DEPARTMENT OF THE NAVY
UNITED STATES OF AMERICA

Final

Feasibility Study Report Addendum Operable Unit 2B Installation Restoration Sites 3, 4, 11, and 21

ALAMEDA POINT
ALAMEDA, CALIFORNIA

October 2012

Prepared for:
Base Realignment and Closure
Program Management Office West
San Diego, California

Prepared under:
NAVFAC
Naval Facilities Engineering Command

Contract Number N62473-08-D-8814
Contract Task Order 0002

DCN: OTIE-8814-0002-0003.A1/F

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APPROVAL PAGE

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ACRONYMS AND ABBREVIATIONS

§	section
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C.F.R.	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
COC	constituent of concern
CTR	California Toxics Rule
EPC	exposure point concentration
FS	feasibility study
GRA	general response action
HHRA	human-health risk assessment
IR	Installation Restoration
MCL	maximum contaminant level
mg/m^3	milligrams per cubic meter
mg/kg-day	milligrams per kilogram per day
NAVFAC SW	Naval Facilities Engineering Command Southwest
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NTR	National Toxics Rule
OU	operable unit
RAO	remedial action objective
RBC	risk-based concentration
RfC_i	inhalation reference concentration
RfD_o	oral reference dose
RSL	Regional Screening Level
SARA	Superfund Amendments and Reauthorization Act
TCE	trichloroethene
USEPA	U.S. Environmental Protection Agency
VC	vinyl chloride

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1. INTRODUCTION

This report is an addendum to the Final Feasibility Study (FS) Report (OTIE 2011a) for Operable Unit-2B (OU-2B), which includes Installation Restoration (IR) Sites 3, 4, 11, and 21 located at Alameda Point, Alameda, California. Based on regulatory agency comments on the Draft Final FS (OTIE 2011b), this FS addendum presents the following:

- A comparison of the updated November 2011 United States Environmental Protection Agency (USEPA) tap water regional screening levels (RSLs) (USEPA 2011a) with the May 2009 RSLs (USEPA 2009), and an evaluation of potential impacts to the Final OU-2B FS groundwater constituent of concern (COC) selection, response action alternatives, and risk-based concentration (RBC) calculations from RSL and associated toxicity value changes.

- An additional OU-2B groundwater FS evaluation for a scenario in which groundwater beneath OU-2B is not classified as a potential drinking water source and reuse of OU-2B area is restricted to commercial use.

This Report was prepared for the Base Realignment and Closure, Program Management Office West and the Naval Facilities Engineering Command Southwest (NAVFAC SW) as authorized by the United States Navy, under contract number N62473-08-D-8814. It complies with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) in 40 Code of Federal Regulations, Part 300.

1.1 ORGANIZATION OF THE REPORT

This Report has been organized into the following sections:

- *Section 1: Introduction* – This section presents the purpose for the FS addendum, and organization of the Report.
- *Section 2: Evaluation of the November 2011 USEPA RSLs* – This section presents a comparison of the May 2009 RSLs to the most current November 2011 RSLs that incorporate the updated toxicity factors, and an evaluation of their effect on the groundwater COC selection, the groundwater response action alternatives, and calculated RBCs.
- *Section 3: Groundwater FS Evaluation – Commercial Reuse and Non-Drinking Water Beneficial Use*- This section presents an overview of Appendix A that includes details of the development and analysis of remedial alternatives assuming a Commercial Reuse and Non-Drinking Water Beneficial Use of groundwater at OU-2B sites.
- *Appendix B – Response to Comments on the Draft FS Addendum.* Based on regulatory comments received on the Draft FS Addendum, technical exchange meetings were held to discuss the groundwater modeling approach and the efficacy of the monitored natural attenuation. A summary of the items discussed along with a supplemental evaluation have been included in Appendix B of this FS Addendum.

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2. EVALUATION OF THE NOVEMBER 2011 UNITED STATES ENVIORNMENTAL PROTECTION AGENCY REGIONAL SCREENING LEVELS

2.1 COMPARISON OF MAY 2009 AND NOVEMBER 2011 RSLS

The Final OU-2B FS used the May 2009 tapwater RSLs and associated toxicity criteria for the evaluation of COC selection, response action alternatives development, and calculation of RBCs. Since the RSLs and toxicity values have been updated since May 2009, a comparison of the May 2009 RSLs to the November 2011 RSLs was performed to assess if changes in the RSL would impact the COC selection, the remedial action alternative development, or the calculation of RBCs. A similar evaluation performed for soil (May 2009 RSLs vs. June 2011 RSLs) is presented in Appendix J of the Final OU-2B FS (OTIE 2011a). Therefore the current evaluation focused on constituents/analytes reported in groundwater within OU-2B and is presented in Table 1. This table summarizes the comparison of the two RSLs for analytes reported during previous environmental investigations at OU-2B and makes a determination as to whether a detailed evaluation is warranted. The more detailed evaluation of constituents for which May 2009 RSLs are different from November 2011 RSLs is presented in Table 2 and is based on the following approach:

1. The exposure point concentrations (EPCs) of the analytes were compared to November 2011 RSLs.
2. If the analyte EPC (organic and inorganic) was less than its November 2011 RSL, then the evaluation presented in Final OU-2B FS remained valid. These analytes are presented in unhighlighted rows of Table 2.
3. If the analyte EPC was greater than its November 2011 RSL, then the chemical was further evaluated in Table 2 as described below:
    - **Inorganic Constituents/Metals:** All metals reported in OU-2B groundwater with EPCs greater than their respective November 2011 RSLs are already selected as secondary COCs in the Final OU-2B FS. The proposed cleanup goals for these metals for OU-2B groundwater are either their respective background values or maximum contaminant levels (MCLs). Therefore, changes in RSLs did not add any new metal to the COC list or impact remedial alternatives evaluated in the Final OU-2B FS.
    - **Organic Constituents:** Each organic constituent with an EPC greater than November 2011 RSL was evaluated separately in Table 2 to determine if, (1) any new COC needs to be added, (2) there are any impacts on the remedial alternatives scope developed/evaluated in the Final OU-2B FS, or (3) there are potential impacts to the RBCs presented in the Final OU-2B FS. Based on this evaluation, changes in RSLs did not add any reported organic analyte to the list of COCs or impact remedial alternatives evaluated in the Final OU-2B FS, except 1,4-dioxane which will be added to the list of secondary COCs (along with metals) for the case in which groundwater is considered a potential drinking water source. The secondary COCs will be monitored if the groundwater remedial action for OU-2B is selected based on OU-2B groundwater being considered a potential drinking water source. Since a significant component of 1,4-dioxane risk is attributed to groundwater ingestion; 1,4-dioxane is not a COC for the commercial reuse scenario where OU-2B groundwater is not considered a potential drinking water source. Additionally, changes in the toxicity factors inherent to RSL changes resulted in revised residential indoor air RBCs for trichloroethene (TCE), vinyl chloride (VC) and cis-1,2-dichloroethene (cis-1,2-DCE) (changes in the commercial indoor RBCs are presented in Appendix A). As a result, the TCE residential RBC changed from 27.2 µg/L (micrograms per liter) to 5.1 µg/L, the vinyl chloride RBC changed from 3.2 µg/L to 1.3 µg/L, and the cis-1,2-DCE RBC changed from 2011 µg/L to 402 µg/L, respectively (see Tables 2 and 3). An evaluation of how the changes in the RBC affect the remedial action scope and cost was performed. This evaluation

concluded that based on the known distribution of VOCs and the distribution of monitoring points, there is no discernable difference in the VOC footprint requiring remediation. Consequently, the estimated remediation timeframes for attaining the revised RBCs are not expected to be significantly different than the timeframes presented in the Final OU-2B FS for cleanup to higher RBCs. In fact, the updated TCE RBC is equivalent to the TCE MCL of 5 µg/L. The remediation timeframes presented in the Final OU-2B FS were estimated using MCL based remediation goals which are less than these RBCs.

Based on this updated RSLs evaluation, no new constituents have been selected as primary groundwater COCs in this FS Addendum. The indoor air RBCs for TCE, VC, and cis-1,2-DCE have been updated; however, no changes are required to the scope, cost, or the estimated remediation time-frames for groundwater remedial alternatives developed in the Final OU-2B FS or their detailed/comparative evaluation.

2.2 EVALUATION OF UPDATED TOXICITY CRITERIA

A comprehensive evaluation of the impact of November 2011 RSLs and associated toxicity criteria on groundwater COC selection, response action alternatives development, and RBCs documented in the Final OU-2B FS is presented in Section 2.1. This section presents detailed evaluation of updated toxicity criteria for cis-1,2-DCE, VC, and TCE.

The oral reference dose (RfD_o) for cis-1,2-DCE was revised from 1 x 10^{-2} milligrams per kilogram per day (mg/kg-day) to 2.0 x 10^{-3} mg/kg-day in November 2011. Based on this, the extrapolated non-cancer inhalation reference concentration (RfC_i) for cis-1,2-DCE changed from 3.5 x 10^{-2} milligrams per cubic meter (mg/m^3) to 7 x 10^{-3} mg/m^3. The revised residential indoor air RBC for cis-1,2-DCE based on the updated toxicity value is presented in Table 3.

The toxicity values for VC reported in November 2011 RSL table did not change from those reported in the May 2009 RSL table. However, the residential indoor air RBC for VC has been revised in this FS Addendum in accordance with the USEPA guidance (USEPA 2011b) considering VC's designation as a mutagen (see Table 3).

In September 2011, USEPA issued a final health assessment for TCE which revised both the cancer risk and non-cancer hazard toxicity values. The inhalation unit risk was revised from 2.0 x 10^{-6} per micrograms per cubic meter (µg/m^3) to 4.1 x 10^{-6} per µg/m^3. In addition, the new non-cancer inhalation reference concentration (RfC_i) was set at 2 x 10^{-3} mg/m^3, while the FS human-health risk assessment (HHRA) used an estimated value of 0.6 mg/m^3 for the vapor intrusion risk based on California's Office of Environmental Health Hazard Assessment database. As a result, the estimated risks for TCE presented in the Final FS are less than risk based on the updated toxicity factors. The designation of TCE as a mutagenic compound also affects the risk calculated for unrestricted exposure scenarios including residential. Based on the updated toxicity values for TCE, the calculated carcinogenic risk associated with TCE in groundwater for Exposure Group 2 (see Section 2 of Appendix B of the Final FS for definition) would increase from 1.2 x 10^{-4} to 6.3 x 10^{-4}, while the non-cancer hazard quotient would increase from 0.23 to 70.

The total groundwater cancer risk for Exposure Group 2 as a result of changes in the TCE toxicity values would change from 2 x 10^{-4} to 7 x 10^{-4} and the non-cancer hazard index would change from 1 to 71. While there are changes to the TCE risk, these changes do not affect the decisions made based on risk, namely whether or not TCE is a COC. The TCE risks presented in the Final FS provide adequate justification for the need to develop response action alternatives. However, the revised toxicity factors affect the basis for evaluating the post remedy risk and the calculated RBCs. With respect to the basis for the response action scope (remediation footprint), the updated RBCs do not significantly alter the scope, cost, or estimated remediation time-frames for groundwater remedial alternatives developed in the Final OU-2B FS or their detailed/comparative evaluation since the MCLs (proposed remediation goals for OU-2B groundwater) are less than these RBCs. In addition, since the updated TCE (primary OU-2B groundwater COC) indoor air RBC is essentially equivalent to the MCL, the FS evaluation in the Final OU-2B FS also applies to the scenario of residential reuse of OU-2B with groundwater not a potential drinking water source.

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3. GROUNDWATER FS EVALUATION – COMMERCIAL REUSE AND NON-DRINKING WATER BENEFICIAL USE

Appendix A of this FS Addendum presents an additional FS analysis (i.e. development and evaluation of remedial alternatives) for groundwater at OU-2B. The FS analysis presented in the Final OU-2B FS document (OTIE 2011a) is based on the classification of groundwater beneath OU-2B as a Class II aquifer, a potential source of drinking water. The additional evaluation in this FS Addendum for OU-2B groundwater assumes the following:

1. Groundwater beneath OU-2B is not considered a potential drinking water source, and
2. The reuse of OU-2B area is restricted to commercial use (i.e. no residential reuse of OU-2B area).

This evaluation is intended to provide risk managers with a detailed evaluation to be considered if groundwater is excepted from domestic use and reuse is limited to commercial. The following bullet items summarize the approach used in Appendix A for the additional FS analysis:

- The remedial action objectives (RAOs) presented in the Final OU-2B FS were revised consistent with the assumptions that groundwater beneath OU-2B is not a potential drinking water source and the reuse of OU-2B area will be restricted to commercial use. The revised RAOs, COCs, and remediation goals are presented in Section 2 of Appendix A. The revised RAOs are based on the protection of potential receptors from exposure to COC vapors from groundwater at concentrations presenting unacceptable risks and potential discharge into the Seaplane lagoon. The COCs were selected based on the following two criteria: (1) potential human health risks due to intrusion of VOC vapors from groundwater into indoor air, and (2) comparison of concentrations of VOCs and metals with concentrations based on the Federal Water Quality Criteria at Title 40 Code of Federal Regulations, Sections 131.36 and 131.38 (referred to as the National Toxics Rule [NTR] and the California Toxics Rule [CTR]) (potential ARARs for discharge of OU-2B groundwater into Seaplane Lagoon). The two COCs (TCE and VC) selected for OU-2B groundwater and their respective RGs are presented in Sections 2.2 and 2.4 of Appendix A. The RBCs for protection against unacceptable indoor air risks under a commercial use scenario were calculated and are presented in Appendix A.
- Based on the updated RAOs, an evaluation of whether the general response actions (GRAs) and target remediation zones for impacted groundwater presented in the Final OU-2B FS needed revisions was performed. This evaluation indicated that no revision to the GRAs was necessary; however, the target remediation zones would need revision. A discussion of the revised target remediation zones is presented in Section 2.5 of Appendix A.
- Based on the GRAs and updated target remediation zones, an evaluation was performed to assess whether the revisions to the identification and evaluation of remediation technologies, and process options presented in the Final OU-2B FS were necessary. This evaluation indicated that no revisions to identification and evaluation of remediation technologies and process options were needed.
- Based on the revised RAOs and revised target remediation zones, an evaluation was performed to assess if the remedial alternatives presented in the Final OU-2B FS needed revision. This evaluation indicated that some remedial alternatives needed minor revisions. The revised remedial alternatives are presented in Section 3 of Appendix A.
- The updated remedial action alternatives were evaluated based on the nine evaluation criteria identified in the NCP (Title 40 Code of Federal Regulations [C.F.R.] Section [§] 300.430 [e][9][iii]). This detailed alternative evaluation is presented in Section 4 of Appendix A.

Appendix A also includes updated evaluation of applicable or relevant and appropriate requirements (ARARs), and updated remedial action costs.

