primary	0.8 U
OS-04	09-Dec-03	--	Primary	0.8 U
OS-04	01-Mar-04	--	Primary	0.8 U
OS-05	16-Feb-99	--	Primary	4 U
OS-05	14-Mar-00	--	Primary	4 U
OS-05	17-Feb-01	--	Primary	1 U
OS-05	31-Jan-03	--	Primary	1 U
OS-05	09-Dec-03	--	Primary	0.8 U
OS-05	01-Mar-04	--	Primary	0.8 U
RD-07	06-Feb-99	--	Primary	4 U
RD-07	16-Mar-00	--	Primary	4 U
RD-07	23-Feb-01	--	Primary	1 U
RD-07	10-Feb-03	3	Primary	0.8 U
RD-07	10-Feb-03	4	Primary	**11**
RD-07	10-Feb-03	5	Primary	0.8 U
RD-07	10-Feb-03	6	Primary	0.8 U
RD-07	10-Feb-03	7	Primary	3.1 J
RD-07	10-Feb-03	8	Primary	0.8 U
RD-07	10-Feb-03	9	Primary	0.8 U
RD-07	10-Feb-03	10	Primary	0.8 U
RD-07	10-Feb-03	11	Primary	0.8 U
RD-07	10-Feb-03	12	Primary	0.8 U
RD-07	10-Feb-03	13	Primary	0.8 U
RD-21	05-May-98	--	Primary	5

See table C-37 for footnotes.

TABLE C-27

Summary of Analytical Laboratory Results for Perchlorate in Chatsworth Formation Groundwater

FSDF Investigation Area

				Perchlorate
			Screening Value	**6**
Location ID	**Sample Date**	**Port**	**Sample Type**	**Results in (ug/L)**
RD-21	04-Aug-98	--	Primary	**8**
RD-21	11-Nov-98	--	Primary	4 U
RD-21	16-Feb-99	--	Primary	**9**
RD-21	15-Mar-00	--	Split	**7.2**
RD-21	15-Mar-00	--	Primary	5
RD-21	24-Oct-01	--	Primary	3.7
RD-21	12-Feb-03	2	Primary	**9.7**
RD-21	12-Feb-03	3	Primary	**9.8**
RD-21	12-Feb-03	4	Primary	**11**
RD-21	12-Feb-03	5	Primary	**12**
RD-21	12-Feb-03	5	Duplicate	**12**
RD-22	28-May-98	--	Primary	4 U
RD-22	19-Aug-98	--	Primary	4 U
RD-22	24-Feb-03	2	Primary	0.8 U
RD-22	24-Feb-03	3	Primary	**17**
RD-22	24-Feb-03	3	Duplicate	**16**
RD-22	24-Feb-03	4	Primary	**6.7**
RD-22	24-Feb-03	5	Primary	2.9 J
RD-22	24-Feb-03	6	Primary	0.8 U
RD-22	24-Feb-03	7	Primary	0.8 U
RD-23	06-May-98	--	Primary	4 U
RD-23	26-Feb-03	1	Primary	0.8 U
RD-23	26-Feb-03	2	Primary	0.8 U
RD-23	26-Feb-03	3	Primary	0.8 U
RD-23	26-Feb-03	5	Primary	0.8 U
RD-23	26-Feb-03	6	Primary	3.8 J
RD-23	26-Feb-03	7	Primary	0.8 U
RD-23	26-Feb-03	8	Primary	0.8 U
RD-23	26-Feb-03	9	Primary	0.8 U
RD-33A	27-May-98	--	Primary	4 U
RD-33A	27-May-98	--	Duplicate	4 U
RD-33A	20-Feb-03	1	Primary	0.8 U
RD-33A	20-Feb-03	1	Duplicate	0.8 U
RD-33A	20-Feb-03	2	Primary	0.8 U
RD-33A	20-Feb-03	3	Primary	3.8 J
RD-33A	20-Feb-03	4	Primary	0.8 U
RD-33A	20-Feb-03	5	Primary	0.8 U
RD-33A	20-Feb-03	6	Primary	0.8 U
RD-33B	27-May-98	--	Primary	4 U
RD-33C	27-May-98	--	Primary	4 U
RD-50	28-May-98	--	Primary	4 U
RD-50	17-Feb-03	2	Primary	0.8 U
RD-50	17-Feb-03	3	Primary	0.8 U
RD-50	17-Feb-03	4	Primary	0.8 U

See table C-37 for footnotes.

TABLE C-27

Summary of Analytical Laboratory Results for Perchlorate in Chatsworth Formation Groundwater

FSDF Investigation Area

				Perchlorate
			Screening Value	6
Location ID	Sample Date	Port	Sample Type	Results in (ug/L)
RD-50	17-Feb-03	5	Primary	0.8 U
RD-54A	05-Nov-97	--	Primary	**10.7**
RD-54A	08-Feb-98	--	Primary	6
RD-54A	07-May-98	--	Primary	**10**
RD-54A	07-Aug-98	--	Split	**11.6**
RD-54A	07-Aug-98	--	Primary	**18**
RD-54A	13-Nov-98	--	Primary	**16**
RD-54A	08-Feb-99	--	Primary	**16**
RD-54A	15-Mar-00	--	Primary	**9**
RD-54A	15-Mar-00	--	Duplicate	**8**
RD-54A	26-Oct-01	--	Primary	0.43 U
RD-54A	18-Feb-03	2	Primary	0.8 U
RD-54A	18-Feb-03	3	Primary	**56 J**
RD-54A	18-Feb-03	4	Primary	**35**
RD-54A	18-Feb-03	5	Primary	**27**
RD-54A	18-Feb-03	6	Primary	**24**
RD-54A	18-Feb-03	7	Primary	0.8 U
RD-54A	18-Feb-03	--	Duplicate	0.8 U
RD-54B	08-Feb-98	--	Primary	4 U
RD-54B	06-May-98	--	Primary	4 U
RD-54B	08-Feb-99	--	Primary	4 U
RD-54B	15-Mar-00	--	Primary	4 U
RD-54B	25-Oct-01	--	Primary	0.43 U
RD-54C	08-Feb-98	--	Primary	4 U
RD-54C	06-May-98	--	Primary	4 U
RD-54C	09-Feb-99	--	Primary	4 U
RD-54C	15-Mar-00	--	Primary	4 U
RD-54C	02-Nov-01	--	Primary	0.43 U
RD-57	26-May-98	--	Primary	4 U
RD-57	21-Feb-03	7	Primary	0.8 U
RD-57	21-Feb-03	8	Primary	0.8 U
RD-57	21-Feb-03	9	Primary	0.8 U
RD-57	21-Feb-03	10	Primary	0.8 U
RD-59A	19-Aug-98	--	Primary	5
RD-59A	12-Nov-98	--	Primary	4 U
RD-59A	16-Feb-99	--	Split	4 U
RD-59A	16-Feb-99	--	Primary	4 U
RD-59A	10-May-99	--	Split	4 U
RD-59A	10-May-99	--	Primary	4 U
RD-59A	06-Aug-99	--	Primary	4 U
RD-59A	06-Nov-99	--	Primary	4 U
RD-59A	14-Mar-00	--	Primary	4 U
RD-59A	14-Mar-00	--	Duplicate	4 U
RD-59A	16-May-00	--	Primary	1 U

See table C-37 for footnotes.