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Tables

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Table 1: Comparison of May 2009 and November 2011 EPA Tapwater RSLs

Analyte[a]	2009 EPA Tapwater RSL[b] (µg/L)	2011 EPA Tapwater RSL[c] (µg/L)	Are the 2009 and 2011 RSLs Different	Notes
Aluminum, dissolved	37000	16000	YES	Please see Table 2 for further evaluation.
Antimony, dissolved	15	6	YES	Please see Table 2 for further evaluation.
Arsenic, dissolved	0.045	0.045	NO	No change in the RSL, therefore no further evaluation required
Barium, dissolved	7300	2900	YES	Please see Table 2 for further evaluation.
Beryllium, dissolved	73	16	YES	Please see Table 2 for further evaluation.
Cadmium, dissolved	18	6.9	YES	Please see Table 2 for further evaluation.
Calcium, dissolved	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Chromium, dissolved	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Chromium, hexavalent	110	0.031	YES	Please see Table 2 for further evaluation.
Cobalt, dissolved	11	4.7	YES	Please see Table 2 for further evaluation.
Copper, dissolved	1500	620	YES	Please see Table 2 for further evaluation.
Iron, dissolved	26000	11000	YES	Please see Table 2 for further evaluation.
Lead, dissolved	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Magnesium, dissolved	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Manganese, dissolved	880	320	YES	Please see Table 2 for further evaluation.
Mercury, dissolved	0.57	0.63	YES	Please see Table 2 for further evaluation.
Molybdenum, dissolved	180	78	YES	Please see Table 2 for further evaluation.
Nickel, dissolved	730	300	YES	Please see Table 2 for further evaluation.
Potassium, dissolved	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Selenium, dissolved	180	78	YES	Please see Table 2 for further evaluation.
Silver, dissolved	180	71	YES	Please see Table 2 for further evaluation.
Thallium, dissolved	NE	0.16	YES	Please see Table 2 for further evaluation.
Vanadium, dissolved	260	NE	YES	Please see Table 2 for further evaluation.
Zinc, dissolved	11000	4700	YES	Please see Table 2 for further evaluation.
Benzo(a)pyrene	0.0029	0.0029	NO	No change in the RSL, therefore no further evaluation required
Naphthalene	0.14	0.14	NO	No change in the RSL, therefore no further evaluation required
Heptachlor	0.015	0.0018	YES	Please see Table 2 for further evaluation.
1,4-Dioxane (P-Dioxane)	6.1	0.67	YES	Please see Table 2 for further evaluation.
Bis(2-Ethylhexyl) Phthalate	4.8	0.071	YES	Please see Table 2 for further evaluation.
Diethyl Phthalate	29000	11000	YES	Please see Table 2 for further evaluation.
1,1,1,2-Tetrachloroethane	0.52	0.5	YES	Please see Table 2 for further evaluation.
1,1,1-Trichloroethane	9100	7500	YES	Please see Table 2 for further evaluation.
1,1,2,2-Tetrachloroethane	0.067	0.066	YES	Please see Table 2 for further evaluation.
1,1,2-Trichloroethane	0.24	0.24	NO	No change in the RSL, therefore no further evaluation required
1,1-Dichloroethane	2.4	2.4	NO	No change in the RSL, therefore no further evaluation required
1,1-Dichloroethene	340	260	YES	Please see Table 2 for further evaluation.
1,2,3-Trichlorobenzene	NE	5.2	YES	Please see Table 2 for further evaluation.
1,2,4-Trichlorobenzene	8.2	0.99	YES	Please see Table 2 for further evaluation.
1,2,4-Trimethylbenzene	15	15	NO	No change in the RSL, therefore no further evaluation required
1,2-Dichlorobenzene	370	280	YES	Please see Table 2 for further evaluation.
1,2-Dichloroethane	0.15	0.15	NO	No change in the RSL, therefore no further evaluation required
1,3,5-Trimethylbenzene	12	87	YES	Please see Table 2 for further evaluation.

Table 1: Comparison of May 2009 and November 2011 EPA Tapwater RSLs (continued)

Analyte[a]	2009 EPA Tapwater RSL[b] (µg/L)	2011 EPA Tapwater RSL[c] (µg/L)	Are the 2009 and 2011 RSLs Different	Notes
1,3-Dichlorobenzene	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
1,4-Dichlorobenzene	0.43	0.42	YES	Please see Table 2 for further evaluation.
2-Butanone	7100	4900	YES	Please see Table 2 for further evaluation.
2-Chlorotoluene	730	180	YES	Please see Table 2 for further evaluation.
2-Hexanone	NE	34	YES	Please see Table 2 for further evaluation.
4-Methyl-2-pentanone	2000	1000	YES	Please see Table 2 for further evaluation.
Acetone	22000	12000	YES	Please see Table 2 for further evaluation.
Benzene	0.41	0.39	YES	Please see Table 2 for further evaluation.
Bromodichloromethane	0.12	0.12	NO	No change in the RSL, therefore no further evaluation required
Bromoform	8.5	7.9	YES	Please see Table 2 for further evaluation.
Bromomethane	8.7	7	YES	Please see Table 2 for further evaluation.
Carbon disulfide	1000	720	YES	Please see Table 2 for further evaluation.
Chlorobenzene	91	72	YES	Please see Table 2 for further evaluation.
Chloroethane	21000	21000	NO	No change in the RSL, therefore no further evaluation required
Chloroform	0.19	0.19	NO	No change in the RSL, therefore no further evaluation required
Chloromethane	190	190	NO	No change in the RSL, therefore no further evaluation required
cis-1,2-Dichloroethene	370	28	YES	Please see Table 2 for further evaluation.
Dichlorodifluoromethane	390	190	YES	Please see Table 2 for further evaluation.
Ethylbenzene	1.5	1.3	YES	Please see Table 2 for further evaluation.
Hexachlorobutadiene	0.86	0.26	YES	Please see Table 2 for further evaluation.
Isopropyl Ether	830	1500	YES	Please see Table 2 for further evaluation.
Isopropylbenzene	680	390	YES	Please see Table 2 for further evaluation.
Methyl Tert-Butyl Ether	12	12	NO	No change in the RSL, therefore no further evaluation required
Methylene chloride	4.8	4.7	YES	Please see Table 2 for further evaluation.
N-Butylbenzene	NE	780	YES	Please see Table 2 for further evaluation.
N-Propylbenzene	NE	530	YES	Please see Table 2 for further evaluation.
o-Xylene	1400	190	YES	Please see Table 2 for further evaluation.
p-Isopropyltoluene	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Sec-Butylbenzene	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
T-Butylbenzene	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Tert-Amyl Methyl Ether	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Tert-Butyl Alcohol	NE	NE	NO	No RSL issued in 2009 and 2011, therefore no further evaluation required.
Tetrachloroethene	0.11	0.072	YES	Please see Table 2 for further evaluation.
Toluene	2300	860	YES	Please see Table 2 for further evaluation.
trans-1,2-Dichloroethene	110	86	YES	Please see Table 2 for further evaluation.
Trichloroethene	1.7	0.44	YES	Please see Table 2 for further evaluation.
Trichlorofluoromethane	1300	1100	YES	Please see Table 2 for further evaluation.
Vinyl chloride	0.016	0.015	YES	Please see Table 2 for further evaluation.
Xylenes (total)	200	190	YES	Please see Table 2 for further evaluation.

Notes:

[a] Analytes reported during prior investigations

[b] RSLs issued by United States Environmental Protection Agency (USEPA) in May 2009.

[c] RSLs issued by USEPA in November 2011.

NE = RSL does not exist.

Table 2: Comparison of Constituents Whose November 2011 EPA Tapwater RSLs changed from May 2009

Analyte	CAS	Calculated EPC Value, µg/L	2009 EPA Tapwater RSL (µg/L)	2011 EPA Tapwater RSL (µg/L)	Does the EPC Exceed the 2011 EPA Tapwater RSL	Is it a Primary/ Secondary COC	Potential Impact to the Remedial Alternatives Evaluated in the FS	Potential Impact to the RBCs	Remarks
Aluminum, dissolved	7429-90-5	34.29	37000	16000	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Antimony, dissolved	7440-36-0	1.905	15	6	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Barium, dissolved	7440-39-3	147.5	7300	2900	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Beryllium, dissolved	7440-41-7	0.438	73	16	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Cadmium, dissolved	7440-43-9	1.165	18	6.9	NO	YES	NO	YES	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Chromium, hexavalent	18540-29-9	32.43	110	0.031	YES	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is MCL.
Cobalt, dissolved	7440-48-4	21.41	11	4.7	YES	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is background value.
Copper, dissolved	7440-50-8	3.495	1500	620	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Iron, dissolved	7439-89-6	18271	26000	11000	YES	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is background value.
Manganese, dissolved	7439-96-5	7704	880	320	YES	YES	NO	YES	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is background value.
Mercury, dissolved	7439-97-6	0.0857	0.57	0.63	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Molybdenum, dissolved	7439-98-7	40.9	180	78	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Nickel, dissolved	7440-02-0	1447	730	300	YES	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is MCL.
Selenium, dissolved	7782-49-2	1.363	180	78	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Silver, dissolved	7440-22-4	1.574	180	71	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Thallium, dissolved	7440-28-0	1.672	NE	0.16	YES	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a secondary COC in the Final FS and its RG for OU-2B groundwater is background value.
Vanadium, dissolved	7440-62-2	7.426	260	NE	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Zinc, dissolved	7440-66-6	15.13	11000	4700	NO	YES	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Heptachlor	76-44-8	0.032	0.015	0.0018	YES	NO	NO	NO	No change from the Final OU-2B FS. The following rationale was presented for the exclusion of heptachlor as a COC in the Final FS which was detected in one of the five samples analyzed: "Heptachlor was detected at only one location (S4-B34) during data gap investigation (see Figure 28A of the FS) at a concentrations of 0.032 µg/L and 0.021 µg/L in the original and duplicate samples respectively, exceeding its MCL of 0.01 µg/L. Heptachlor was not detected above its MCL at any other sample analyzed for pesticides at OU-2B. Given the uncertainty in the quantitation and the very low concentrations, heptachlor was excluded from the list of COCs".
1,4-Dioxane (P-Dioxane)	123-91-1	127.6	6.1	0.67	YES	NO	NO	NO	Added to the list of secondary COCs for the case in which groundwater is considered a potential drinking water source.
Bis(2-Ethylhexyl) Phthalate	117-81-7	3.003	4.8	0.071	YES	NO	NO	NO	No change from the Final OU-2B FS. The following rationale was presented for exclusion of bis(2-ethylhexyl)phthalate as a COC in the Final FS: Bis(2-ethylhexyl)phthalate was detected at concentration (52 µg/L) exceeding its MCL (4 µg/L) in a sample collected below influent piping of former OWS-163 at only one location (S4-OWS163-INF). Soil was removed from this location in 2009 prior to ZVI treatability study in conjunction with removal of OWS-163 (Tetra Tech 2010b). Soil and groundwater samples were collected subsequent to the OWS-163 removal and soil excavation, and the results are presented on Figure 22 (Tetra Tech 2010a and Tetra Tech 2010b). Bis(2-ethylhexyl)phthalate was not reported above its screening levels (USEPA 2004 soil RSL or MCL) in any soil or groundwater sample collected within or in the vicinity of the excavated area. In addition to location mentioned above, bis(2-ethylhexyl)phthalate was reported in 4 liquid samples of the total of 28 liquid samples (10 content samples from OWS-163, 360, 372A, 14A, 14B, and 14D; and 18 groundwater samples) collected after 2002 (dataset considered to be representative of current groundwater conditions and used in the OU-2B FS). Of the total of 4 detections, 2 detections of bis(2-ethylhexyl)phthalate were in liquid samples from within OWS-360 and OWS-163, and two detections were in groundwater samples collected from location S11-B15 and S11-B19 located near Building 14 in IR Site 11. The two reported values of bis(2-ethylhexyl)phthalate in S11-B15 and S11-B19 were 2.8J and 2.4J µg/L, respectively, less than its MCL of 4 µg/L.
Diethyl Phthalate	84-66-2	11	29000	11000	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
1,1,1,2-Tetrachloroethane	630-20-6	0.28	0.52	0.5	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
1,1,1-Trichloroethane	71-55-6	1.314	9100	7500	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
1,1,2,2-Tetrachloroethane	79-34-5	1.5	0.067	0.066	YES	NO	NO	NO	No change from the Final OU-2B FS. No significant change in the RSL. Only one sample was detected out of the 653 samples analyzed.
1,1-Dichloroethene	75-35-4	247.4	340	260	NO	YES	NO	NO	No change from the Final OU-2B FS. The constituent was selected as a groundwater COC in the Final FS and its RG for OU-2B groundwater is MCL. No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
1,2,3-Trichlorobenzene	87-61-6	0.978	NE	5.2	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.

Table 2: Comparison of Constituents Whose November 2011 EPA Tapwater RSLs changed from May 2009 (continued)

Analyte	CAS	Calculated EPC Value, µg/L	2009 EPA Tapwater RSL (µg/L)	2011 EPA Tapwater RSL (µg/L)	Does the EPC Exceed the 2011 EPA Tapwater RSL	Is it a Primary/ Secondary COC	Potential Impact to the Remedial Alternatives Evaluated in the FS	Potential Impact to the RBCs	Remarks
1,2,4-Trichlorobenzene	120-82-1	1.072	8.2	0.99	YES	NO	NO	NO	No change from the Final OU-2B FS. The EPC is consistent with the 2011 EPA RSL.
1,2-Dichlorobenzene	95-50-1	24.82	370	280	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
1,3,5-Trimethylbenzene	108-67-8	0.358	12	87	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
1,4-Dichlorobenzene	106-46-7	3.515	0.43	0.42	YES	YES	NO	NO	No change from the Final OU-2B FS. No significant change in the RSL. Not identified as a vapor intrusion COPC for groundwater during risk assessment in the Final OU-2B FS.
2-Butanone	78-93-3	6.819	7100	4900	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
2-Chlorotoluene	95-49-8	4.9	730	180	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
2-Hexanone	591-78-6	2.437	NE	34	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
4-Methyl-2-pentanone	108-10-1	3.074	2000	1000	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Acetone	67-64-1	760.7	22000	12000	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Benzene	71-43-2	16.67	0.41	0.39	YES	YES	NO	NO	No change from the Final OU-2B FS. No significant change in the RSL. No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
Bromoform	75-25-2	0.7	8.5	7.9	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Bromomethane	74-83-9	0.253	8.7	7	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Carbon disulfide	75-15-0	0.547	1000	720	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Chlorobenzene	108-90-7	5.598	91	72	NO	YES	NO	NO	No change from the Final OU-2B FS. No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
cis-1,2-Dichloroethene	156-59-2	694.1	370	28	YES	YES	NO	YES	New RBC for cis-1,2-DCE for indoor air is 402 µg/L (previous RBC was 2011 µg/L).
Dichlorodifluoromethane	75-71-8	1.1	390	190	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Ethylbenzene	100-41-4	7.398	1.5	1.3	YES	NO	NO	NO	No change from the Final OU-2B FS. The following rationale was presented for exclusion of ethylbenzene as a COC in the Final FS: "Ethylbenzene exceeded its MCL of 300 µg/L at only one location (S3-HP07) during groundwater monitoring conducted as part of Supplemental DGI (Figure 28A). The concentration of ethylbenzene at this location was 550 µg/L. Ethylbenzene did not exceed its MCL in any of the remaining more than 600 groundwater samples collected and analyzed at OU-2B (see Table 12). Therefore, ethylbenzene was excluded from the list of COCs because of an isolated detection exceeding its MCL at only one hydropunch location".
Hexachlorobutadiene	87-68-3	0.4	0.86	0.26	YES	NO	NO	NO	No change from the Final OU-2B FS. Only one sample was detected out of the 542 samples analyzed. The risk thresholds (cancer risk and HI) are less than 1E-06 or 1 based on the maximum reported concentration for this constituent with the new toxicity criteria.
Isopropyl Ether	108-20-3	0.117	830	1500	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Isopropylbenzene	98-82-8	0.539	680	390	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Methylene chloride	75-09-2	3.645	4.8	4.7	NO	YES	NO	NO	No change from the Final OU-2B FS. No significant change in the RSL. No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
N-Butylbenzene	104-51-8	0.408	NE	780	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
N-Propylbenzene	103-65-1	0.641	NE	530	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
o-Xylene	95-47-6	0.44	1400	190	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Tetrachloroethene	127-18-4	0.619	0.11	0.072	YES	YES	NO	NO	No change from the Final OU-2B FS. No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
Toluene	108-88-3	2.914	2300	860	NO	YES	NO	NO	No change from the Final OU-2B FS. Not identified as a vapor intrusion COPC for groundwater during risk assessment in the Final OU-2B FS.
trans-1,2-Dichloroethene	156-60-5	24.07	110	86	NO	YES	NO	YES	No change from the Final OU-2B FS.No change in the Residential RBC as the Inhalation Unit Risk Factor/Inhalation Reference Concentration did not change.
Trichloroethene	79-01-6	3277	1.7	0.44	YES	YES	NO	YES	New residential RBC for TCE in indoor air is 5.1 µg/L (previous RBC was 27.2 µg/L).
Trichlorofluoromethane	75-69-4	0.356	1300	1100	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.
Vinyl chloride	75-01-4	103.1	0.016	0.015	YES	YES	NO	YES	New Residential RBC based on it being listed as a mutagenic is 1.3 µg/L (previous RBC was 3.2 µg/L).
Xylenes (total)	1330-20-7	2.63	200	190	NO	NO	NO	NO	No change from the Final OU-2B FS. EPC is less than the 2011 RSL.

Notes:
COC = constituent of concern
EPC = exposure point concentration
FS = feasibility study
MCL = maximum contaminant level
NE = RSL value does not exist
OU = Operable unit
RBC = risk-based concentration
RG = remediation goal
RSL = regional screening level
TCE = trichloroethene

Table 3: Remediation Goals – OU-2B Groundwater

Analyte	RBCs – Residential Use	Potential Chemical-Specific ARARs							Background Value (μg/L)	Selected Remediation Goal for OU-2B Groundwater[c] (μg/L)	Selected Remediation Goal for Protection Against Unacceptable Indoor Air Risks(μg/L)	Selected Remediation Goal for Groundwater Discharge into Seaplane Lagoon (μg/L)
	Inhalation - Indoor Air (μg/L)	Federal Primary MCL (μg/L) 40 C.F.R. § 141.61	Federal MCLG (μg/L) 40 C.F.R. § 141.50	California MCL (μg/L) Cal. Code Regs. tit. 22, §§ 64444 and 64449(a)	Based on NTR[d] 40 C.F.R § 131.36		Based on CTR[d] 40 C.F.R. § 131.38					
					Potential Aquatic Receptor (μg/L)	Potential Human Receptor[f] (μg/L)	Potential Aquatic Receptor (μg/L)	Potential Human Receptor[g] (μg/L)				
PRIMARY COCs												
Benzene	11.3	5	0	1	--[e]	710	--[e]	710	--[e]	**1**	11.3	**710**
cis-1,2-DCE	402 (2011)*	70	70	6	--[e]	--[c]	--[e]	--[e]	--[e]	**6**	402 (2011)*	--[e]
trans-1,2-DCE	1592.48	100	100	10	--[e]	--[c]	--[e]	1,400,000	--[e]	**10**	1592.48	**1,400,000**
1,1-DCA	--	--	--	5	--[e]	--[c]	--[e]	--[e]	--[e]	**5**	--	--[e]
1,2-DCA	14.23	5	0	0.5	--[e]	990	--[e]	990	--[e]	**0.5**	14.23	**990**
1,4-Dichlorobenzene	--	--	--	5	--[e]	26,000	--[e]	26,000	--[e]	**5**	--	**26,000**
1,1-DCE	1526.96	7	7	6	--[e]	32	--[e]	32	--[e]	**6**	1526.96	**32**
PCE	5.91	5	0	5	--[e]	88.5	--[e]	88.5	--[e]	**5**	5.91	**88.5**
TCE	5.1 (27.2)*	5	0	5	--[e]	810	--[e]	810	--[e]	**5**	5.1 (27.2)*	**810**
VC	1.3 (3.2)*	2	0	0.5	--[e]	5,250	--[e]	5,250	--[e]	**0.5**	1.3 (3.2)*	**5,250**
1,1,2-TCA	--	5	3	5	--[e]	420	--[e]	420	--[e]	**3**	--	**420**
Methylene Chloride	374.41	--	--	5	--[e]	16,000	--[e]	16,000	--[e]	**5**	374.41	**16,000**
Chlorobenzene	3472.19	100	100	70	--[e]	210,000	--[e]	210,000	--[e]	**70**	3472.19	210,000
Toluene	--	1,000	1,000	150	--[e]	2,000,000	--[e]	2,000,000	--[e]	**150**	--	**2,000,000**
Arsenic[a]	--	10	0	10	360[f]	1.4	360[f]	--[e]	20.7	**20.7[h]**	--	**20.7**
Antimony[a]	--	6	6	6	--[e]	43,000	--[e]	43,000	37.5	**37.5[h]**	--	**43,000**
SECONDARY COCs												
Arsenic[b]	--	10	0	10	360[f]	1.4	360[f]	--[e]	20.7	**20.7[h]**	--	**20.7**
Cadmium	--	5	5	5	93	--[e]	93	--[e]	3.9	**5**	--	**93**
Chromium	--	100	100	50	--[e]	--[e]	--[e]	--[e]	12.5	**50**	--	**--**
Chromium, hexavalent	--	100	100	50	500	--[e]	500	--[e]	--[e]	**50**	--	**500**
Cobalt	--	--	--	--	--[e]	--[e]	--[e]	--[e]	17.2	**17.2**	--	**--**
Copper	--	--	--	1,000	24	--[e]	31	--[e]	24.2	**--[k]**	--	**24.2**
Iron[b]	--	--	--	300	--[e]	--[e]	--[e]	--[e]	6,585.5	**6,585.5[h]**	--	--
Lead [j]	--	15	0	15	81	--[e]	81	--[e]	6.7	**15**	--	**81**
Manganese[b]	--	--	--	50	--[e]	--[e]	--[e]	--[e]	1,741	**1,741[h]**	--	--
Mercury	--	2	2	2	0.25	1.5	--[e]	0.51	0.2	**--[k]**	--	**0.25**
Nickel[b]	--	--	--	100	82	46,000	82	46,000	21	**100[i]**	--	**82**
Selenium	--	50	50	50	710	--[e]	710	--[e]	8.4	**--[k]**	--	**710**
Silver	--	--	--	100	19	--[e]	19	--[e]	4.9	**--[k]**	--	**19**
Thallium	--	0.5	2	2	--[e]	63	--[e]	63	13.8	**13.8**	--	**63**
Zinc	--	--	--	5,000	810	--[e]	810	--[e]	36.4	**--[k]**	--	**810**
1,4-dioxane	--	--	--	--	--	--	--	--	--	**--[m]**	--	--

Notes:

*The residential RBCs changed for the constituents highlighted in yellow. The RBCs for cis,-1,2-DCE and TCE were revised based on the new November 2011 RSLs. The revised RBCs for TCE and VC reflect classification of these two chemicals as mutagens. The values in parenthesis are previously estimated RBCs presented in the Final OU-2B FS (OTIE 2011a). 1,4-dioxane highlighted in yellow was added as a secondary COC based on the new November 2011 RSLs.

[a] Primary COC only for the localized area north of Building 170. The groundwater remedy for elevated arsenic and antimony in the area north of Building 170 will be to remove the source as described in the soil alternatives to reduce groundwater impact with groundwater monitoring to confirm the response action effectiveness. Arsenic is also selected as a secondary COC in the areas other than the localized area north of Building 170 as explained in note b below. Antimony is not selected as a secondary COC since it was not reported at concentrations greater than its background value at location other than the area north of Building 170.

[b] Secondary COC (Arsenic is a secondary COC in the areas other than the localized area north of Building 170). No active response action alternatives were developed/evaluated in this FS for secondary COCs. However, metals monitoring has been made part of each remedial alternative for VOCs to assess whether their concentrations revert to background ranges once the VOC concentrations are reduced (see Section 5.1.2.2 for details).

[c] For VOCs, least of the following values: Calculated RBCs, federal MCL, non-zero federal MCLG, and California MCL.

[d] Assuming chemical is attenuated/diluted 10 times as it discharges into the lagoon.

[e] Numerical criterion does not exist.

[f] Lesser of the criteria maximum concentration and criteria continuous concentration.

[g] For consumption of organisms only.

[h] The selected remediation goal represents the established background concentration for OU-2B. Background concentrations for the subject analytes are higher than their MCLs, and/or concentrations based on NTR/CTR.

[i] The selected remediation goal is the California MCL.

[j] Action level

[k] The analyte did not exceed its MCL in groundwater investigations conducted from 2002 to Winter 2010, and is not a risk driver. Therefore, no remediation goal required for OU-2B groundwater.

[m] The analyte has a California Department of Public Health notification level of 1 μg/L and a response level of 35 μg/L.

Appendix A
Groundwater FS Evaluation – Commercial Reuse and Non-Drinking Water Beneficial Use

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ATTACHMENTS

Attachment A Methodology for Calculation of Risk-Based Groundwater Concentrations – Commercial Use

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Table 2: Comparison of Metal Concentrations (Group 1 Wells)a with Concentrations Based on National Toxics Rule and California Toxics Rule

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Table 4: Individual and Comparative Analysis of Remedial Alternatives – OU-2B Groundwater

Table 5: Summary of Assumptions for Cost Estimates

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ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
Cal. Code Regs.	California Code of Regulations
CTR	California Toxics Rule
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C.F.R.	Code of Federal Regulations
COPCs	chemicals of potential concern
COCs	constituents of concern
1,1-DCE	1,1-dichloroethene
FS	feasibility study
GRAs	general response actions
HI	hazard index
ICs	Institutional Controls
ISCO	in-situ chemical oxidation
ISTT	in-situ thermal treatment
MCLs	maximum contaminant levels
MCLG	maximum contaminant level goal
MNA	Monitored Natural Attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NTR	National Toxics Rule
OU-2B	Operable Unit-2B
PRB	permeable reactive barrier
§	Section
RAOs	remedial action objectives
RBCs	risk-based concentrations
RD/RA	remedial design/remedial action
RG	remediation goal
TCE	trichloroethene
tit.	title
U.S. EPA	United States Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound

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1. Introduction

This appendix presents an additional feasibility study (FS) analysis (i.e. development and evaluation of remedial alternatives) for groundwater at Operable Unit-2B (OU-2B), Alameda Point, Alameda, California. The FS analysis presented in the Final OU-2B FS document (OTIE 2011) is based on the classification of groundwater beneath OU-2B as a Class II aquifer, a potential source of drinking water. This appendix presents an additional FS analysis for OU-2B groundwater for a scenario in which both of the following conditions are true:

1. Groundwater beneath OU-2B is *not* considered a potential drinking water source, and
2. The reuse of OU-2B area is restricted to commercial use (i.e. no residential reuse in areas overlying the plume where groundwater concentrations exceed vapor intrusion risk-based concentrations [RBCs])

The following bullet items summarize the approach used in this appendix for the additional FS analysis:

- The remedial action objectives (RAOs) presented in the Final OU-2B FS were revised consistent with the assumptions that groundwater beneath OU-2B is not a potential drinking water source and the reuse of OU-2B area will be restricted to commercial use. The revised RAOs are presented in Section 2 of this appendix.
- Based on the updated RAOs, an evaluation of whether the general response actions (GRAs) and target remediation zones for impacted groundwater presented in the Final OU-2B FS needed revisions was performed. This evaluation indicated that no revision to the GRAs was necessary; however, the target remediation zones would need revision. A discussion of the revised target remediation zones is presented in Section 2.5 of this appendix.
- Based on the GRAs and updated target remediation zones, an evaluation was performed to assess whether the revisions to the identification and evaluation of remediation technologies, and process options presented in the Final OU-2B FS were necessary. This evaluation indicated that no revisions to identification and evaluation of remediation technologies and process options were needed.
- Based on the revised RAOs and revised target remediation zones, an evaluation was performed to assess if the remedial alternatives presented in the Final OU-2B FS needed revision. This evaluation indicated that some remedial alternatives needed minor revisions. The revised remedial alternatives are presented in Section 3 of this appendix.
- The updated remedial action alternatives were evaluated based on the nine evaluation criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Title 40 Code of Federal Regulations [C.F.R.] Section [§] 300.430 [e][9][iii]). This detailed alternative evaluation is presented in Section 4 of this appendix.

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2. Remedial Action Objectives

RAOs consist of medium-specific goals for protecting human-health and the environment. In accordance with the NCP, 40 C.F.R. § 300.430 (e)(2)(i), RAOs for OU-2B groundwater were established by specifying medium of concern (groundwater), potential exposure pathways, constituents of concern (COCs), and remediation goals.

2.1 POTENTIAL EXPOSURE PATHWAYS

Groundwater beneath Alameda Point (including OU-2B) is not currently used for drinking water, irrigation, or industrial supply. The FS analysis presented in this appendix is based on the assumption that OU-2B groundwater will not be used for drinking purposes and that the future use of OU-2B area will be restricted to commercial. Therefore, future receptors for OU-2B groundwater include commercial workers. The exposure of commercial workers to COCs in groundwater could occur via inhalation of COC vapors from groundwater that may migrate to indoor air.

In addition, continued migration of impacted groundwater and potential discharge into the Seaplane Lagoon at concentrations exceeding the values derived based on the applicable or relevant and appropriate requirements (ARARs) pertaining to surface water discharge will need to be addressed.

2.2 CONSTITUENTS OF CONCERN

All remedial actions at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites must be protective of human health and the environment, and comply with ARARs unless a waiver is justified. Therefore, the selection of COCs for OU-2B groundwater was based on human health risk considerations and the ARARs as summarized below.

The exposure of commercial workers to COCs in OU-2B groundwater could occur via inhalation of COC vapors from groundwater that may migrate to indoor air. Therefore, the constituent reported in OU-2B groundwater was selected as a COC if the following conditions were satisfied:

1. Constituent was considered a risk driver for commercial receptor via indoor air inhalation pathway (i.e. results in a cancer risk of greater than 10^{-6} or a noncancer hazard index (HI) of greater than 1).
2. Constituent was detected at relatively high frequency and its distribution indicates a release.

The following analytes satisfied the above criteria (see Appendix B of the Final OU-2B FS for cancer and non-cancer risks [using U.S. EPA toxicity factors] associated with potential vapor intrusion of chemicals of potential concern [COPCs] in groundwater) and were selected as COCs:

1. Trichloroethene (TCE)
2. Vinyl chloride (VC)

In addition to selection of COCs based on risk considerations, an evaluation was performed to determine whether any COCs need to be selected based on the potential chemical specific ARARs. The Federal Water Quality Criteria at 40 C.F.R. §§ 131.36 and 131.38 (referred to as the National Toxics Rule [NTR] and the California Toxics Rule [CTR]) constitute potential ARARs for discharge of OU-2B groundwater into the Seaplane Lagoon. Therefore, consistent with the ecological risk assessment documented in the Final OU-2B FS (OTIE 2011), this evaluation was based on the analytical results from groundwater monitoring wells, OU2B-MW01, OU2B-MW02, S21-TT-MW02A, S21-TT-MW03E, OU2B-MW04, S11-TT-MW04C, S11-TT-MW04D, S11-TT-MW04E, S11-TT-MW05C, S11-TT-MW05D, and S11-TT-MW05E, collected as part of investigations from

May 2006 and October 2008. These wells are referred to as Group 1 Wells in the Final OU-2B FS and are at locations immediately upgradient of the seawall and in closest proximity to receiving waters in the Seaplane lagoon. As such, analyte concentrations in samples from these wells are expected to be most representative of analyte concentrations in groundwater discharging into the lagoon.

2.2.1 Volatile Organic Compounds

EPCs for volatile organic compounds (VOCs) were calculated based on the upper confidence limits (UCLs) of the mean concentrations for all groundwater samples collected from the Group 1 wells between May 2006 and October 2008. These EPCs were compared to 10 times their respective NTR and CTR concentrations presented in Table 1. The dilution factor of 10 was applied to the most stringent of NTR and CTR values to account for dilution resulting from mixing with water in the Seaplane Lagoon. The dilution factor backup calculations are presented in Appendix H of the Final OU-2B FS document (OTIE 2011).

Based on this comparison, EPCs for all detected VOCs were less than 10 times their respective NTR and CTR concentrations (Table 1). In addition, the maximum detected concentrations of all detected VOCs in Group 1 wells were also less than 10 times their respective NTR and CTR concentrations, with the exception of TCE. Therefore, TCE was selected as a COC for discharge into the Seaplane Lagoon based on comparison with NTR and CTR concentrations.

2.2.2 Metals

Similar to VOCs, the calculated EPCs for metals in Group 1 wells were compared to 10 times their respective NTR and CTR concentrations presented in Table 2. The dilution factor of 10 was applied to the most stringent of NTR and CTR values to account for dilution resulting from mixing with water in the Seaplane Lagoon (see Final OU-2B FS Appendix H [OTIE 2011]).

Based on this comparison, with the exception of arsenic, the EPCs for all metals were less than 10 times their respective NTR and CTR concentrations. Arsenic exceeded 10 times its NTR and CTR concentrations; however, as shown on Table 2, its calculated EPC (8.02 µg/L) is lower than its background value (20.7 µg/L). In addition, the concentration of arsenic exceeded its background value in only one sample out of the total of 34 samples. Based on this, no metals warrant selection as COCs.