TABLE C-27

Summary of Analytical Laboratory Results for Perchlorate in Chatsworth Formation Groundwater

FSDF Investigation Area

				Perchlorate
			Screening Value	**6**
Location ID	**Sample Date**	**Port**	**Sample Type**	**Results in (ug/L)**
RD-59A	10-Aug-00	--	Primary	1 U
RD-59A	03-Nov-00	--	Primary	1 U
RD-59A	03-Nov-00	--	Duplicate	1 U
RD-59A	16-May-01	--	Primary	1 U
RD-59A	12-Nov-01	--	Primary	0.43 U
RD-59A	31-Jan-03	--	Primary	1 U
RD-59A	15-May-03	--	Primary	0.8 U
RD-59A	08-Aug-03	--	Primary	0.8 U
RD-59A	14-Nov-03	--	Primary	0.8 U
RD-59B	19-Aug-98	--	Primary	4 U
RD-59B	19-Aug-98	--	Duplicate	4 U
RD-59B	16-Feb-99	--	Primary	4 U
RD-59B	06-Aug-99	--	Primary	4 U
RD-59B	14-Mar-00	--	Primary	4 U
RD-59B	10-Aug-00	--	Primary	1 U
RD-59B	17-Feb-01	--	Primary	1 U
RD-59B	12-Nov-01	--	Primary	0.43 U
RD-59B	31-Jan-03	--	Primary	1 U
RD-59B	08-Aug-03	--	Primary	0.8 U
RD-59B	04-Dec-03	--	Primary	0.8 U
RD-59C	19-Aug-98	--	Primary	4 U
RD-59C	16-Feb-99	--	Primary	4 U
RD-59C	06-Aug-99	--	Primary	4 U
RD-59C	14-Mar-00	--	Primary	4 U
RD-59C	10-Aug-00	--	Primary	1 U
RD-59C	17-Feb-01	--	Primary	1 U
RD-59C	12-Nov-01	--	Primary	0.43 U
RD-59C	31-Jan-03	--	Primary	1 U
RD-59C	08-Aug-03	--	Primary	0.8 U
RD-59C	04-Dec-03	--	Primary	0.8 U
RD-64	28-May-98	--	Primary	4 U
RD-64	19-Feb-03	4	Primary	0.8 U
RD-64	19-Feb-03	6	Primary	0.8 U
RD-64	19-Feb-03	7	Primary	0.8 U
RD-64	19-Feb-03	8	Primary	0.8 U
RD-64	19-Feb-03	9	Primary	0.8 U
RD-64	19-Feb-03	10	Primary	0.8 U
RD-64	19-Feb-03	11	Primary	0.8 U
RD-64	19-Feb-03	12	Primary	0.8 U
RD-65	06-May-98	--	Primary	4 U
RD-65	11-Feb-03	5	Primary	**6.2 J**
RD-65	11-Feb-03	5	Duplicate	4.3
RD-65	11-Feb-03	6	Primary	0.8 U
RD-65	11-Feb-03	7	Primary	0.8 U

See table C-37 for footnotes.

TABLE C-27

Summary of Analytical Laboratory Results for Perchlorate in Chatsworth Formation Groundwater

FSDF Investigation Area

				Perchlorate
			Screening Value	6
Location ID	Sample Date	Port	Sample Type	Results in (ug/L)
RD-65	11-Feb-03	8	Primary	1.6 J
RD-65	17-Feb-03	9	Primary	1.8 J
RD-65	17-Feb-03	10	Primary	2.7 J
RD-65	17-Feb-03	11	Primary	3.8 J
RD-65	19-Feb-03	12	Primary	0.8 U
RD-74	19-Aug-99	--	Primary	4 U

See table C-37 for footnotes.

TABLE C-36

Summary of Analytical Laboratory Results for Total NDMA in Chatsworth Formation Groundwater

FSDF Investigation Area

			N-Nitrosodi methylamine
		Screening Value	0.01
Location	Date	Sample Type	Screening Values and Results in ug/L
OS-03	07-Jun-85	Primary	80 U
OS-04	07-Jun-85	Primary	80 U
OS-05	07-Jun-85	Primary	80 U
RD-21	12-Sep-89	Primary	10 U
RD-22	13-Sep-89	Primary	10 U
RD-23	13-Sep-89	Primary	10 U
RD-33A	01-Oct-91	Primary	10 U
RD-33A	07-Nov-91	Primary	10 U
RD-33B	01-Oct-91	Primary	10 U
RD-33C	01-Oct-91	Primary	10 U
RD-50	20-Aug-93	Primary	6 U
RD-54A	29-Sep-93	Primary	6 U
RD-57	16-Mar-94	Primary	6 U
RD-59A	16-Aug-94	Primary	6 U
RD-59A	08-Nov-94	Primary	6 U
RD-59B	16-Aug-94	Primary	6 U
RD-59B	08-Nov-94	Primary	6 U
RD-59C	16-Aug-94	Primary	30 U
RD-59C	08-Nov-94	Primary	6 U
RD-74	13-May-99	Primary	2 U

See table C-37 for footnotes

TABLE C-37
Analytical Table Footnotes

FSDF Investigation Area

	Definition
TPH	Total petroleum hydrocarbon
VOC	Volatile organic compound
SVOC	Semivolatile organic compound
NDMA	N-Nitrosodimethylamine
U	Analyte not detected
J	Estimated result
UJ	Estimated reporting limit
B	Method blank contamination
*	Data not reviewed according to EPA level V validation procedures. Result reported by laboratory without additional validation shown.
ug/L	micrograms per liter
mg/L	milligrams per liter
(ug/ml MeOH)	micrograms per milliliter in methanol
MCL	Federal or State Maximum Contaminant Level for Drinking Water
NL	Notification Level for Drinking Water Established by the California Department of Health Services
PRG	Preliminary Remediation Goal
--	Not analyzed
NA	Not applicable
BOLD	Result exceeds Screening Values

Applicable to tables C-1 through C-36

APPENDIX D

TECHNICAL MEMORANDUM

TO: David W. Dassler, P.E. **DATE:** June 25, 2008

FROM: Steven H. Reiners
Richard G. Andrachek, P.E.