2.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section discusses the revisions to potential ARARs affecting the development of RAOs for groundwater remediation if groundwater beneath OU-2B is ***not*** considered a potential drinking water source.

If groundwater beneath OU-2B is *not* considered suitable for use as a potential drinking water source, the Federal or State drinking water maximum contaminant levels (MCLs) will *not* be potential ARARs for groundwater remedial action.

2.4 REMEDIAL ACTION OBJECTIVES

Consistent with the NCP (40 C.F.R. § 300.430 [e][2][i]), the following RAOs were developed for remediation of OU-2B groundwater:

- Minimize the potential for exposure of on-site receptors to COC vapors from groundwater at concentrations exceeding their respective remediation goals (RGs) for protection against indoor air risks.
- Minimize the potential for migration of impacted groundwater into Seaplane Lagoon at concentrations exceeding the values derived based on potential surface water discharge ARARs (Federal Water Quality Criteria at 40 C.F.R. § 131.36 and 131.38 [NTR and CTR]).

The above RAOs are consistent with the provisions of 40 C.F.R. § 300.430 (e)(2)(i), since they specify COCs (listed in Section 2.2), medium of concern (groundwater), potential exposure pathways (vapor inhalation and potential discharge into the Seaplane Lagoon) and RGs. The NCP further specifies that remediation goals shall establish acceptable exposure levels that are protective of human health and the environment and shall be developed by considering several factors including ARARs, cancer risk/non-cancer hazards, factors related to technical limitations such as detection/quantification limits, factors related to uncertainty, and other pertinent information (40 C.F.R. § 300.430 [e][2][i]). Based on this, the RGs for COCs in OU-2B groundwater were established at the levels that comply with potential chemical-specific ARARs, and are protective of human health and the environment as explained below.

2.4.1 Remediation Goals for OU-2B Groundwater

The groundwater RGs for OU-2B are the calculated RBCs for the COCs in groundwater assuming commercial use scenario (Table 3). The RBCs are the concentrations that are protective of human-health corresponding to a cancer risk of 10^{-6} or noncancer hazard quotient of 1. Attachment A of this appendix presents a summary of RBC calculation methodology corresponding to commercial use scenario.

2.4.2 Remediation Goals for Discharge into Seaplane Lagoon

The Federal Water Quality Criteria at 40 C.F.R. §§ 131.36 and 131.38 (NTR and CTR) are potentially relevant and appropriate federal requirements for discharge of OU-2B groundwater into the Seaplane Lagoon. As the groundwater discharges into the Seaplane Lagoon, some attenuation of COC concentrations will occur due to dilution resulting from mixing with water in the Seaplane Lagoon. A dilution factor of 10 was applied to the most stringent of NTR and CTR values to calculate RGs for discharge of groundwater into the Seaplane Lagoon (see Appendix H of the Final OU-2B FS for dilution factor calculations) (see Table 3).

2.5 TARGET REMEDIATION ZONE

A discussion of conceptual horizontal and vertical extents of target remediation zone is presented below. It should be noted that the horizontal and vertical extents of target remediation area will be finalized during the remedial design/remedial action phase. VOCs at the top of the water table are responsible for causing potential vapor intrusion problems rather than VOCs present at deeper intervals (DTSC 2011). Therefore, groundwater sampling during the remedial design/remedial action (RD/RA) phase at saturated-unsaturated interface (top of the water table) where partitioning from the groundwater to soil gas occurs (ITRC 2007, DTSC 2011, Tri-Service 2009) may be performed to establish the target remediation zones.

2.5.1 Vertical Extent

Groundwater modeling was conducted to evaluate the depth of cleanup below water table using active remediation technologies that will provide an appropriate buffer to minimize the potential for vapor intrusion risk. The details of this modeling are presented in Appendix F of the Final OU-2B FS. Based on this modeling, it was recommended that treatment of the hot-spots (greater than 10,000 micrograms per liter [µg/L] of total VOCs) and impacted groundwater down to 30 feet below ground surface would provide an adequate buffer to minimize vapor intrusion risk. As discussed above, the final target remediation depth to address vapor intrusion risks from impacted groundwater will be finalized during the RD/RA phase.

2.5.2 Horizontal Extent

For cost estimating purposes, the horizontal extents of two representative COCs (TCE and VC) in shallow groundwater (approximately 30 feet below ground surface [bgs]) exceeding their respective *residential* RBCs for vapor intrusion pathway are presented on Figure 41 of the Final OU-2B FS. An examination of distribution and magnitude of TCE and VC concentrations shown on Figure 41 of the Final OU-2B FS indicates that there is no significant difference between the TCE and VC extents exceeding residential RBCs and the extents exceeding commercial RBCs for vapor intrusion pathway. As discussed above, the final target remediation area to address vapor intrusion risks from impacted groundwater will be finalized during the RD/RA phase.

3. Remedial Action Alternatives

The remedial action alternatives for OU-2B groundwater were developed by combining different technologies and process options corresponding to different GRAs developed in Section 5.2 of the Final OU-2B FS report. The target remediation zone identified in Section 2.5 of this appendix was also considered while developing the alternatives. This process ensured the development of a range of alternatives from those involving active restoration of the entire plume to those involving limited action but providing protection of human-health by minimizing the potential for unacceptable exposure:

- Alternative GM-1: No Action
- Alternative GM-2: In-Situ Thermal Treatment (ISTT) of Hot-Spots, Control/Treatment at the Seaplane Lagoon using Permeable Reactive Barrier (PRB), Monitored Natural Attenuation (MNA) and Institutional Controls (ICs)
- Alternative GM-3: Hot-Spots Treatment, Shallow Groundwater Treatment, Monitoring and ICs
  - Option GM-3a: ISTT of Hot-Spots and Shallow Groundwater Treatment using In-situ Chemical Oxidation (ISCO)
  - Option GM-3b: Hot-Spots and Shallow Groundwater Treatment using ISTT and In-Situ Bioremediation
- Alternative GM-4: Treatment of Entire Plume using Groundwater Recirculation, PRBs, and ICs

3.1 ALTERNATIVE GM-1: NO ACTION

Alternative GM-1 is the same as Alternative G-1 discussed in Section 5.5.1 of the Final OU-2B FS report.

3.2 ALTERNATIVE GM-2: ISTT OF HOT-SPOTS, CONTROL/TREATMENT AT THE SEAPLANE LAGOON USING PRB, MNA AND ICS

The individual components of Alternative GM-2 are summarized below.

3.2.1 ISTT of Source Areas/Hot-Spots

ISTT of source areas/hot-spots under Alternative GM-2 is the same as discussed for Alternative G-2 in Section 5.5.2.1 of the Final OU-2B FS.

3.2.2 Control/Treatment at the Seaplane Lagoon

Control/treatment at the Seaplane lagoon would be implemented as a contingency measure if groundwater monitoring results indicate that it is required to attain the RGs based on the groundwater discharge into Seaplane Lagoon. The control/treatment at the Seaplane Lagoon under Alternative GM-2 is the same as discussed for Alternative G-2 in Section 5.5.2.2 of the Final OU-2B FS.

3.2.3 MNA and ICs

MNA and ICs under Alternative GM-2 is the same as discussed for Alternative G-2 in Sections 5.5.2.3 and 5.5.2.4 of the Final OU-2B FS with the following exceptions:

- The overall scope of implementation of MNA and ICs under Alternative GM-2 would be less compared to Alternative G-2.

- MNA and ICs similar to Alternative G-2 would be implemented under Alternative GM-2 until concentrations of COCs decrease below their respective commercial RBCs in shallow groundwater.
- Following attainment of commercial RBCs, ICs would be continued to prevent residential use of area overlying OU-2B groundwater exceeding residential RBCs. In addition, groundwater monitoring would be required to assess if residential RBCs are attained in shallow groundwater and ICs can be terminated, and to assess the concentrations of COCs potentially discharged to the Seaplane Lagoon. ICs to prohibit residential use above the plume will be implemented as part of this remedial alternative until residential RBCs are attained.

Based on the groundwater modeling results presented in Appendix F of the Final OU-2B FS, for cost-estimation purposes, it is estimated that it would take 20 years (± 50 percent) to attain commercial RBCs and 25 years (± 50 percent) to attain residential RBCs after the implementation of ISTT at the hot-spots.

3.3 ALTERNATIVE GM-3: HOT-SPOTS TREATMENT, SHALLOW GROUNDWATER TREATMENT, MONITORING AND ICS

The individual components of Alternative GM-2 are summarized below.

3.3.1 Hot-Spots Treatment

Hot-spots treatment under Alternative GM-3 would be the same as discussed for Alternative G-3 in Section 5.5.3.1 of the Final OU-2B FS.

3.3.2 Shallow Groundwater Treatment

Shallow groundwater treatment under Alternative GM-3 would be the same as discussed for Alternative G-3 in Section 5.5.3.1 of the Final OU-2B FS with the exception that the scope of shallow groundwater treatment for Alternative GM-3 is less compared to Alternative G-3 since the commercial RBCs are higher than the residential RBCs.

The horizontal and vertical extents of target remediation area to address potential vapor intrusion risks will be finalized during the RD/RA phase. VOCs at the top of the water table are responsible for causing potential vapor intrusion problems rather than VOCs present at deeper intervals (DTSC 2011). Therefore, groundwater sampling during the RD/RA phase at saturated-unsaturated interface (top of the water table) where partitioning from the groundwater to soil gas occurs (ITRC 2007, DTSC 2011, Tri-Service 2009) may be performed to establish the target remediation zones.

3.3.3 ICs and Monitoring

The implementation of ICs under Alternative GM-3 would the same as discussed for Alternative G-3 in Section 5.5.3.3 of the Final OU-2B FS with the following exceptions:

- The overall scope of implementation of ICs under Alternative GM-3 would be less compared to Alternative G-3.
- ICs would be implemented under Alternative GM-3 until concentrations of COCs decrease below their respective commercial RBCs.
- Following attainment of commercial RBCs, ICs would be continued to prevent residential use of area overlying OU-2B groundwater exceeding residential RBCs.

- ICs to prohibit residential use above the plume will be implemented as part of this remedial alternative until residential RBCs are attained.

Alternative GM-3 would also include groundwater monitoring following active remediation to assess if residential RBCs are attained in shallow groundwater and ICs can be terminated, and to assess the concentrations of COCs potentially discharged to the Seaplane Lagoon.

For cost-estimation purposes, it is estimated that the time required to attain commercial RBCs in shallow groundwater (approximately 30 feet bgs) using Option GM-3a and Option GM-3b, would be 3 years, and 5 years, respectively. Based on the groundwater modeling results presented for Alternative G-3 on Figures 23 through 25 of Appendix F of the Final OU-2B FS, the plumes dissipated between the 10 year and 20 year timeframe for Layers 1 and 2 (top 30 feet of the aquifer), and therefore it is estimated that it would take 15 years (± 50 percent) to attain residential RBCs after the implementation of hot-spot and shallow groundwater treatment for both Option GM-3a and Option GM-3b.

3.4 ALTERNATIVE GM-4: TREATMENT OF ENTIRE PLUME USING GROUNDWATER RECIRCULATION, PRBS, AND ICS

Alternative GM-4 is the same as Alternative G-4 discussed in Section 5.5.4 of the Final OU-2B FS report with the following exceptions:

- The scope of implementation of groundwater recirculation, and PRBs would be less compared to Alternative G-4 since the remediation goals for Alternative GM-4 (vapor intrusion RBCs) are lower compared to remediation goals for Alternative G-4 (Federal/State MCLs).
- The overall scope of implementation of ICs under Alternative GM-4 would be less compared to Alternative G-4.
- ICs would be implemented under Alternative GM-4 until concentrations of COCs decrease below their respective commercial RBCs.
- Following attainment of commercial RBCs, ICs would be continued to prevent residential use of area overlying OU-2B groundwater exceeding residential RBCs.
- ICs to prohibit residential use above the plume will be implemented as part of this remedial alternative until residential RBCs are attained.

Alternative GM-4 would also include groundwater monitoring following active remediation to assess if residential RBCs are attained in shallow groundwater and ICs can be terminated, and to assess the concentrations of COCs potentially discharged to the Seaplane Lagoon.

Based on the groundwater modeling results presented in Appendix F of the Final OU-2B FS, for cost-estimation purposes, it is assumed that it would take 20 years (± 50 percent) to attain commercial RBCs and 25 years (± 50 percent) to attain residential RBCs across the estimated extent of OU-2B impacted groundwater.

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4. Detailed Analysis of Alternatives

The NCP (40 C.F.R. § 300.430 [e][9][i] and [ii]) requires that a detailed analysis of remedial alternatives be conducted during the FS, based on the nine evaluation criteria identified in 40 C.F.R. § 300.430 (e)(9)(iii). The results of the detailed analysis provide the basis for identifying a preferred alternative and preparing the Proposed Plan.

Section 5.6.1 of the Final OU-2B FS provides a brief description of each of the nine evaluation criteria. Table 4 presents a summary of individual and comparative analysis of alternatives with respect to each evaluation criteria. The detailed analysis presented in Table 4 is not significantly different from the analysis presented in the Final OU-2B FS (OTIE 2011). The overall ratings of the updated remedial alternatives are similar to those for the original remedial alternatives presented in the Final OU-2B FS. The revised cost estimates for remedial alternatives are listed in Table 4 and discussed in Section 6.

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5. Applicable or Relevant and Appropriate Requirements

The Federal and State requirements determined to be potential location- and action-specific ARARs for Alternatives G-2, G-3a, G-3b, and G-4 (presented in the main text and Appendix A of the Final OU-2B FS) constitute potential Federal and State location-specific ARARs for Alternatives GM-2, GM-3a, GM-3b, and GM-4 (presented in this appendix) with the following exceptions.

The following requirements will not be potential ARARs for Alternatives GM-2, GM-3a, GM-3b, and GM-4:

- Federal MCLs and maximum contaminant level goals (MCLGs) (40 C.F.R. §§ 141.61[a] and [c], and 141.50)
- State MCLs (California Code of Regulations [Cal. Code Regs.] title [tit.] 22, § 64444)

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6. Cost Estimates

Cost estimates for Alternatives GM-2, GM-3a, GM-3b, and GM-4 were developed using existing cost estimates for Alternatives G-2, G-3a, G-3b, and G-4 documented in Appendix C of the Final OU-2B FS. The assumptions and methodology for cost estimates are summarized in Table 5. The estimated present-worth costs for Alternatives GM-2, GM-3a, GM-3b, and GM-4 are presented in Table 6.

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7. References

Department of Toxic Substances Control (DTSC). 2011. Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air (Vapor Intrusion Guidance). October.

OTIE. 2011. *Final Feasibility Study Report for Operable Unit (OU) 2B Installation Restoration Sites 3, 4, 11, and 21, Alameda Point. Alameda, California*. December.

The Interstate Technology & Regulatory Council (ITRC). 2007. Technical and Regulatory Guidance, Vapor Intrusion Pathway: A Practical Guideline. January.

The Tri-Service Environmental Risk Assessment Workgroup (Tri-Service). 2009. DoD Vapor Intrusion Handbook. January.