REVIEWED: Simon Bluestone, R.G.

SUBJECT: SSFL Interim Measures Approach and List of Proposed Extraction Wells

1.0 INTRODUCTION

This memorandum presents a summary of the approach used to identify and select proposed extraction wells for the groundwater Interim Measures (IM) at the Santa Susana Field Laboratory (SSFL). The location of the SSFL is shown in Figure 1. This memorandum has been prepared in response to a letter from the California Department of Toxic Substances Control (DTSC) dated May 16, 2008 (DTSC, 2008). In this letter, DTSC directed the SSFL to implement the following interim measures:

1. "Groundwater data indicate the advancement of a solvent plume(s) offsite to the northeast of the site and an increase in solvent concentrations in the southernmost groundwater extraction well (WS-9A) at the buffer zone since the facility ceased groundwater extraction at all other extraction wells. Groundwater extraction should be initiated at each location." and
2. "Groundwater extraction should be initiated at all groundwater monitoring wells within source zones, defined as any monitoring wells where the reported concentrations of TCE have been 1,000 micrograms per liter (µg/L) or higher and /or any monitoring wells where TCE concentrations and water levels are trending higher since the shut-down of groundwater extraction wells."

2.0 EXTRACTION FOR PLUME FRONTS

To address the requirements of Item 1 above, it is recommended that well WS-09A be pumped at the rate necessary to dewater springs FDP-890 and FDP-881, and that groundwater extraction be initiated at corehole C-1, well RD-72 and corehole RD-84 to augment the natural containment of the off-site plume front in the northeast area. Locations of these proposed extraction wells are shown in Figure 2. Extraction from WS-09A in late 2006 was shown to be an effective method of dewatering springs FDP-890 and FDP-881 (Boeing, 2007).

Groundwater extraction from C-1, RD-72 and RD-84 in the northeast area should be initiated sequentially in this order to ensure that the transport of high concentration zones of contaminated groundwater is not enhanced from the source area near C-1 toward the plume front. C-1 should be pumped at the highest flow rate, with an intermediate pumping rate at RD-72 and a lower pumping rate at RD-84.

3.0 EXTRACTION AT SOURCE ZONES

As stated in their letter (DTSC, 2008), the DTSC's objective associated with Item 2 of the requirements was stated as follows:

> "The objective of the groundwater extraction is two-fold; to prevent contaminated vadose zone from becoming saturated and provide capture of contaminated groundwater moving through the source zones."

Considerable data evaluation was required to address the requirements specified in Item 2. First, available data were analyzed using statistical tools to identify wells with increasing trichloroethene (TCE) concentrations and groundwater elevations. Second, all wells from which samples have been collected that contained TCE at concentrations greater than or equal to 1,000 µg/L (potential source zone wells) were identified. IM recommendations for groundwater extraction were then developed based on the results of these evaluations to address Item 2 of DTSC's requirements. Discussion of the performance and outcomes of the statistical trend analysis, the review of potential source zone wells and the resultant recommendations are presented below.

3.1 STATISTICAL TREND ANALYSIS

The Boeing Environmental Data Management System (BEDMS) for the SSFL was queried for data from all wells with a reported TCE result between the third quarter of 2000 (when SSFL extraction wells began to be shut off) and the first quarter of 2008. This data set, comprised of 420 wells, was then analyzed using a software program developed for the statistical analysis of groundwater monitoring data. The software program was used to create intra-well control charts which were then evaluated for statistically significant trends in groundwater elevation and TCE concentration. This method of analysis is consistent with the general water quality monitoring and system requirements identified in section 22264.97 of Title 22 of the California Code of Regulations. This analysis uses a combined Shewhart and CUSUM method to calculate the control limit for each constituent (in this case groundwater elevation and TCE concentration) in each well, and identifies trends using Sen's two-sided non-parametric estimation of slope (Sen, 1968) at a 99 percent confidence level. This method for trend analysis is also identified in U.S. Environmental Protection Agency guidance (1989 and 1992). Results of the trend analysis are graphically depicted in Figure 3.

This analysis identified six wells with statistically significant increasing trends in both groundwater elevation and TCE concentration as follows: HAR-20, RD-01, RD-04, RD-10, RD-56B, WS-09. Of these six wells, the concurrent increasing groundwater elevation and TCE concentration trends identified in RD-01, RD-04, WS-09 and HAR-20 are consistent with those identified in the Appendix C of the Groundwater IM Work Plan (MWH, 2008). Samples collected from wells RD-01, RD-04 and WS-09 also have had TCE concentrations above 1,000 µg/L, while TCE has been detected in samples from HAR-20 at concentrations of up to 510 µg/L. Each of these four wells meets the DTSC's criteria for an interim measures extraction well. Locations are shown on Figure 2. Extraction from RD-10 and RD-56B is not recommended for the reasons noted below.

At well RD-10, a FLUTe multilevel monitoring system was installed in the well from March 2002 through July 2004. Because the multilevel data are not directly comparable to the open-hole data, the trends that were identified based partly on the multilevel data are not believed to be comparable and hence representative of the true variability in the well. The trend evaluation presented in Appendix C of the IM Work Plan (MWH, 2008) did not identify an increasing TCE concentration trend in RD-10. The groundwater elevation and TCE concentration at RD-10 have been relatively stable since 2006, and the TCE concentration in samples collected from this well has not exceeded 20 µg/L. Furthermore, previous work has shown that RD-10 is hydraulically connected to RD-1, which is proposed as an interim measure extraction well. Hence, it is expected that groundwater present in RD-10 will be influenced by planned groundwater withdrawals from RD-1. For these reasons, extraction from RD-10 as an interim measure is not being proposed.

At well RD-56B, the TCE concentrations in samples collected from this well have not been greater than 0.6 µg/L. RD-56B was not included in the trend analysis in the IM Work Plan (MWH, 2008). Most of the TCE concentration data for this well are "J" values (estimated concentrations below the reporting limit), and the remaining are "U" results (not detected; the value reported is the method detection limit); as such, the statistically significant increasing concentration trend identified based on these data need to be considered in this context. Also, this well's location is believed to be near a plume front and does not fall within the second of DTSC's performance criteria, i.e. "capture of contaminated groundwater moving through source zones." However, the TCE concentration should continue to be monitored at RD-56B to determine if the plume might be expanding (horizontally or vertically) at that location.