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Tables

Table 1: Comparison of VOC Concentrations (Group 1 Wells)[a] with Concentrations Based on National Toxics Rule and California Toxics Rule

Analyte	Number of Samples	Number of Detects	Number of Non-Detects	Frequency of Detection	Maximum Detected Concentration (µg/L)	Calculated EPC Value (µg/L)	Concentration Based on NTR[b] 40 C.F.R § 131.36		Concentration Based on CTR[b] 40 C.F.R § 131.38		Does the EPC Exceed the Lowest Concentration Based on NTR?	Does the EPC Exceed the Lowest Concentration Based on CTR?	Does the Maximum Detected Concentration Exceed the Lowest Concentration Based on NTR?	Does the Maximum Detected Concentration Exceed the Lowest Concentration Based on CTR?
							Potential Aquatic Receptor[c] (µg/L)	Potential Human Receptor[d] (µg/L)	Potential Aquatic Receptor[c] (µg/L)	Potential Human Receptor[d] (µg/L)				
Acetone	29	4	25	13.8%	7.7	4.202	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Tert-Butyl Alcohol	21	11	10	52.4%	160	39.55	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
N-Butylbenzene	21	2	19	9.5%	0.5	0.345	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Sec-Butylbenzene	21	11	10	52.4%	1.4	0.422	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
T-Butylbenzene	21	11	10	52.4%	0.3	0.252	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
T-Butylbenzene	21	11	10	52.4%	0.3	0.252	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
T-Butylbenzene	21	11	10	52.4%	0.3	0.252	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Benzene	29	4	25	13.8%	5.6	0.926	--[e]	710	--[e]	710	No	No	No	No
Toluene	29	4	25	13.8%	0.42	0.335	--[e]	2,000,000	--[e]	2,000,000	No	No	No	No
Carbon disulfide	21	3	18	14.3%	2.7	0.547	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
2-Chlorotoluene	21	1	20	4.8%	4.9	4.9	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Chloroethane	29	1	28	3.4%	0.31	0.31	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
p-Isopropyltoluene	21	2	19	9.5%	0.09	0.101	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
1,2-Dichlorobenzene	21	2	19	9.5%	0.1	0.107	--[e]	170,000	--[e]	170,000	No	No	No	No
1,1-Dichloroethene	29	3	26	10.3%	1.9	0.558	--[e]	32	--[e]	32	No	No	No	No
cis-1,2-Dichloroethene	29	3	26	10.3%	320	102.6	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
trans-1,2-Dichloroethene	29	3	26	10.3%	11	3.139	--[e]	--[e]	--[e]	1,400,000	--[e]	No	--[e]	No
Ethylbenzene	29	6	23	20.7%	3	0.592	--[e]	290,000	--[e]	290,000	No	No	No	No
Isopropylbenzene	21	13	8	61.9%	10	3.111	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
4-Methyl-2-pentanone	29	4	25	13.8%	1.6	0.994	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Methylene chloride	29	1	28	3.4%	0.4	0.4	--[e]	16,000	--[e]	16,000	No	No	No	No
N-Propylbenzene	21	6	15	28.6%	0.9	0.296	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
1,1,2,2-Tetrachloroethane	29	1	28	3.4%	0.5	0.5	--[e]	110	--[e]	110	No	No	No	No
Tetrachloroethene	29	2	27	6.9%	1	1	--[e]	88.5	--[e]	88.5	No	No	No	No
1,1,2-Trichloroethane	29	1	28	3.4%	1.9	1.9	--[e]	420	--[e]	420	No	No	No	No
1,2,4-Trichlorobenzene	29	1	28	3.4%	0.52	0.52	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Trichloroethene	29	12	17	41.4%	1800	754.2	--[e]	810	--[e]	810	No	No	Yes	Yes
Chloroform	29	1	28	3.4%	1.8	1.8	--[e]	4,700	--[e]	4,700	No	No	No	No
1,2,4-Trimethylbenzene	21	3	18	14.3%	0.2	0.227	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
1,2,4-Trimethylbenzene	21	3	18	14.3%	0.2	0.227	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
1,3,5-Trimethylbenzene	21	3	18	14.3%	0.2	0.191	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]
Vinyl chloride	29	3	26	10.3%	53	11.32	--[e]	5,250	--[e]	5,250	No	No	No	No
Xylenes, m & p	20	3	17	15.0%	0.2	0.191	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]

Notes:

[a] Group 1 wells include, OU2B-MW01, OU2B-MW02, S21-TT-MW02A, S21-TT-MW03E, OU2B-MW04, S11-TT-MW04C, S11-TT-MW04D, S11-TT-MW04E, S11-TT-MW05C, S11-TT-MW05D, and S11-TT-MW05E, consistent with ecological risk assessment conducted in the Final OU-2B FS. These wells are located immediately upgradient of the seawall and in closest proximity to receiving waters in the Seaplane lagoon. As such, analyte concentrations in samples from these wells are expected to be most representative of analyte concentrations in groundwater discharging into the lagoon.

[b] Assuming chemical is attenuated/diluted 10 times as it discharges into the lagoon (see Appendix H of the Final OU-2B FS for dilution factor backup).

[c] Lesser of criteria maximum concentration and criteria continuous concentration (40 C.F.R §§ 131.36 and 131.38).

[d] For consumption of organisms only.

[e] Numerical criterion does not exist / Not applicable

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Table 2: Comparison of Metal Concentrations (Group 1 Wells)[a] with Concentrations Based on National Toxics Rule and California Toxics Rule

Analyte	Number of Samples	Number of Detects	Number of Non-Detects	Frequency of Detection	Maximum Detected Concentration (µg/L)	Background Value (µg/L)	Number of Detections Exceeding Background	Calculated EPC Value (µg/L)	Concentration Based on NTR[a] 40 C.F.R § 131.36		Concentration Based on CTR[a] 40 C.F.R § 131.38		Does the EPC Exceed the Lowest Concentration Based on NTR?	Does the EPC Exceed the Lowest Concentration Based on CTR?	Does the EPC Exceed the Background Value?	Does the Maximum Concentration Exceed the Lowest Concentration Based on NTR	Does the Maximum Concentration Exceed the Lowest Concentration Based on CTR
									Potential Aquatic Receptor[b] (µg/L)	Potential Human Receptor[c] (µg/L)	Potential Aquatic Receptor[b] (µg/L)	Potential Human Receptor[c] (µg/L)					
Aluminum, dissolved	28	8	20	28.6%	69	1070	0	35.4	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Antimony, dissolved	33	12	21	36.4%	1.5	37.5	0	0.42	--[e]	43000	--[e]	43000	No	No	No	No	No
Arsenic, dissolved	34	31	3	91.2%	26	20.7	1	8.024	360	1.4	360	1.4	Yes	Yes	No	Yes	Yes
Barium, dissolved	34	34	0	100.0%	400	569.5	0	175	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Beryllium, dissolved	29	13	16	44.8%	1.5	2.5	0	0.516	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Cadmium, dissolved	32	6	26	18.8%	1.3	3.9	0	0.582	93	--[e]	93	--[e]	No	No	No	No	No
Chromium, dissolved	33	11	22	33.3%	3.5	12.5	0	1.548	500	--[e]	500	--[e]	No	No	No	No	No
Cobalt, dissolved	33	19	14	57.6%	1.5	17.2	0	0.346	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Copper, dissolved	26	10	16	38.5%	2	24.2	0	1.079	24	--[e]	31	--[e]	No	No	No	No	No
Lead, dissolved	33	32	1	97.0%	57	6.7	22	27.84	81	--[e]	81	--[e]	No	No	Yes	No	No
Manganese, dissolved	35	35	0	100.0%	7100	1741	11	2886	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	Yes	--[e]	--[e]
Mercury, dissolved	34	3	31	8.8%	0.12	0.2	0	0.117	0.25	1.5	--[e]	0.51	No	No	No	No	No
Molybdenum, dissolved	33	5	28	15.2%	3.1	12.7	0	1.514	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Nickel, dissolved	32	17	15	53.1%	2.4	21	0	0.837	82	46,000	82	46,000	No	No	No	No	No
Selenium, dissolved	33	17	16	51.5%	11	8.4	2	4.49	710	--[e]	710	--[e]	No	No	No	No	No
Silver, dissolved	31	9	22	29.0%	4.3	4.9	0	2.164	19	--[e]	19	--[e]	No	No	No	No	No
Thallium, dissolved	30	5	25	16.7%	3	13.8	0	1.681	--[e]	63	--[e]	63	No	No	No	No	No
Vanadium, dissolved	32	20	12	62.5%	2.8	26.3	0	1.585	--[e]	--[e]	--[e]	--[e]	--[e]	--[e]	No	--[e]	--[e]
Zinc, dissolved	34	14	20	41.2%	25	36.4	0	9.648	810	--[e]	810	--[e]	No	No	No	No	No

Notes:

[a] Group 1 wells include, OU2B-MW01, OU2B-MW02, S21-TT-MW02A, S21-TT-MW03E, OU2B-MW04, S11-TT-MW04C, S11-TT-MW04D, S11-TT-MW04E, S11-TT-MW05C, S11-TT-MW05D, and S11-TT-MW05E, consistent with ecological risk assessment conducted in the Final OU-2B FS. These wells are located immediately upgradient of the seawall and in closest proximity to receiving waters in the Seaplane lagoon. As such, analyte concentrations in samples from these wells are expected to be most representative of analyte concentrations in groundwater discharging into the lagoon.

[b] Assuming chemical is attenuated/diluted 10 times as it discharges into the lagoon (see Appendix H of the Final OU-2B FS for dilution factor calculations).

[c] Lesser of criteria maximum concentration and criteria continuous concentration (40 C.F.R §§ 131.36 and 131.38**)**.

[d] For consumption of organisms only.

[e] Numerical criterion does not exist / Not applicable.

[f] The listed concentrations based on NTR and CTR values are for hexavalent chromium.

"--" = Not applicable

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Table 3: Remediation Goals – OU-2B Groundwater

Analyte	**RBCs – Commercial Use**	**Potential Chemical-Specific ARARs**				**Selected Remediation Goal for OU-2B Groundwater[e] (µg/L)**	**Selected Remediation Goal for Groundwater Discharge into Seaplane Lagoon (µg/L)**
	Inhalation - Indoor Air (µg/L)	**Based on NTR[a] 40 C.F.R § 131.36**		**Based on CTR[a] 40 C.F.R. § 131.38**			
		Potential Aquatic Receptor[b] (µg/L)	**Potential Human Receptor[c] (µg/L)**	**Potential Aquatic Receptor[b] (µg/L)**	**Potential Human Receptor[c] (µg/L)**		
TCE	116 (91.2)	--[d]	810	--[d]	810	**116** (91.2)	**810**
VC	31.4 (10.7)	--[d]	5,250	--[d]	5,250	**31.4** (10.7)	**--**

Notes:

The RBCs for TCE and VC highlighted in yellow were revised based on the new November 2011 RSLs and the 2011 EPA Exposure Factors Handbook. The value in parenthesis is the previously estimated RBC presented in the Final OU-2B FS (OTIE 2011).

-- Not applicable

[a] Assuming chemical is attenuated/diluted 10 times as it discharges into the lagoon (see Appendix H of the Final OU-2B FS for dilution factor calculations).

[b] Lesser of criteria maximum concentration and criteria continuous concentration (40 C.F.R §§ 131.36 and 131.38**)**.

[c] For consumption of organisms only.

[d] Numerical criterion does not exist.

[e] Based on the RBC for commercial use (see Attachment A for RBC calculation methodology).

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Table 4: Individual and Comparative Analysis of Groundwater Remedial Alternatives

Criterion	Alternative GM-1 – No Action	Alternative GM-2 – ISTT of Hot Spots, Control/Treatment at the Seaplane Lagoon Using PRB, MNA, and ICs	Alternative GM-3a – ISTT of Hot Spots, Shallow Groundwater Treatment using ISCO, Monitoring, and ICs	Alternative GM-3b – Hot Spots and Shallow Groundwater Treatment using ISTT and In-situ Bioremediation, Monitoring, and ICs	Alternative GM-4: Treatment of the Entire Plume using Groundwater Recirculation and PRBs Plus ICs
Overall Protection of Human-Health and the Environment	Not Satisfied No remedial activities would be performed to contain, treat, or reduce exposure to COCs in groundwater. In addition, there would be no way to assess fate of COCs in groundwater. This alternative does not reduce risks to potential receptors due to exposure to impacted groundwater since no restrictions are imposed on the area overlying OU-2B impacted groundwater.	Satisfied Treatment of the hot-spots/source areas using ISTT would reduce and minimize further migration of high concentrations of COCs downgradient. PRB upgradient of the Seaplane lagoon would control discharge of COCs into the Seaplane lagoon. Natural attenuation mechanisms would reduce concentrations of COCs in groundwater downgradient of source areas over time to concentrations less than the calculated RBCs protective of potential commercial receptors. In addition, ICs including land and groundwater use restrictions (e.g. requirement to install and operate an engineered vapor intrusion mitigation technology/system for buildings) would minimize the potential for exposure to COCs above their respective RGs.	Satisfied Treatment of the hot-spots/source areas using ISTT would reduce and minimize further migration of high concentrations of COCs downgradient. In addition, the treatment of shallow groundwater using ISCO would reduce concentrations of COCs to levels less than their respective RGs (commercial RBCs for vapor intrusion) and control their discharge into the Seaplane lagoon. ICs including land and groundwater use restrictions would minimize the potential for exposure to COCs above their respective RGs.	Satisfied Treatment of the hot-spots/source areas using ISTT would reduce and minimize further migration of high concentrations of COCs downgradient. In addition, the treatment of shallow groundwater using in-situ bioremediation would reduce concentrations of COCs to levels less than their respective RGs (commercial RBCs for vapor intrusion) and control their discharge into the Seaplane lagoon. ICs including land and groundwater use restrictions would minimize the potential for exposure to COCs above their respective RGs.	Satisfied Extraction of impacted groundwater and its treatment above-ground along with installation of PRBs would reduce COC concentrations in groundwater and reduce further discharge of COCs into Seaplane Lagoon. Alternative G-4 would include implementation of ICs until the concentrations of COCs in OU-2B groundwater are reduced to less than or equal to RGs. These ICs would minimize the potential for exposure of on-site receptors to COCs that could pose unacceptable risk.
Compliance with ARARs	The No Action Alternative does not trigger ARARs. Therefore, this criterion is not applicable.	Satisfied Complies with all identified ARARs.	Satisfied Complies with all identified ARARs.	Satisfied Complies with all identified ARARs.	Satisfied Complies with all identified ARARs.
Long-Term Effectiveness	Not Applicable This criterion is not applicable since the threshold criteria (Overall Protection of Human-Health and the Environment, and Compliance with ARARs) are not met.	Fair ISTT at the source areas would provide long-term effectiveness in reducing relatively high concentrations of COCs. In addition, a PRB upgradient of the Seaplane lagoon would provide long-term effectiveness in controlling the discharge of COCs into the lagoon. This alternative is considered more effective and reliable for treatment of impacted groundwater compared to Alternative G-1 because of the active remediation at the source areas and upgradient of the Seaplane lagoon.	Good ISTT at the source areas would provide long-term effectiveness in reducing relatively high concentrations of COCs. In addition, shallow groundwater treatment using ISCO would provide reasonable buffer against unacceptable vapor intrusion risk, and would lead to control of the discharge of COCs into the Seaplane lagoon. This alternative is considered more effective and reliable for treatment of impacted groundwater compared to Alternatives G-1 and G-2 because of the larger scale of proposed active remediation.	Good ISTT and in-situ bioremediation at the source areas would provide long-term effectiveness in reducing relatively high concentrations of COCs. In addition, shallow groundwater treatment using in-situ bioremediation would provide reasonable buffer against unacceptable vapor intrusion risk, and would lead to control of the discharge of COCs into the Seaplane lagoon. This alternative is considered more effective and reliable for treatment of impacted groundwater compared to Alternatives G-1 and G-2 because of the larger scale of proposed active remediation.	Good The implementation of multiple groundwater recirculation loops and PRBs would be effective to reduce COC concentrations in groundwater and prevent further uncontrolled discharge of COCs into Seaplane Lagoon. This alternative is considered more effective and reliable for treatment of impacted groundwater compared to Alternatives G-1 and G-2 because of the larger scale of proposed active remediation.
Reduction in Toxicity, Mobility, and Volume through Treatment	Not Applicable This criterion is not applicable since the threshold criteria (Overall Protection of Human-Health and the Environment, and Compliance with ARARs) are not met.	Fair to Good Approximately 60 percent of the total VOC mass present in hot-spots would be treated using ISTT. The toxicity, mobility, and volume of the remaining VOCs would be reduced by PRB at the Seaplane Lagoon and natural attenuation mechanisms such as dilution dispersion, and biodegradation. The PRB at the Seaplane Lagoon under Alternative G-2a would be designed to treat the entire estimated vertical extent of COCs (downgradient of the hot-spots) passing through it as compared to just shallow groundwater treatment for Alternatives G-3a through G-3d. The treatment media for PRB would include ZVI which would lead to complete destruction of COCs into potentially non-toxic products such as ethene, ethane, and chloride.	Fair ISTT would remove relatively high concentrations of COCs at the source areas and transfer majority of the COCs to activated carbon. ISCO would completely destroy COCs to potentially non-toxic products such as carbon dioxide and water, thereby reducing toxicity, mobility, and volume of VOCs in shallow groundwater. Approximately 90 percent of the total VOC mass present in OU-2B groundwater is estimated to be treated by ISTT and ISCO.	Fair ISTT would remove relatively high concentrations of COCs at the source areas and transfer majority of the COCs to activated carbon. In-situ bioremediation would completely destroy COCs to potentially non-toxic products such as ethane, ethane, carbon dioxide and water, thereby reducing toxicity, mobility, and volume of VOCs in shallow groundwater. Approximately 90 percent of total VOC mass present in OU-2B groundwater is expected to be treated by ISTT and in-situ bioremediation.	Good Treatment of extracted groundwater above-ground and in-situ treatment using PRBs would reduce toxicity, mobility, and volume of COCs in groundwater. If ex-situ treatment is conducted using technologies such as advanced oxidation, COCs would be completely destroyed to potentially non-toxic products such as carbon dioxide and water. The PRB containing ZVI and/or organic medium would completely destroy COCs into innocuous products such as ethene, ethane, and chloride, resulting in reduction of toxicity, mobility, and volume of COCs in groundwater.