Only two other wells (RD-55B and RS-21) showed a statistically significant increasing TCE concentration trend but did not exhibit an increasing trend in groundwater elevation. The increasing TCE concentration trend identified at RD-55B is consistent with the evaluation presented in Appendix C of the IM Work Plan (MWH, 2008), and the TCE concentrations in samples should continue to be monitored to determine if the plume may be expanding at this location. The recent increasing TCE concentration trend in samples collected from RS-21 began around 2005; RS-21 was not included in the trend evaluation in the IM Work Plan. The recent TCE concentrations and trend in RS-21 are consistent with the range of historical TCE concentrations and trends in this well. Neither of these two wells meets the DTSC's criteria for selection as an IM extraction well candidate because neither well exhibited a statistically significant increasing trend in groundwater elevation after the extraction wells were shut off.

3.2 COMPARISON OF STATISTICAL RESULTS TO FEBRUARY 2008 IM WORK PLAN

The wells identified in the IM Work Plan (MWH, 2008) with an increasing TCE concentration trend (Table 6 of Revised IM Work Plan, Appendix C) included: RD-01, RD-02, R-04, RD-09, RD-21, RD-49A, RD-49B, RD-51B, RD-55B, WS-09 and HAR-20.

The increasing TCE concentration trends identified in wells RD-01, RD-04, RD-55B, WS-09 and HAR-20 are consistent with the results of the statistical trend analysis. For the other six wells in the list above where an increasing TCE concentration trend was identified based only on inspection (Table 6 of the IM Work Plan, Appendix C), a statistically significant increasing TCE concentration trend was not identified by the statistical analysis program. Several factors may contribute to this discrepancy:

- The data sets used for the two evaluations were not identical.
    - Q1 2000 through Q1 2006 for the IM Work Plan evaluation versus Q3 2000 through Q1 2008 for the statistical analysis

  - Annual maximums were used for the IM Work Plan trend evaluation versus all data used for the statistical analysis.

- Apparent trends identified by observation may not be statistically significant.

- The statistical trend analysis results are likely to be strongly dependent upon the time frame selected for analysis.

  - Example – RD-02 is a similar case, but there is just one result in the data set (11/30/2000; 120 µg/L) before the concentration increased (700 µg/L in the next sample result, which is more indicative of a jump). In the statistical analysis, the 120 µg/L result is "just one data point" that is outweighed by the several years of subsequent results. If additional results were included in the analyzed data set prior to the cessation of extraction, the trend result might be different. To discern by observation if there was a concentration increase from 2000 to 2001 or if the 120 µg/L result is within the range of historical fluctuation and not indicative of an increasing trend, additional prior results would have to be examined.

- Trend analyses performed on data sets that include data from multilevel systems (e.g. FLUTe multilevel in RD-21) may yield misleading results because the data from a single multilevel port are not directly comparable to the open-hole data. This is true for both water elevation and groundwater contaminant/chemistry data.

3.3 SUMMARY OF STATISTICAL ANALYSIS

A statistical analysis program was used in a manner consistent with Title 22 to evaluate trends in groundwater elevation and TCE concentration in SSFL wells following the shutdown of most of the SSFL extraction wells starting in late 2000. The statistical evaluation identified six wells with increasing trends in both groundwater elevation and TCE concentration. Of these six wells, RD-01, RD-04, WS-09 and HAR-20 were shown to be good candidate wells for IM groundwater extraction. Finally, although each meets a strict interpretation of the DTSC's selection criteria, wells RD-10 and RD-56B were shown to be poor candidates for IM groundwater extraction for reasons described earlier.

3.4 IDENTIFICATION OF WELLS WITH TCE CONCENTRATIONS GREATER THAN 1,000 µG/L

The BEDMS was queried for all wells that have yielded at least one sample where TCE was detected at a concentration equal to or greater than 1,000 µg/L at any time in its sampling history. This query identified 64 wells, the list of which is presented in Table 1. The complete record of TCE concentration and groundwater elevation at each of these wells were studied to further evaluate the appropriateness of each well as a candidate for source zone interim measures extraction. This evaluation is summarized in Table 1.

Forty three of these wells were eliminated as potential interim measure extraction wells for any of the following reasons:

- The detections of TCE at concentrations above 1,000 µg/L were infrequent or long ago (typically more than 10 years ago), and more recent TCE concentrations in samples are consistently less than 1,000 µg/L.
- The well is most often dry or contains insufficient water to pump productively.
- The well diameter is too small to facilitate groundwater extraction (piezometers).

Nearly all of these 43 wells are screened in alluvium/colluvium and/or weathered bedrock with small saturated thicknesses. Another 9 of the 64 wells were removed from consideration because of their relatively close proximity to other wells that were identified as candidates for IM groundwater extraction; 7 of these 9 wells are in the northeast area where extraction from C-1 as part of the northeast plume front containment IM is expected to provide sufficient capture based on the results of the C-1 pumping test (MWH, 2004). Additionally, 2 of the 64 wells have been identified as candidate extraction wells for other interim measures (WS-09A and RD-72) as noted earlier.

Four of the 64 wells (RD-01, RD-04, WS-09 and HAR-20) have been identified as candidates for IM groundwater extraction as a result of the statistical trend evaluation presented earlier. The remaining six wells (RD-41B, RD-46A, RD-49A, RS-54, HAR-07 and HAR-18) have been identified as candidate source zone IM extraction wells. Locations are shown in Figure 2.

4.0 GROUNDWATER INTERIM MEASURE EXTRACTION WELL RECOMMENDATIONS

The wells identified as candidates for groundwater extraction as an interim measure, the basis for their selection and the associated IM objectives are summarized below.

Well ID	Selection Basis	IM Objective
WS-09A (1)	Satisfies DTSC requirement for groundwater extraction at well WS-09A. Demonstrated to be effective at dewatering springs FDP-890 and FDP-881.	Dewater springs FDP-890 and FDP-881 (plume front)
C-1 RD-72 RD-84	Satisfies DTSC requirement to initiate groundwater extraction to augment containment of the off-site Northeast	Augment the natural containment of the off-site northeast plume front

Well ID	Selection Basis	IM Objective
(3)	plume front. Groundwater extraction from C-1 and RD-72 will minimize enhanced transport of hicg concentrations groundwater toward RD-84.	
RD-01 RD-04 WS-09 HAR-20 (3)	Meet DTSC selection criteria of increasing trends in groundwater elevation and TCE concentration. RD-01, RD-04 and WS-09 also meet DTSC selection criteria of TCE concentration greater than or equal to 1,000 µg/L.	Primary: Prevent further increases in groundwater elevation and TCE concentrations Secondary: Collection of contaminated groundwater moving through source zones.
RD-41B RD-46A RD-49A RS-54 HAR-07 HAR-18 (6)	Meet DTSC selection criteria of TCE concentration greater than or equal to 1,000 µg/L.	Collection of contaminated groundwater moving through source zones.

In summary, 14 wells are being proposed for groundwater extraction as an interim measure at the SSFL as directed by the DTSC. Locations are shown in Figure 2. Additional information on the proposed list of wells is provided in Table 2. The combined targeted extraction rate from the 14 wells is projected to be about 50 gallons per minute, with expected variances to range from a low of 14 gallons per minute to a high of 120 gallons per minute. Treatment systems are currently being evaluated that will allow for treatment of the contaminated groundwater to the appropriate discharge limits.

5.0 REFERENCES

Boeing, 2007. Letter to Mr. Gerard Abrams, California Department of Toxic Substances Control from David Dassler, The Boeing Company, re Sampling Results from Springs at and around the SSFL. July 13.

DTSC, 2008. Letter to David Dassler, The Boeing Company, from Mr. Jim Pappas, P.E., California Department of Toxic Substances Control, re Groundwater Interim Measures Work Plan, Santa Susana Field Laboratory, Ventura County, Dated February 2008. May 16.

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US Environmental Protection Agency, 1989. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance. PB89-151047. February.

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Attachments:

Table 1 - Listing of Wells with Historical Trichloroethene (TCE) Concentrations Greater Than 1,000 Micrograms per Liter (µg/L)

Table 2 - Summary of Extraction Wells Proposed for SSFL Groundwater Interim Measure

Figure 1 – Site Location Map

Figure 2 – Locations of Proposed Extraction Wells for Groundwater Interim Measure

Figure 3 – Results, Statistical Evaluation, Groundwater Elevation and TCE Concentration Increases Since Q3 2000, Santa Susana Field Laboratory

Table 1
Listing of Wells with Historical Trichloroethene (TCE) Concentrations Greater Than 1,000 Micrograms per Liter (ug/L)
Santa Susana Field Laboratory

Well Identifier	Maximum Concentration Detected (ug/L)	Total Number of Samples Analyzed	Total Number of Samples with TCE Concentrations >1,000 ug/L	Total Number of Samples with TCE Concentrations >1,000 ug/L After August 2000	Shallow/ Chatsworth	Comments/ Notes
Wells Proposed for Plume Front Interim Measure						
RD-72	6,900	24	12	5	Chatsworth	TCE generally >1,000 ug/L through 2003. Only two subsequent samples; TCE = 20J and 22 ug/L. FLUTe multilevel well since 4/2/2001. Incorporate in notheast plume front containment IM.
WS-09A	2,000	108	9	5	Chatsworth	Part of FDP-890 dewatering interim measure.
Wells Proposed for Interim Measure Based on Statistical Evaluation of Groundwater Elevations and TCE Concentrations						
RD-04	5,000	77	23	12	Chatsworth	Also increasing groundwater elevation trend, and TCE increasing trend since ~2005. Candidate for IM pumping.
WS-09	27,000	84	37	19	Chatsworth	Increasing groundwater elevation trend, and increasing TCE trend (increase in ~2002); TCE stable since 2002 at >1,000 ug/L.
HAR-20	2,000	35	11	none	Chatsworth	No detects > 1,000 ug/L since ~1991. Since 2000 is 5.2 to 510 ug/L. However, well is a candidate for IM pumping because of statistically increasing groundwater elevation and trends.
RD-01	1,200	204	4	4	Chatsworth	One detect >1,000 ug/L 11/6/2002. Since then is 510 to 1,000 ug/L. Also exhibits increasing TCE and groundwater elevation trends. Candidate for IM pumping.
Additional Wells Proposed for Interim Measure Based on TCE Concentrations Greater than 1,000 ug/L						
HAR-07	61,000	78	78	24	Chatsworth	Candidate for IM pumping.
HAR-18	28,000	63	62	17	Chatsworth	Candidate for IM pumping.
RD-41B	3,200	41	29	16	Chatsworth	Candidate for IM pumping. RD-41A <10 ug/L.
RS-54	4,500	37	32	10	Shallow	Candidate for IM pumping.
RD-46A	21,000	42	41	21	Chatsworth	Candidate for IM pumping.
RD-49A	5,900	48	47	28	Chatsworth	Candidate for IM pumping.
Wells with TCE Concentrations Greater Than 1,000 ug/L to be Controlled by Extraction From Wells Noted Above						
HAR-04	22,000	62	24	8	Shallow	Detection = 27 to 22,000 ug/L since ~2000; all but one 27 to 2,400 ug/L. Q1 2008 = 340 ug/L. Pump from C-1 in this area.
HAR-16	73,000	71	69	21	Chatsworth	Pump from C-1 in this area.
HAR-19	3,500	14	7	none	Chatsworth	Detects generally >1,000 ug/L prior to 1991; no results since. Well dry 1991 - 2005. Water in well since 2005, but no samples have been analyzed. Pump from HAR-20 in this area.
HAR-32	1,500	6	3	1	Shallow	Detect = 940 ug/L 11/21/2002; no data since, and most recent prior data was ~1991. Minimal historical data. Pump from HAR-18 in this area.
HAR-34	2,600	9	2	none	Shallow	Two detects >1,000 ug/L (~1988 and ~1991). No data after ~1993. Pump from HAR-18 in this area.
RD-35A	110,000	27	26	3	Chatsworth	Detects >1,000 ug/L through 2002. One result of 840 in 2003; no samples since. Pump from C-1 in this area.
RD-35B	94,000	44	31	4	Chatsworth	Detects >1,000 ug/L through 2004. No samples since. (Avoid dragging TCE downward in 35A > in 35B. Pump from C-1 in this area.)
RD-73	40,000	39	30	15	Chatsworth	Pump from C-1 in this area.
RD-77	7,600	3	3	3	Chatsworth	Detects always >1,000 ug/L. Most recent result 8/12/2004. Pump from C-1 in this area.
Wells with Historical TCE Concentrations Greater Than 1,000 ug/L, No Extraction Proposed						
ES-03	4,800	30	4	none	Shallow	No detects > 1,000 ug/L since 1986. [TCE] since 2000 is 84 to 450 ug/L.