Table 4: Individual and Comparative Analysis of Groundwater Remedial Alternatives (continued)

Criterion	**Alternative GM-1 – No Action**	**Alternative GM-2 – ISTT of Hot Spots, Control/Treatment at the Seaplane Lagoon Using PRB, MNA, and ICs**	**Alternative GM-3a – ISTT of Hot Spots, Shallow Groundwater Treatment using ISCO, Monitoring, and ICs**	**Alternative GM-3b – Hot Spots and Shallow Groundwater Treatment using ISTT and In-situ Bioremediation, Monitoring, and ICs**	**Alternative GM-4: Treatment of the Entire Plume using Groundwater Recirculation and PRBs Plus ICs**
Short-Term Effectiveness	Not Applicable This criterion is not applicable since the threshold criteria (Overall Protection of Human-Health and the Environment, and Compliance with ARARs) are not met.	Poor Drilling and trenching activities would present short-term risks of exposure of work crews to COC-impacted groundwater and the inherent physical risk of using mechanized well drilling/trenching equipment. Above-ground treatment of contaminated vapors extracted from the subsurface as part of ISTT would present short-term risk of exposure of work crews to COCs during the O&M phase. ISTT also presents short-term risk of exposure of work crews to hot surfaces or to energized electrical sources. The risks to on-site workers during the O&M phase of PRB are expected to be minimal since treatment of COCs would occur in-situ. This alternative would have a high degree of environmental impact as evaluated through the sustainable environmental remediation (SER) analysis (see Appendix D of the Final OU-2B FS[a]). The pollutant and GHG emissions, and energy use are estimated to be the highest for operation of ISTT system when compared to other activities. The injury and fatality risks are estimated to be the highest for transportation of field personnel during construction and O&M phases.	Poor to Fair Drilling and well/electrode installation activities would present short-term risks of exposure of work crews to COC-impacted groundwater and the inherent physical risk of using mechanized equipment. ISTT would require above-ground treatment of contaminated vapors extracted from the subsurface, which would present short-term risk of exposure of work crews to COCs during the O&M phase. ISTT also presents short-term risk of exposure of work crews to hot surfaces or to energized electrical sources. The risks to on-site workers during the O&M phase of ISCO are expected to be minimal since treatment of COCs would occur in-situ. This alternative would have a high degree of environmental impact as evaluated through the SER analysis (see Appendix D of the Final OU-2B FS[a]). The pollutant and GHG emissions, and energy use are estimated to be the highest for operation of ISTT system when compared to other activities. The injury and fatality risks are estimated to be the highest for transportation of field personnel during construction and O&M phases.	Poor to Fair Drilling and well/electrode installation activities would present short-term risks of exposure of work crews to COC-impacted groundwater and the inherent physical risk of using mechanized equipment. ISTT would require above-ground treatment of contaminated vapors extracted from the subsurface, which would present short-term risk of exposure of work crews to COCs during the O&M phase. ISTT also presents short-term risk of exposure of work crews to hot surfaces or to energized electrical sources. The risks to on-site workers during the O&M phase of in-situ bioremediation are expected to be minimal since treatment of COCs would occur in-situ. This alternative would have a high degree of environmental impact as evaluated through the SER analysis (see Appendix D of the Final OU-2B FS[a]). The pollutant and GHG emissions, and energy use are estimated to be the highest for operation of ISTT system when compared to other activities. The injury and fatality risks are estimated to be the highest for transportation of field personnel during construction and O&M phases.	Fair Installation of PRB, groundwater treatment system and extraction/injection wells would likely pose increased risks to site workers due to exposure of work crews to COCs-impacted groundwater and the inherent physical risk of using drilling and construction equipment. There is a risk for exposure of site workers to impacted groundwater when it is extracted and treated aboveground. Alternative G-4 would have a high degree of environmental impact as evaluated through the SER analysis (see Appendix D of the Final OU-2B FS[a]). The pollutant and GHG emissions, and energy use are estimated to be the highest for operation of ex-situ treatment system (assumed to advanced oxidation process using hydrogen peroxide and ozone) when compared to other activities. The injury and fatality risks are estimated to be the highest for transportation of field personnel during construction and O&M phases.
Implementability	Not Applicable This criterion is not applicable since the threshold criteria (Overall Protection of Human-Health and the Environment, and Compliance with ARARs) are not met.	Fair Both ISTT and PRB are well-developed technologies with equipment and vendors readily available. ISTT has been successfully implemented at OU-2B in the past. The design, construction, and operation of a PRB will require pilot studies and experienced personnel.	Fair to Good Both ISTT and ISCO are well-developed technologies with equipment and vendors readily available. ISCO and ISTT pilot studies have been conducted at OU-2B and would provide valuable data to optimize the design of the full-scale remediation.	Fair Both ISTT and ISB are well-developed technologies with equipment and vendors readily available. ISTT has been successfully implemented at OU-2B in the past. However, pilot tests and experienced personnel will be required for full-scale design and implementation of bioremediation.	Poor Full-scale implementation of groundwater recirculation will require pilot testing and detailed groundwater modeling. The design, construction, and operation of PRB would also require pilot studies and experienced personnel.
State Acceptance	The State has not commented on this alterative.	The State has not commented on this alterative.	State review of this alternative is pending.	The State has not commented on this alterative.	The State has not commented on this alterative.
Community Acceptance	Community acceptance of this alternative will be assessed following the public review process.	Community acceptance of this alternative will be assessed following the public review process.	Community acceptance of this alternative will be assessed following the public review process.	Community acceptance of this alternative will be assessed following the public review process.	Community acceptance of this alternative will be assessed following the public review process.
Cost[b]	No Costs	Fair $14,419,000 [c]	Fair $14,786,000 [d]	Good $12,421,000[e]	Poor $16,752,000[f]

Notes:

[a] SER analysis was performed for Alternatives G-2, G-3a, G-3b, and G-4 and is documented in Appendix D of the Final OU-2B FS. Because of the use of the same remediation technologies, the environmental footprints of Alternatives GM-2, GM-3a, GM-3b, and GM-4 will be proportional to Alternatives G-2, G-3a, G-3b, and G-4, respectively.

[b] Alternative that costs the least was rated as good.

[c] The present worth analysis was performed assuming construction and O&M period of 27 years and a discount rate of 2.7 percent.

[d] The present worth analysis was performed assuming construction and O&M period of 18 years and a discount rate of 2.7 percent.

[e] The present worth analysis was performed assuming construction and O&M period of 20 years and a discount rate of 2.7 percent.

[f] The present worth analysis was performed assuming construction and O&M period of 26 years and a discount rate of 2.7 percent.

ARARs = applicable or relevant and appropriate requirements   ZVI =zero valent iron
COC = Contaminants of Concern
ICs = Institutional Controls
ISCO = In Situ Chemical Oxidation
MNA = monitored natural attenuation
O&M = operation and maintenance
PRB = permeable reactive barrier
SER = sustainable environmental remediation
TCE = trichloroethene
VC = vinyl chloride

Table 5: Summary of Assumptions for Cost Estimates

Remedial Alternatives	Summary of Assumptions
Alternative GM-2 Hot-Spots Treatment using ISTT, Control/Treatment at the Seaplane Lagoon using PRB, MNA and ICs	• Present-Worth costs were developed using the estimated costs for Alternative G-2 presented in Appendix C of the Final OU-2B FS. • The following Alternative G-2 costs were left unchanged: o Remedial design costs o Capital costs for implementation of ISTT, PRB, MNA and ICs o O&M costs for ISTT • The remaining O&M and periodic costs were parametrically estimated based on the differences in estimated O&M durations of Alternatives G-2 and GM-2 per the formula[a] presented in the notes below.
Alternative GM-3a Hot-Spots Treatment using ISTT and Shallow Groundwater Treatment using ISCO, MNA, and ICs	• Present-Worth costs were developed using the estimated costs for Alternative G-3a presented in Appendix C of the Final OU-2B FS. • The following Alternative G-3a costs were left unchanged: o Remedial design costs o Capital costs for implementation of ISTT, MNA and ICs o O&M costs for ISTT • Capital costs for ISCO were revised to include costs for two injection events. The O&M costs for ISCO were revised to include costs for two years of monitoring. • The remaining O&M and periodic costs were parametrically estimated based on the differences in O&M durations of Alternatives G-3a and GM-3a per the formula[a] presented in the notes below.
Alternative GM-3b Hot-Spots and Shallow Groundwater Treatment using ISTT and In-Situ Bioremediation, MNA, and ICs	• Present-Worth costs were developed using the estimated costs for Alternative G-3b presented in Appendix C of the Final OU-2B FS. • The following Alternative G-3b costs were left unchanged: o Remedial design costs o Capital costs for implementation of ISTT, in-situ bioremediation, MNA and ICs o O&M costs for ISTT • The O&M costs for in-situ bioremediation were revised for include costs for four years of monitoring. • The remaining O&M and periodic costs were parametrically estimated based on the differences in O&M durations of Alternatives G-3b and GM-3b per the formula[a] presented in the notes below.

Table 5: Summary of Assumptions for Cost Estimates (continued)

Remedial Alternatives	Summary of Assumptions
Alternative GM-4 Treatment of Entire Plume using Groundwater Recirculation, PRBs, and ICs	• Present-Worth costs were developed using the estimated costs for Alternative G-4 presented in Appendix C of the Final OU-2B FS. • The following Alternative G-4 costs were left unchanged: o Remedial design costs o Capital costs for implementation of groundwater extraction and treatment, groundwater monitoring, PRBs, and ICs • The remaining O&M and periodic costs were parametrically estimated based on the differences in O&M durations of Alternatives G-4 and GM-4 per the formula[a] presented in the notes below.

Notes:

[a] Formula used for parametric estimation of costs:

$$\frac{Total\ \ O\,\&\,M\ \ and\ \ Periodic\ Costs\ \ for\ \ Alternative\ G-X}{Estimated\ \ O\,\&\,M\ \ Duration\ \ for\ \ Alternative\ G-X} \times\ Estimated\ \ O\,\&\,M\ \ Duration\ of\ \ Alternative\ GM-X$$

Table 6: Summary of Present-Worth Costs

Remedial Alternatives	**Remedial Construction and O&M Duration (years)[a]**	**Period of Analysis (years)[f]**	**Present-Worth ($)[g]**
Impacted Groundwater			
Alternative GM-2 Hot-Spots Treatment using ISTT, Control/Treatment at the Seaplane Lagoon using PRB, MNA and ICs	27[b]	30	$14,419,000
Alternative GM-3a Hot-Spots Treatment using ISTT and Shallow Groundwater Treatment using ISC), MNA, and ICs	18[c]	22	$14,786,000
Alternative GM-3b Hot-Spots and Shallow Groundwater Treatment using ISTT and In-Situ Bioremediation, MNA, and ICs	20[d]	23	$12,421,000
Alternative GM-4 Treatment of Entire Plume using Groundwater Recirculation, PRBs, and ICs	26[e]	29	$16,752,000

Notes:

[a] Based on the assumed duration of remediation using active remediation technologies, and the assumed durations presented in Section 3 of Appendix A.

[b] Based on the assumed construction duration of 1 year, 1 year of active hot-spot remediation, and 25 years of implementation of ICs/MNA/groundwater monitoring.

[c] Based on the assumed construction/implementation duration of 3 years for ISTT/ISCO, and 15 years of implementation of ICs/groundwater monitoring.

[d] Based on the assumed construction duration/implementation duration of 5 years for ISTT/In-Situ Bioremediation, and 15 years of implementation of ICs/groundwater monitoring.

[e] Based on the assumed construction duration of 1 year for groundwater recirculation and 25 years of implementation of the remedy.

[f] Assuming it takes 3 years for planning and design (from base year 2010 up to 2013).

[g] The costs are rounded off to nearest thousands.

Attachment A
Methodology for Calculation of Risk-Based Groundwater Concentrations – Commercial Use

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1. INTRODUCTION

This appendix presents a brief methodology for calculation of risk-based concentrations (RBCs) for vapor intrusion pathway for potential commercial receptors for the groundwater constituents of concern (COCs) selected in Appendix A. The RBCs are the concentrations that are protective of human health or correspond to a cancer risk of 10^{-6} or noncancer hazard quotient of 1.

1.1 RBCS – INDOOR AIR INHALATION

Per Section 2.2 of Appendix A, RBCs based on vapor intrusion pathway were calculated for the following COCs:

- trichloroethene (TCE)
- vinyl chloride (VC)

The following sections present a brief summary of the methodology and parameters used to calculate RBCs for COCs in groundwater that are protective of potential indoor air exposure.

1.1.1 Overall Methodology

Consistent with the United States Environmental Protection Agency (U.S. EPA) guidance (U.S. EPA 2004), the Johnson and Ettinger (J&E) Model was used to estimate RBCs for VOCs in groundwater that are protective of potential commercial receptors at OU-2B. The toxicity values for the COCs used in the J&E Model were consistent with toxicity values used by the U.S. EPA Region 9 in development of November 2011 Regional Screening Levels (RSLs) (U.S. EPA 2011a).

1.1.2 Model Parameters

A summary of site-specific parameters used in the J&E Model along with the basis for each is presented in Table 1. Because of the close proximity of OU-2A and OU-2B and the anticipated similarity of conditions, a single-set of input parameters (primarily based on that data collected at OU-2B) was developed for use at OU-2A and OU-2B for calculation of vapor intrusion RBCs.