Table 1
Listing of Wells with Historical Trichloroethene (TCE) Concentrations Greater Than 1,000 Micrograms per Liter (ug/L)
Santa Susana Field Laboratory

Well Identifier	Maximum Concentration Detected (ug/L)	Total Number of Samples Analyzed	Total Number of Samples with TCE Concentrations >1,000 ug/L	Total Number of Samples with TCE Concentrations >1,000 ug/L After August 2000	Shallow/ Chatsworth	Comments/ Notes
ES-04	1,100	27	1	none	Shallow	One detect > 1,000 ug/L in ~1993. [TCE] since 2000 is ND to 200 ug/L.
ES-05	2,600	25	3	none	Shallow	No detects > 1,000 ug/L since ~1998. Since 2000 is ND to 1.2 ug/L.
ES-06	7,600	41	15	none	Shallow	No detects > 1,000 ug/L since ~1998. Since 2000 is 0.48J to 170 ug/L.
ES-07	4,100	14	5	none	Shallow	No detects > 1,000 ug/L since ~1994. Only one analysis since ~2000 (in 2005); detect=5.5 ug/L.
ES-11	6,100	17	7	none	Shallow	No detects > 1,000 ug/L since ~1998. Since 2000 is 0.41J to 50 ug/L.
ES-13	1,000	6	#N/A	none	Shallow	One non-detect from 1986 with detection limit >1,000 ug/L. Only two historical TCE detects, both <10 ug/L. No data since ~1992.
ES-14	2,700	25	5	none	Shallow	No detects > 1,000 ug/L since ~1996. Since 2000 is 290 to 550 ug/L.
ES-17	18,000	39	33	6	Shallow	Often <5 feet of water in well.
ES-21	2,900	29	2	none	Shallow	No detects > 1,000 ug/L since ~1999. Since 2000 is 35J to 650 ug/L.
ES-24	18,000	35	32	7	Shallow	Often <5 feet of water in well.
ES-27	1,400	35	7	1	Shallow	No detects > 1,000 ug/L since 11/30/2000. Since then is 4.4 to 820 ug/L.
ES-32	7,600	32	8	none	Shallow	No detecs > 1,000 ug/L since ~1997. Since 2000 is 1.8 to 850 ug/L.
HAR-02	18,000	4	2	none	Shallow	Two detects > 1,000 ug/L in ~1987. One detect of approx. 4 ug/L in ~1993. No other results available; well is most often dry.
HAR-03	4,100	31	4	2	Shallow	Three detects >1,000 ug/L; most = 2 to 500 ug/L. Q1 2008 = 150 ug/L.
HAR-25	1,300	17	2	none	Chatsworth	No detects > 1,000 ug/L since ~1988. Since 2000 is 91 to 100 ug/L.
PZ-015B	1,200	1	2	2	Shallow	4/26/2001 result.
PZ-015C	3,600	1	2	2	Shallow	4/26/2001 result.
PZ-015D	5,600	1	2	2	Shallow	4/26/2001 result.
PZ-015E	2,000	1	2	2	Shallow	4/26/2001 result.
PZ-015F	3,300	1	2	2	Shallow	4/26/2001 result.
PZ-015G	7,300	2	4	4	Shallow	4/26/2001 and 3/28/2003 (3,400 ug/L) results.
PZ-047	1,400	2	2	2	Shallow	4/4/2002 and 5/28/2003 (67 ug/L) results.
PZ-087B	1,600	2	4	4	Shallow	5/2/2001 and 5/27/2003 (1,500 ug/L) results.
RD-02	2,000	108	1	none	Chatsworth	One detect >1,000 ug/L ~1985. Since 2000 is 1.1 to 700 ug/L; generally 200 to 400 ug/L.
RD-09	2,400	72	13	none	Chatsworth	No detects > 1,000 ug/L since ~1993. Since 2000 is 55 to 580 ug/L.
RD-21	2,900	64	25	none	Chatsworth	No detects > 1,000 ug/L since ~1997. Since 2000 is 66 to 770 ug/L. FLUTe multilevel well.
RD-52A	2,900	8	2	none	Chatsworth	One detect >1,000 ug/L ~1993. Only sample since ~1998 had [TCE] = 110 ug/L (3/15/2005). Well typically has only ~10 feet of water, and does not produce enough water to sample.
RD-55A	1,500	57	1	1	Chatsworth	One detect >1,000 ug/L 8/28/2002. 2005 - 2008 is 0.31J to 27 ug/L.
RD-58A	1,100	48	2	none	Chatsworth	One detect >1,000 ug/L ~1995. Since 2000 is 58 to 740 ug/L.
RS-02	2,400	1	1	none	Shallow	Only one sample from ~1985. Well is almost always dry.
RS-03	11,000	7	6	none	Shallow	All results prior to ~1985 >1,000 ug/L; only one subsequent sample ~1992 approximately 15 ug/L. Well is often dry.

Table 1
Listing of Wells with Historical Trichloroethene (TCE) Concentrations Greater Than 1,000 Micrograms per Liter (ug/L)
Santa Susana Field Laboratory

Well Identifier	Maximum Concentration Detected (ug/L)	Total Number of Samples Analyzed	Total Number of Samples with TCE Concentrations >1,000 ug/L	Total Number of Samples with TCE Concentrations >1,000 ug/L After August 2000	Shallow/ Chatsworth	Comments/ Notes
RS-04	5,500	11	8	none	Shallow	Detects usually >1,000 ug/L; most recent data ~1993. Well is most often dry.
RS-05	2,100	16	8	none	Shallow	Detects often >1,000 ug/L; only four results ~1989 to ~1993 all <1,000 ug/L. No more recent data. Well is often dry.
RS-12	2,900	11	7	none	Shallow	Detects often >1,000 ug/L; most recent result ~1993 approximately 100 ug/L. Well is most often dry.
RS-14	1,600	24	4	none	Shallow	Two detects >1,000 ug/L in ~1990. Most recent data ~1993. Well is most often dry.
RS-15	1,400	17	7	none	Shallow	Most results prior to 1988 are >1,000 ug/L; seven results since are <1,000 ug/L. Most recent data ~1998 approximately 100 ug/L.
RS-18	3,200	34	11	none	Shallow	No detects >1,000 ug/L since ~1999. Since 2000 is 8 to 550 ug/L.
RS-20	3,300	17	9	none	Shallow	Detects usually >1,000 ug/L; most recent data ~1992. Often <5 feet of water in well.
RS-22	2,400	17	3	none	Shallow	Two detects >1,000 ug/L in ~1985. All other results <1,000 ug/L. Most recent data ~1993.
SH-03	1,000	37	1	none	Shallow	One detect >1,000 ug/L in ~1985. Since 2000 is 38 to 190 ug/L.
SH-04	5,000	71	11	none	Shallow	No detects >1,000 ug/L since ~1995. Since 2000 is 70 to 100 ug/L.
WS-SP	1,700	20	4	none	Chatsworth	Three detects >1,000 ug/L in ~1985; all subsequent results <1,000 ug/L. Most recent results 2004 = 320 to 380 ug/L.

Notes:

IM - Interim Measures
> = greater than
< = less than

Table 2
Summary of Extraction Wells Proposed for SSFL Groundwater Interim Measure

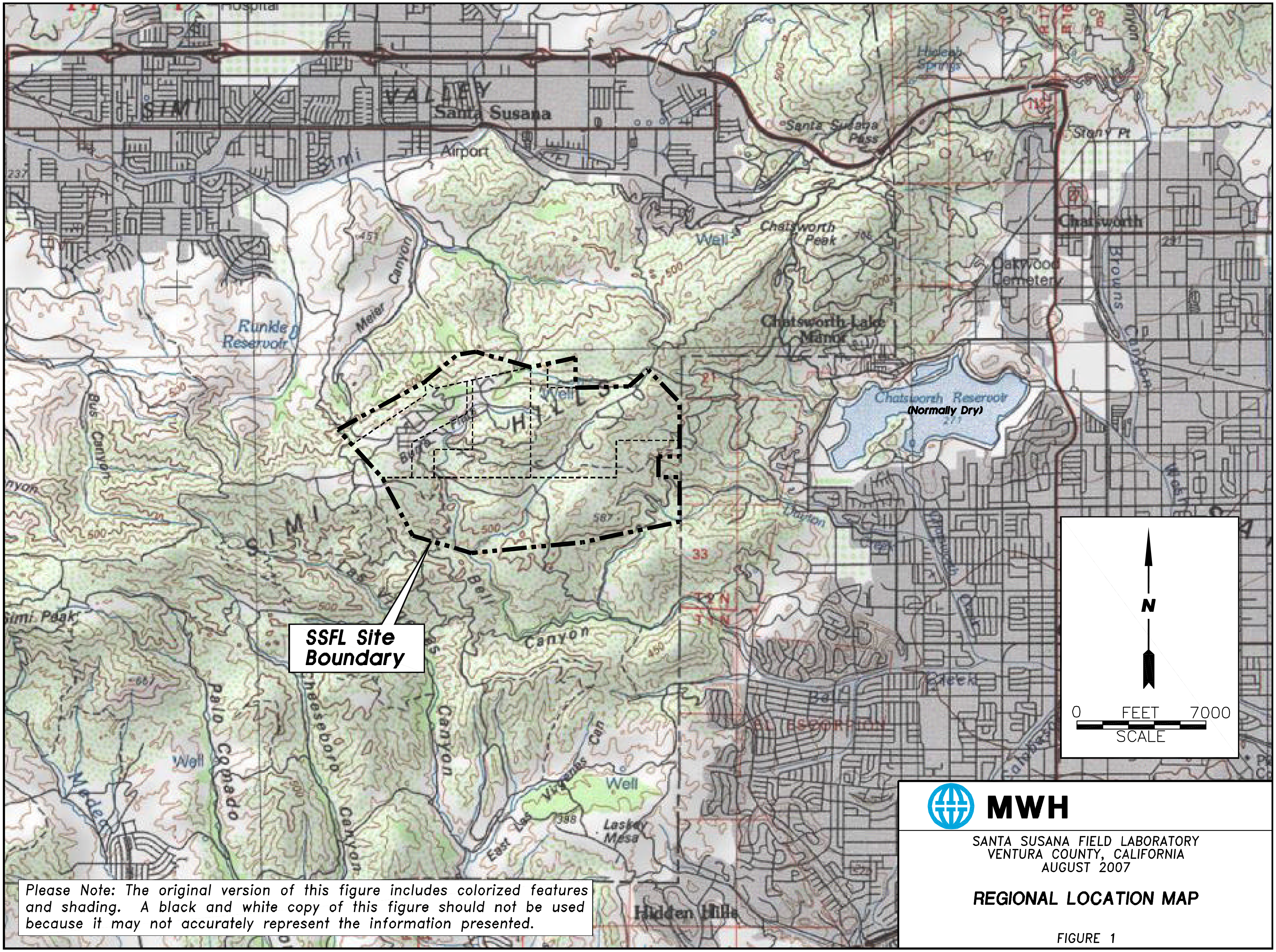
Well Identifier	Interim Measure Pumping Objective	Source/Area of Impacted Groundwater Being Extracted	Ground Elev (ft msl)	Well Completion Details	Depth to Groundwater (ft btc)					Extraction Rates (GPD)		
					Q1 2007	Q2 2007	Q3 2007	Q4 2007	Q1 2008	Minimum	Target	Maximum
WS-09A	Dewater FDP-890/ -881	Delta/STL-IV	1647.61	8.25" casing screened 20 - 539 ft.	33.44	63.73	44.43	35.70	13.45	150	3000	15000
C-1	Northeast plume front	IEL	1916.1	open 5" hole 48.6 - 600 ft.	Approximately 95 ft (pump and packer in corehole)					15000	30000	45000
RD-72			1907.25	open 6.5" hole 27 - 182 ft.	Approximately 90 ft (FLUTe multilevel in well)					750	3000	7500
RD-84			1907.82	open 4" hole 40 - 171 ft.	133.93	134.89	136.34	137.16	138.00	150	750	4500
HAR-07	Source Zone Mass Removal from Wells with TCE >1,000 ug/L	Delta	1728.38	open 8" hole 30 - 100 ft.	67.38	74.10	76.47	78.19	46.84	150	300	750
HAR-18		STL-IV	1749.41	open 8" hole 30 - 80 ft.	19.57	19.51	22.19	24.61	26.97	150	1500	7500
RD-1		Canyon	1935.89	open 8.625" hole 26 - 506 ft.	200.10	199.61	200.50	202.81	202.10	150	1500	7500
RD-4		Bravo	1883.85	open 8.625" hole 27 - 496 ft.	293.94	292.43	290.73	290.21	289.03	1500	15000	30000
RD-41B		Coca/Delta	1774.71	open 5.875" hole 340 - 390 ft.	113.61	120.71	123.98	123.36	121.60	150	1500	4500
RD-46A		CTL-III	1806.13	open 6.25" hole 29.5 - 140 ft.	70.55	71.98	74.42	76.58	77.81	150	1500	7500
RD-49A		Alfa	1867.25	open 6.25" hole 18 - 50 ft.	20.87	23.00	25.12	26.36	13.42	150	1500	7500
RS-54		FSDF	1846.66	open 5.875" hole 7 - 38 ft.	22.34	23.76	dry	29.51	32.19	150	750	1500
WS-9		Bravo	1883.99	open 15" hole 17 - 690 ft. open 10" hole 690 - 1800 ft.	292.89	291.38	289.81	289.39	288.19	1500	15000	30000
HAR-20	Stop Increasing TCE and GW Elevation Trend	Alfa/Bravo	1830.47	open 8" hole 30 - 230 ft.	189.60	189.19	188.63	188.38	188.06	150	1500	4500
									Total-GPD	20,250	76,800	173,250
									Total-GPM	14	53	120

Notes:
ft msl - feet above mean sea level
ft btc - feet below top of casing
GPD - gallons per day
GPM - gallons per minute
ug/L - micrograms per liter
ft - feet
TCE - trichloroethene
" - inches

STL-IV Systems Test Laboratory IV
IEL - Instrument and Equipment Laboratory
CTL-III Components Test Laboratory III
FSDF Former Sodium Disposal Facility
GW Groundwater

FILE: INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\ROSS GEOLOGY REPORT 7 04\SITE LOCATION 12 06

JOB No.