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Table 1: Summary of J&E Vapor Intrusion Model Input Parameters

Parameter[a]	Input Value - Commercial	Basis
		Soil Parameters
Average soil/groundwater temperature (degrees C)	18.5	Based on the data collected at OU-2B during Data Gap Investigation conducted in 2008 (Tetra Tech 2008).
Depth below grade to bottom of enclosed space floor (cm)	15	Default value for slab-on-grade construction presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).
Depth below grade to water table (cm and feet)	182.88 cm (6 feet)	Based on the data collected at OU-2B during Data Gap Investigation conducted in 2008 (Tetra Tech 2008) and Fall 2007 Basewide Semiannual Monitoring Report (ITSI 2008).
Soil stratum	A	One soil stratum was assumed between the soil surface and the top of contamination or groundwater table.
Thickness of soil stratum A (cm)	182.88	Thickness of stratum A was set to be equal to the depth below grade to groundwater table.
SCS soil type directly above water table/ Soil stratum A SCS soil type	Loamy sand (LS)	Based on the sieve analysis data reported in the OU-2B Remedial Investigation (RI) Report (SulTech 2005) and Table 11 of the U.S. EPA Guidance (U.S. EPA 2004). The U.S. EPA Guidance (U.S. EPA 2004) recommends that texture classification for soil with approximately 12 percent to 25 percent fines (smaller than 0.075 mm in size) should be "Loamy Sand." Based on the sieve analysis data reported in the OU-2B RI Report, the average percentage of fines in fifteen soil samples collected from 1 to 5.5 feet bgs is approximately 15 percent.
Stratum A soil dry bulk density (g/cm^3)	1.66	Average value of dry density based on the geotechnical data reported in the OU-2B RI Report (SulTech 2005). The dry density value used is the average value from eleven samples collected from 0.5 to 5.5 feet below ground surface (bgs).
Stratum A soil total porosity	0.380	Calculated using the following formula per the U.S. EPA Guidance (U.S. EPA 2004): 1 - (Soil dry bulk density – Soil particle density). Soil particle density was estimated to be 2.68 grams per cubic centimeter based on the specific gravity data reported in the OU-2B RI Report (SulTech 2005) for a sample collected from 4.5 feet bgs.
Stratum A soil water-filled porosity	0.13	Calculated using the moisture content, dry density and total porosity values reported in the OU-2B RI Report (SulTech 2005). The values for dry density and total porosity are presented above. The moisture content value used is the average value from eleven samples collected from 0.5 to 5.5 feet below ground surface (bgs).
		Building Parameters
Enclosed space floor thickness (cm)	15	Equal to the value of the parameters depth below grade to bottom of enclosed space floor, specified above.
Soil-bldg. pressure differential ($g/cm\text{-}sec^2$)	40	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).
Enclosed space floor length (cm)	3,696	Based on the average commercial structure of 5,000 m^3 (U.S. EPA 2011b).
Enclosed space floor width (cm)	3,696	Based on the average commercial structure of 5,000 m^3 (U.S. EPA 2011b).
Enclosed space height (cm)	366	Based on the height for a commercial structure (U.S. EPA 2011b).
Floor-wall seam crack width (cm)	0.1	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).
Indoor air exchange rate (1/hour)	1	Based on the recommended air exchange rates in DTSC guidance document (DTSC 2005).
Average vapor flow rate into building (liters per minute)	5	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).
		Exposure Parameters
Averaging time for carcinogens (years)	70	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).
Averaging time for noncarcinogens (years)	25	Per the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004), averaging time for noncarcinogens was set equal to the exposure duration.
Exposure duration (years)	25	Default value for commercial exposure presented in the U.S. EPA guidance documents (U.S. EPA 1991 and U.S. EPA 2004).
Exposure frequency (days)	250	Default value for commercial exposure presented in the U.S. EPA guidance documents (U.S. EPA 1991 and U.S. EPA 2004).
Target risk for carcinogens	1.0E-06	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004). Lower end of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP)-defined cancer risk range.
Target hazard quotient for non-carcinogens	1	Default value presented in the User's Guide for Subsurface Vapor Intrusion into Buildings (U.S. EPA 2004).

Note:
[a] Values calculated by the model are not listed.

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2. REFERENCES

California Environmental Protection Agency Department of Toxic Substances Control (DTSC). 2005. *Vapor Intrusion Guidance Document – Final Interim.* DTSC/California EPA. 15 December 2004, Revised 7 February 2005

Innovative Technical Solutions, Inc. (ITSI). 2008. *Fall 2007 Alameda Basewide Semi-Annual Groundwater Monitoring Report.* April.

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Appendix B
Responses to Comments on the Draft Feasibility Study Addendum

Document Title: *Draft Feasibility Study Addendum, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point, Alameda, California. February 2012.*

Reviewer: Pankaj Arora, LEED AP, Superfund Division, Environmental Protection Agency. Comments Dated March 20, 2012.

Comment No.	Comment	Response
1.	The following comments are related to Table 2 of the Addendum a. The new RSL for heptachlor is 0.0018 ug/l and the EPC concentration noted in the table is 0.032 ug/l. It is not clear why heptachlor is not included as a primary or secondary COC. Also, please clarify if heptachlor will be monitored or not. If not a part of the monitoring plan then please explain why. b. The risk for 1,4-Dioxane has increased to $1.2x10^{-04}$, it is not clear why 1,4-dioxane should not be included as a primary or secondary COC. Please clarify if 1,4-Dioxane will be monitored or not. If not a part of the monitoring plan then please explain why. c. For Bis(2-ethylhexyl) Pthalate- the explanation is not clear about why to exclude it from the primary or secondary COC list. In addition, it will be helpful to receive a figure that shows locations of exceedences for Bis (2-ethylhexyl) Pthalate as compared to the new RSL.	a. The rationale for excluding heptachlor from the list of COCs was presented in the Final Operable Unit 2B (OU-2B) Feasibility Study (FS) (Section 5.1.2.1) and repeated in the remarks column of Table 2 of the FS Addendum. The reasons for exclusion include, detection of heptachlor at one location, risk based on the use of maximum detected concentration as exposure point concentration, and uncertainty in quantitation, and detection at low concentration. Since heptachlor is not identified as a COC it will not be monitored. b. 1,4-Dioxane will be added to the list of secondary constituents of concern (COCs) along with metals for the case in which groundwater is considered a potential drinking water source. The secondary COCs will be monitored if the groundwater remedial action for OU-2B is selected based on OU-2B groundwater being considered a potential drinking water source. Since a significant component of 1,4-dioxane risk is attributed to groundwater ingestion; 1,4-dioxane will not be added as a COC (and therefore will not be monitored) for groundwater remedial action for the scenario where OU-2B groundwater is not considered a potential drinking water source c. The rationale for excluding bis(2-ethylhexyl) pthalate from the list of COCs was presented in the Final OU-2B FS (Section 5.1.2.1) and repeated in the remarks column of Table 2 of the FS Addendum. The locations S11-B15 and S11-B19 with detections of bis(2-ethylhexyl)phthalate less than its MCL of 4 μg/L are presented on Figure 28A of the Final OU-2B FS. It is noted that a groundwater beneficial use exception is applicable to OU2B. As a result, the revised COCs and RAOs outlined in FS Addendum Appendix A are applicable for remedy selection and the cleanup at OU2B.
2.	Please let EPA know about when and how the Navy plans to submit revised risk calculations for commercial-mixed use scenario for review. It is our understanding that the Navy is recalculating the risks for commercial-mixed scenario.	No further risk calculations will be submitted. FS and Addendum present evaluations for two scenarios; residential and commercial. Risks for commercial mixed use scenario are represented by the residential use scenario risk calculations in the Final FS Table 16. The Navy was considering a scenario for residential units above commercial space at the request of the City of Alameda. No studies or comparable evaluations were found as precedent to inform the proposed evaluation. Uncertainty in the scenario assumptions and modeling parameters, including specifics of future construction, lead to either using

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		the residential or the commercial risk evaluations.
3.	Appendix A, page 5 indicates that that the targeted remediation zones will be established during RD/RA stage. It is not clear why the targeted remediation zones were not established during the RI/FS stage. Typically, these types of details are established during the RI/FS stage. In general, the additional data needed to fine tune the actual implementation of the remedy is conducted under the RD/RA stage.	Sections 2.5.1 and 2.5.2 of the FS Addendum state that horizontal and vertical target remediation extents will be ***finalized*** during the RD/RA stage. The additional data needed to optimize the actual implementation of the remedy will be conducted under the RD/RA. The FS Addendum uses the conceptual target remediation extents to develop and evaluate groundwater remedial alternatives and estimate costs.
4.	There are numerous references in the addendum to the modeling conducted in the final OU2B FS. The addendum refers to modeling details are located in the Appendix F of the final OU2B FS. There appear to be many concerns with the modeling effort: **a. Flow Model** i. The hydraulic conductivity used for the third layer varies between 0.25 - 80 ft/day. The 80 ft/day hydraulic conductivity seems very high. The higher value was used so that the ARM/head range percentage will be around 10% or less.	(a)(i) The hydraulic conductivity value of 80 ft/D is only applied at a few locations outside of the plume in Layer 3. Within the plume area of OU-2B, the hydraulic conductivity values are as follows: Layer 1 8.0, 1.0, and 10 ft/D Layer 2 2.0 ft/D Layer 3 24.96 and 44.52 ft/D The majority of the plume is in Layers 1 and 2 and for a majority of the plume the hydraulic conductivity values range from 2 ft/day to 24.96 ft/day.
	ii. Even after using a 0.25 to 80 ft/day hydraulic conductivity, the ARM/head range for OU2B area are 17.43% and 26.53% for layer 2 and 3, respectively. Much higher than the 10% upper bound mentioned in the final FS.	(a)(ii) The ARM/Head Range corresponding to all model layers within OU-2B is 9.11 percent. Layers 2 and 3 have narrower head range; and the ARM values for each of the three model layers are less than 0.7. Therefore, as stated in Section F2.2 of Appendix F of the final OU-2B FS, the hydraulic calibration is considered acceptable.
	iii. Please provide rationale for: (a) for using 80 ft/day hydraulic conductivity and (b) why the ARM/head range of more than 10% is acceptable?	(a)(iii) See (a)(i) and (a)(ii) above.
	iv. Please clarify if the flow model was validated or not. EPA could not locate any information that suggests the model was validated. If the model was not validated, then please explain the reasons for not validating it. b. Transport model – Review of the Appendix F indicates that the transport model was neither calibrated nor validated. Please confirm if the transport model cited in Appendix F of the final FS was calibrated and validated. c. Furthermore, the addendum indicates that the rational for	(a)(iv) Model was hydraulically calibrated. Validation of the model entails comparing model predictions to future stresses and resultant values and this is typically not performed at the FS stage. The modeling included the use of site-specific parameters to the maximum extent possible; therefore, it is considered representative of site-specific conditions at OU-2B. In addition, sensitivity analysis was performed by varying the biodegradation rate by a half order of magnitude lower and a half order of magnitude higher than the site specific rate to account for the effect of uncertainties. The results indicated that the cleanup time for the highest degradation rate was approximately 50 percent less than the site specific

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	cleaning up to 30 feet bgs is to provide enough buffer zone. The document states that buffer zone was quantified from the modeling effort documented in the Appendix F of the Final FS. The modeling related comments listed above are for the Appendix F of the Final FS. In Summary: i. It is very doubtful that EPA can draw any quantitative conclusions from the modeling effort presented in Appendix F. ii. ii. The final FS cautions the reader to abstain from using modeling results for quantitative purposes. d. In addition, the hydraulic conductivity of up to 80 ft/day for Layer 3 in the model is potentially forcing the groundwater to flow thru the site at enormous and unrealistic rates. This high hydraulic conductivity might not give enough residence time for VOCs to diffuse back into layers above. e. It is not clear if a sensitivity analysis was conducted for adsorption parameter(s). EPA believes that it is important to understand this sensitivity. The adsorption impacts the amount of available VOCs present in the liquid phase that could go into vapor phase. If more VOCs are adsorbed then relatively less amount of VOCs is available to go from liquid to vapor phase, hence, the vapor risks might be artificially reduced. f. Also, please let EPA know if the conceptual site model used for the groundwater use exception request is compatible with the 30 feet bgs cleanup proposal. In other words, please confirm if the stratigraphy or lithologic cross sections used for the groundwater use exception site conceptual model are compatible with the modeling effort under OU2B FS and Addendum.	rate's cleanup time, while the duration for the lowest degradation rate was approximately 100 percent longer than the site specific cleanup rate. (b) Modeling in the FS is used to predict the relative performance of the alternatives. The transport component was not calibrated or validated. A comprehensive concentration dataset over a relatively long time-frame is required for transport calibration/validation in order to approximate the modeled plume morphology to the actual distribution of chemicals of potential concern. At the time of the OU-2B groundwater model set up, there was a significant amount of groundwater data for model use, however, the majority of that data was collected over the past four years, not the relatively long time frame required to accurately calibrate and validate transport. Therefore, transport calibration was not performed. (c) The detailed rationale (including the results of groundwater modeling) for treatment of groundwater down to 30 feet below ground surface to provide an adequate buffer to minimize vapor intrusion risk is presented in Section F5 of Appendix F of the OU-2B Final FS. The groundwater modeling estimated that treatment depth to 30 feet bgs will provide an adequate buffer to minimize vapor intrusion risk due to potential upward diffusion and dispersion of VOCs into shallow groundwater from deeper groundwater. It should be noted that the rationale for the location at which vapor intrusion occurs is independently supported (i.e. does not depend on groundwater modeling) by guidance documents issued by various agencies including Department of Toxic Substances Control (DTSC 2011), Interstate Technology and Regulatory Council (ITRC 2007), and Department of Defense (Tri-Service 2009). Cleanup alternatives (including alternatives proposing active shallow groundwater treatment to mitigate potential for vapor intrusion) were developed based on extensive discussions with the regulatory agencies including USEPA, DTSC, and California Regional Water Quality Control Board. (d) See (a)(i) and (a)(ii) above. (e) The state-of-the science practice is to calculate adsorption coefficient (Kd) from the literature-reported values of organic carbon partitioning coefficient (Koc) and the *site-specific value* for fraction organic carbon (foc) using the following formula: Kd = Koc x foc. Adsorption coefficient (Kd) used in the OU-2B groundwater model was a calculated value based on

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Reviewer: Pankaj Arora, LEED AP, Superfund Division, Environmental Protection Agency. Comments Dated March 20, 2012.

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		the literature reported value of Koc and the *site-specific value* for foc from soil samples taken below the groundwater table at OU-2B and reported in the OU-2B Remedial Investigation Report. The Koc values are dependent only on the properties of the chemical (not on the type of soil) and have been widely reported in literature. Therefore, the use of literature-based Koc value and site-specific foc is reasonable to simulate site-specific adsorption at OU-2B. Sensitivity analysis for adsorption coefficient was not performed because site specific soil values and peer reviewed literature chemical property values were used to derive adsorption potential at OU2B. (f) The groundwater use exception does not alter the CSM for the site with the exception that the domestic use exposure pathways, including; drinking water, inhalation while showering, and dermal exposure while showering do not need to considered if groundwater beneath OU-2B is not considered for domestic/potable use. The details regarding the model layers are presented in Section F2.1 of Appendix F of the OU-2B Final FS. The model layers correlate with the lithologies used in the beneficial use evaluation. The upper three layers of the model represent the artificial fill in the west and the Posey/Merritt/San Antonio formation in the east; and a bottom layer represents Yerba Buena Mud.
5.	It is very difficult to conduct a meaningful comparison of estimated clean up times of different remedy alternatives if the model parameters are not realistic and do not represent the actual site conditions. a. EPA recognizes that models have uncertainties associated with them. We also believe that the modeling uncertainties should not be further exacerbated by using unrealistic input parameters. The modeling uncertainties could increase exponentially, if unrealistic input parameters are used in the model. b. It is important to highlight that once a remedy is selected from a comparative modeling analysis, the associated cleanup times and depth of clean up for the selected remedy will be carried over with that remedy. The future decision making and remedy implementation documents will be based on the modeling assumptions used for the remedy selected.	The groundwater model presented in the Final FS is sufficient to perform relative comparison of cleanup time-frames for remedial alternatives. The model was set up using available site-specific parameters/data including water level elevations, adsorption coefficient, biodegradation rate, and chemical concentrations (realistic input parameters). The sensitivity analysis was conducted and Table 2 of Appendix F of the Final FS shows the cleanup time ranges for decision makers to evaluate when selecting the remedy. The time frame projections are within the accuracy of the model and expectations for an FS. Similarly the costs are within the expected range for FS documents (+50/-30%).