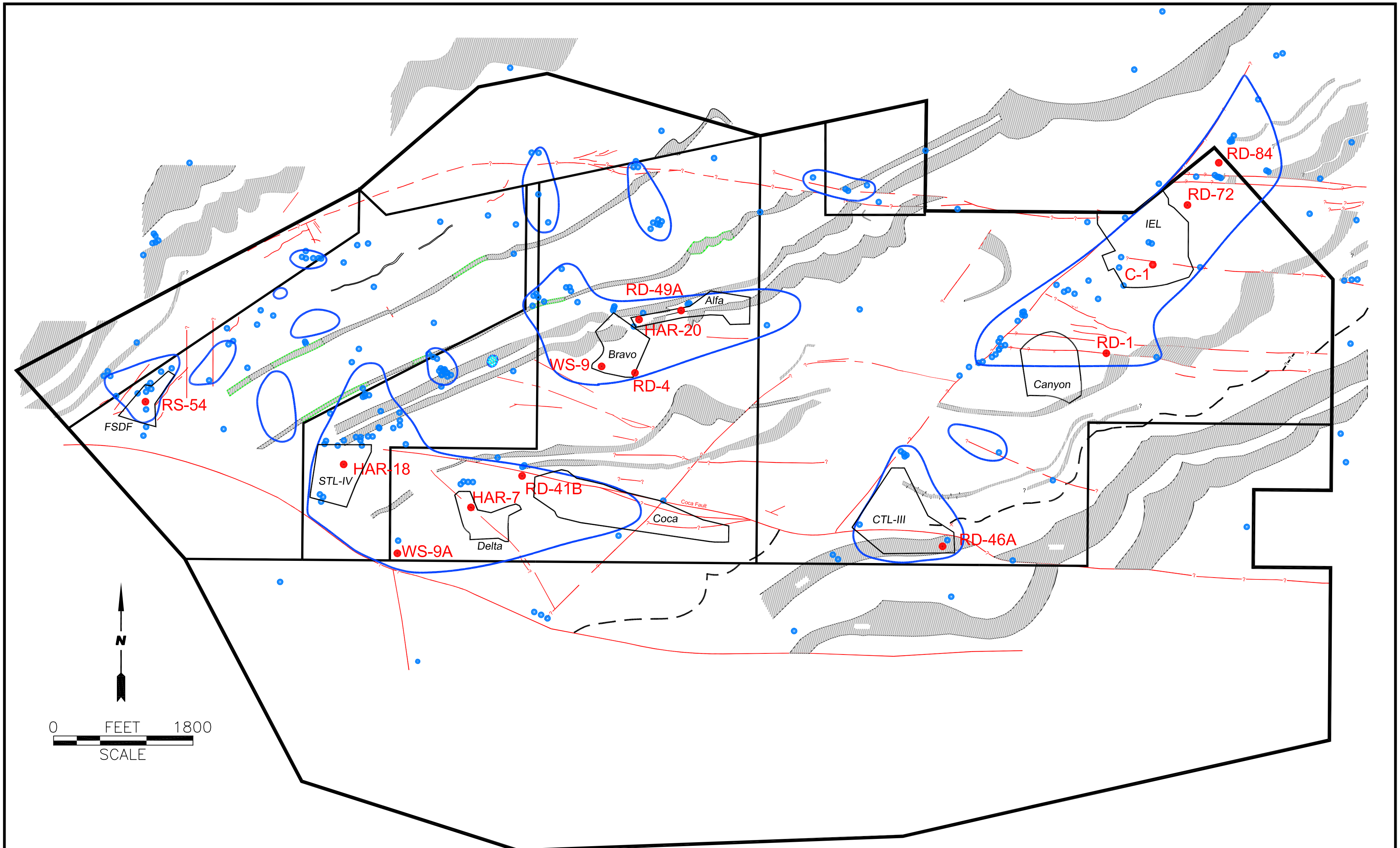
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
AUGUST 2007

REGIONAL LOCATION MAP

FIGURE 1

Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.



Legend

- Finer-Grained Unit
- Fault Location
- TCE in Groundwater >5 Micrograms per Liter (ug/L)
- Monitoring Well
- Well Proposed for Groundwater Extraction Interim Measure
- RFI Site Boundary

The original version of theis figure includes colorized features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.

MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA
JUNE 2008

LOCATIONS OF PROPOSED EXTRACTION WELLS FOR GROUNDWATER INTERIM MEASURE

FIGURE 2

CAD MLUEBKE\BOEING\SANTA SUSANA\SITE WIDE WORKPLAN\PROPOSED GW EXTRACTION WELLS 6 17 08

FILE No.

Legend

Shallow Wells

- Increasing Trend in Groundwater Elevation
- Increasing Trend in TCE
- No Increasing Trend in Groundwater Elevation or TCE Concentration

Deep Wells

- Increasing Trend in Groundwater Elevation
- Increasing Trend in TCE
- Increasing Trend in Both Groundwater and TCE
- No Increasing Trend in Groundwater Elevation or TCE Concentration

- Administrative Area Boundary
- SSFL Property Boundary
- Faults
- Fine-grained unit
- TCE Trichloroethene

Notes:

(1)Map coordinates in Stateplane, NAD 27, Zone V.

(2)Color aerial photo obtained from Google Earth Pro.

(3)The TCE results presented on this figure are a composite over time. The results depicted are the most recent available for every well from which a sample has been collected and span a time frame of 22 years, starting in June of 1985 through October of 2007.

Results - Statistical Evaluation Groundwater Elevation and TCE Concentration Increases Since Q3 2000 Santa Susana Field Laboratory

FEET

0 250 500 1,000 1,500 2,000

1 Inch = 500 feet

MWH

DATE CREATED: 6-17-2008

FIGURE 3

Printing Date: June 17, 2008 File: \\uswck1netapp1\nrii\Industrial Projects\GIS\BoeingSantaSusana\MXD\June2008\Figure3_TCEGdWtrTrend.mxd