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	c. It is also possible that we might select a remedy that is not an effective, viable, or reasonable remedy based on an unrealistic modeling effort. d. The clean up time plays a critical role in selecting a remedy for a site. Furthermore, the time for clean up also impacts the remedy implementation and O&M costs. Both the clean up time of a remedy and the associated costs are part of the nine criteria for evaluating and selecting a remedy under the NCP.	
6. **Alternative G-2 /GM-2**	a. It is not clear why the actual feasibility and viability of the In-Situ Thermal Treatment (ISTT) was not evaluated during the FS stage. The ISTT options are left open ended, i.e., it could be Electro Resistive Heating (ERH), Conductive Heating, or Steam Flushing. These three technology options are very different and require very different specific data for their evaluation, construction, and monitoring. In other words, the technology options are not simple variations of the same technology. i. The actual feasibility of the technology that could be used at the site has been pushed down to the RD/RA stage. Since technical feasibility and its effectiveness were not conducted during the RI/FS, it is not clear if any of these three technologies will be feasible, viable, or effective at OU2B. ii. For example, if groundwater is expected to be high in salinity due to proximity to sea water then groundwater will be more conductive, hence, it is not clear if resistive heating for more conductive groundwater is feasible, viable, or effective. Issues like this continue to be of concern to EPA. iii. The Navy presented an update on the ERH pilot study at the OU2B site at the March 2012 RAB Meeting. • It is not clear why the study was not completed in the last four years while the FS was being finalized.	(a) Various thermal remediation technologies such as electric resistance heating (ERH) and low-temperature six-phase heating have been tested/evaluated at OU-2B and the results are summarized in the final FS. Therefore, the listed ISTT technologies are expected to be effective. The FS approach with respect to ISTT affords flexibility during the design/implementation phase of the project. In addition, the data available from the previous pilot studies for ISTT technologies is sufficient to perform detailed evaluation of alternatives. Please note that USEPA's guidance on conducting treatability studies under CERCLA (USEPA 1992) recommends tiered approach to treatability studies with options to perform treatability studies during the following stages of CERCLA process: remedy screening, remedy selection and remedial design/remedial action phase (see page 8 of the USEPA guidance). Therefore, treatability evaluations during the FS and RD/RA stage are consistent with USEPA guidance (USEPA 1992). (b) MNA is not proposed as a standalone technology for any OU-2B groundwater remedial alternative. MNA has been combined with active source control and institutional controls for all remedial alternatives (except No Action alternative). Therefore, the evaluation of alternatives (including protectiveness evaluation) in the FS and FS Addendum are based on alternatives as a whole that have been formulated to combine different technologies to achieve the remedial action objectives. Please note that biodegradation (although important) is just one of the natural attenuation mechanisms. The complete definition of MNA per the USEPA's Directive (USEPA 1999) includes physical processes such as dilution and dispersion: *"The term "monitored natural attenuation", as used in this Directive, refers*

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Comment No.	Comment	Response
	- Also, it is not clear what happens if the pilot study indicates that ERH is not a viable option. - Will there be pilot studies for conductive heating and steam flushing? - Will conductive heating work with existing utility lines at the site? - Finally, is the RD/RA the right stage to do these types of evaluations? b. It is not clear why MNA was carried over as a viable remedy, i.e., how did it pass the protectiveness analysis. The Addendum refers to the final OU2B FS document and the final FS document refers to the EPA guidance on MNA “Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater”, EPA/600/R-98/128, September 1998. i. Page 3 of the EPA MNA guidance states that biodegradation is the most important destructive attenuation mechanism, although abiotic destruction of some compounds does occur. The EPA MNA guidance lists six steps for the screening process. They are described in the guidance document from page 27 onwards. ii. Table 2.3 on page 30 of the EPA MNA guidance document lists analytical parameters and weighting for preliminary screening for anaerobic biodegradation processes. - Page 31 of the EPA MNA guidance states that “If the score totals 15 or more points, it is likely that biodegradation is occurring, and the investigator should proceed to Step 2.” - The guidance provides an example with screening scores less than 15 and states “…the investigator can infer that biodegradation is probably not occurring or is occurring too slowly to contribute to natural attenuation at the time of sampling. In this case, the investigator should evaluate whether other natural attenuation	*to the reliance on natural attenuation processes……The “natural attenuation processes” that are at work in such a remediation approach include a variety of physical, chemical, or biological processes……………….These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants. (USEPA 1999).* (c) & (d) The evaluation proposed in Steps 2 through 6 have been completed through groundwater modeling presented in Appendix F of the final OU-2B FS. The cleanup durations are based on groundwater modeling results and are sufficient to perform detailed and comparative analysis of remedial alternatives.

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	processes can meet the cleanup objectives of the site (e.g., abiotic degradation or transformation, volatilization or sorption) or select a remedial option other than MNA.” iii. Appendix L of the final OU2B FS provides information about the first step of the screening process. • The screening scores for monitoring wells with appropriate weighting factors for anaerobic biodegradation are reported to be: 11, 8, 13, 6, 11, and 3. All the scores are below 15. • Please provide rationale for moving forward with MNA even if the screening scores are below 15. c. It is not clear how the remaining steps 2 thru 6 as described in the EPA MNA guidance were evaluated in the final OU2B FS or FS Addendum. d. It is not clear how the cleanup duration of 35 years (+/- 50 percents) has been derived. The Note 1 on Figures 19-21 depicting the modeling results states: “…….<u>These results are not intended to be used as prediction of required restoration durations.</u>”	
7. **Alternative G3/GM-3 (a) and (b)**	Same issues listed under Comment#6 (a) about the ISTT portion of the remedy are applicable for this alternative(s) too. a. It is not clear how did the Navy establish that it will take 3 years under sub-scenario 3(a) and 5 years under sub-scenario 3(b) to achieve commercial RBCs for the shallow groundwater . The shallow groundwater is defined as approximately 30 ft bgs. EPA is assuming that 3 and 5 years were used for cost estimation, please confirm. b. EPA could not locate the modeling simulation in Appendix F that indicates that it will take 15 years (+/- 50 percent) to attain residential RBCs. c. Please clarify the last sentence of the last paragraph under section 3.3.3 on page 9 of the Appendix A. It is not clear how the number of years is developed for different scenarios.	(a) The 3 years and 5 years to attain commercial RBCs are engineering estimates for cost estimating purposes based on the proposed conceptual design. (b) The 15 year time frame is estimated based on the modeling results for Alternative G-3 presented on Figures 23 through 25 of Appendix F of the Final OU-2B FS. These figures show the plumes dissipating between the 10 year and 20 year timeframe for Layers 1 and 2 (top 30 feet of the aquifer). Therefore a 15 year duration was assigned. (c) See response to comment (b) above, a specific reference to modeling results for Alternative G-3 will be added to the text.
8.	The toxicity values for tetrachloroethene (PCE) were updated on	Please note that PCE is not a COC for the commercial reuse scenario

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Reviewer: Pankaj Arora, LEED AP, Superfund Division, Environmental Protection Agency. Comments Dated March 20, 2012.

Comment No.	Comment	Response
	February 10, 2012 and were posted http://cfpub.epa.gov/ncea/iris/index.cfm?fuseaction=iris.showQuickView&substance_nmbr=0106 Please calculate revised RSLs and risk-based concentrations (RBCs) using the updated toxicity values.	therefore the PCE RBC was not calculated.
9. Appendix A, Section 3, Remedial Action Alternatives	It appears that the descriptions of Alternatives GM-2, GM-3 and GM-3 might be missing the need for institutional controls (ICs) prohibiting residential reuse for areas that exceed residential RBCs. The first mention of ICs to prohibit residential reuse is, “Following attainment of commercial RBCs, ICs would be continued to prevent residential reuse of areas of OU-2B groundwater exceeding residential RBCs.” However, ICs to prohibit residential RBCs are needed from the beginning of remedy implementation over portions of the plume that do not meet residential RBCs, including areas that will not be treated because they do not exceed commercial RBCs. Please revise the alternative descriptions to include ICs prohibiting residential RBCs over all portions of the plumes that do not meet residential RBCs.	Sections 3.2 through 3.4 will be revised to specify that ICs to prohibit residential use above the plume including an adequate buffer will be implemented as part of each remedial alternative until residential RBCs are attained.
10. Appendix A, Table 5, Summary of Assumptions for Cost Estimates	Please explain why two applications of ISCO will be sufficient.	The two applications of ISCO are based on the total estimated treatment volume/mass and estimated oxygen demand of approximately 10 grams of oxidant per kilogram of treated material (based on the previously conducted ISCO pilot test at Plume 4-1 and revised target remediation goals – commercial VI RBCs). The estimates in the FS and FS Addendum were based on the quote from ISOTEC (ISCO vendor).

From: Wanyoike, Crispin
Sent: Tuesday, March 20, 2012 5:19 PM
To: Dhody, Gaurav; Singh, Harvinder
Subject: FW: Alameda Point - draft OU-2B FS Report Addendum

-----Original Message-----
From: Moss, Curtis M CTR NAVFACHQ, BRAC PMO [mailto:curtis.m.moss.ctr@navy.mil]
Sent: Tuesday, March 20, 2012 5:00 PM
To: Wanyoike, Crispin
Cc: Thomas Mulder
Subject: FW: Alameda Point - draft OU-2B FS Report Addendum

FYI below, DTSC has no comments on 2B FS Addendum.

Curtis

-----Original Message-----
From: James Fyfe [mailto:JFyfe@dtsc.ca.gov]
Sent: Monday, March 19, 2012 13:51
To: Moss, Curtis M CTR NAVFACHQ, BRAC PMO; Robinson, Derek J CIV NAVFACHQ, BRAC PMO
Cc: Karen Toth; Michelle Dalrymple; Pankaj Arora; Peter Russell; John West
Subject: Alameda Point - draft OU-2B FS Report Addendum

Hello Curtis,

DTSC has reviewed the draft Feasibility Study Report Addendum for OU-2B, Alameda Point, dated February 2012. We have no comment on the document.

Thank you,
J. Fyfe

James R. Fyfe, P.E.
Project Manager
Brownfields and Environmental Restoration Program

California Environmental Protection Agency Department of Toxic Substances Control
700 Heinz Avenue, Suite 200
Berkeley, CA 94710
Phone: (510) 540-3850
Fax: (510) 540-3819
jfyfe@dtsc.ca.gov

Dhody, Gaurav

From: Wanyoike, Crispin
Sent: Wednesday, April 18, 2012 2:03 PM
To: Dhody, Gaurav
Subject: FW: 2B FS Addendum comments

FYI

-----Original Message-----
From: Moss, Curtis M CTR NAVFACHQ, BRAC PMO [mailto:curtis.m.moss.ctr@navy.mil]
Sent: Wednesday, April 18, 2012 1:36 PM
To: Wanyoike, Crispin
Cc: Singh, Harvinder
Subject: FW: 2B FS Addendum comments

Water Board....

-----Original Message-----
From: John West [mailto:JWest@waterboards.ca.gov]
Sent: Wednesday, April 18, 2012 13:10
To: Moss, Curtis M CTR NAVFACHQ, BRAC PMO
Subject: Re: 2B FS Addendum comments

Curtis,

Water Board staff have no comments except to support EPA's comments, in particular, resolution of disagreements in the contaminant groundwater modeling assumptions and applicability.

Thanks, john

>>> "Moss, Curtis M CTR NAVFACHQ, BRAC PMO" <curtis.m.moss.ctr@navy.mil> 4/18/2012 10:52 AM
>>>
Hi John,

Does the Water Board plan to submit comments on the OU2B draft FS Addendum?

Thanks,

Curtis

Curtis M. Moss, PG
Alameda Team
Navy BRAC PMO West
Office: 619.532.0775

Title: U.S.EPA Comments on Groundwater Modeling, Final *Feasibility Study, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point, Alameda, California.*

Reviewer: Pankaj Arora, LEED AP, Superfund Division, *Environmental Protection Agency. Comments Dated May 25, 2012.*

Comment No.	*Comment*	*Response*
1.	The authors of the model acknowledge that the level of confidence in the model as a predictive tool is rather low, but the model was used extensively for assessing the remedial options, even though the model authors specifically stated that the model should not be used to predict cleanup times. In part, this low level of confidence may be due to the fact that the flow model was not validated and only partially calibrated and that the transport model was neither calibrated nor validated. The low confidence also is related to other issues discussed below. To improve confidence in the model, the flow model should be calibrated and the transport model should be both calibrated and validated. A sensitivity analysis should also be completed. Please rerun the model to ensure that the flow and transport models are both calibrated and validated and that a sensitivity analysis is run for each input parameter, including boundary conditions.	The responses to individual components of the comment are provided below: Comment: *"The authors of the model acknowledge that the level of confidence in the model as a predictive tool is rather low, but the model was used extensively for assessing the remedial options, even though the model authors specifically stated that the model should not be used to predict cleanup times."* Response: The purpose of the OU-2B feasibility study (FS) was to perform a detailed and comparative analysis of alternatives with respect to nine criteria stipulated in the National Oil and Hazardous Substances Control Pollution Contingency Plan (NCP). Groundwater modeling conducted for OU-2B was of appropriate level of detail to support this objective. This modeling approach is consistent with the United States Environmental Protection Agency (USEPA) guidance (USEPA 1988), which states whether or not to use modeling and the level of effort that should be expended is made on the basis of the objectives of the modeling. Groundwater model for OU-2B was developed consistent with its purpose to perform comparative analysis of groundwater remedial alternatives, including *relative predictions* of remediation time frames and future volatile organic compound (VOC) concentrations. There are inherent uncertainties in any groundwater model, and modeling should not be used as an absolute/definitive predictive tool. The disclaimer in the Final OU-2B FS regarding the use of the model for remediation durations is intended to alert the reader against using the model for prediction of absolute/definitive restoration durations, however, these estimates are considered to be representative of these restoration durations. Comment: *"In part, this low level of confidence may be due to the fact that the flow model was not validated and only partially calibrated and that the transport model was neither calibrated nor validated. The low confidence also is related to other issues discussed below. To improve confidence in the model, the flow model should be calibrated and the transport model*

Title: U.S.EPA Comments on Groundwater Modeling, Final *Feasibility Study, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point, Alameda, California.*

Reviewer: Pankaj Arora, LEED AP, Superfund Division, *Environmental Protection Agency. Comments Dated May 25, 2012.*

Comment No.	*Comment*	*Response*
		should be both calibrated and validated. A sensitivity analysis should also be completed. Please rerun the model to ensure that the flow and transport models are both calibrated and validated and that a sensitivity analysis is run for each input parameter, including boundary conditions." Response Regarding Flow Modeling: The flow model for OU-2B is calibrated and the calibration results are presented in Section F2.2 of Appendix F of the OU-2B Final FS. Validation/verification of the flow model entails comparing the performance of the calibrated flow model to data obtained from known hydraulic stresses, such data was and is not available and therefore validation/verification was not performed. Absent of a validation dataset, the comparison of the observed to computed heads along with resultant flow regime reflects an appropriate representation of the groundwater flow system at OU 2B. A sensitivity analysis for flow model parameters including hydraulic conductivity, recharge, and boundary conditions will be conducted and the results will be presented to USEPA in a revised modeling summary report. It should be noted that this sensitivity analysis provides an understanding of how the input parameters affect the calibrated flow model. These results are not carried through to the contaminant plume transport modeling phase. As a result, the predicted cleanup durations will not change since the transport model only uses the calibrated flow model. Response Regarding Transport Modeling: A comprehensive concentration dataset over a relatively long time-frame is required for transport calibration/validation in order to approximate the modeled plume morphology to the actual distribution of chemicals of potential concern. At the time of the OU-2B groundwater model set up, there was a significant amount of groundwater data for model use, however, the majority of that data was collected over the past four years, not the relatively long time frame required to accurately calibrate and validate transport. Therefore, transport calibration was not performed.

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Comment No.	*Comment*	*Response*
2.	The report (page F3-1) states that "A sensitivity analysis was performed with the degradation half life multiplied by 0.5 and 5." What is the rationale for using "5 times" factor? More importantly, at the bottom of the Table 2 (page F4-1), there is a note indicating that only for Alternative G-1 the sensitivity was performed. For other alternatives the predictive times were based on the results of Alternative G-1. Please provide reasoning and appropriateness to take the predicted time for one alternative and apply the results to a different alternative(s).	Section F3 of Appendix F of the Final OU-2B FS explains the degradation rate (3.1 years per half-life) used in the groundwater model (calculated from site-specific data at Plume 4-1). This site specific degradation rate is 300 times less than the fastest reported TCE degradation rate (0.01 years per half-life) in literature (USEPA 1998). Variability in the values of degradation half-lives are likely but are very difficult to quantify both temporally and spatially. Use of the maximum value observed at Plume 4-1 was considered to be too optimistic for FS purposes, therefore, a sensitivity analysis was run by varying the degradation half-life by a half order of magnitude lower and higher than the site specific calculated value and is based on professional judgment. All remedial alternatives were simulated using the same flow and transport model with each simulation differing only in the parameters/conditions reflective of individual remedial technologies/scenarios that are part of different alternatives. Since the same flow/transport model was used for all remedial alternatives, the response to a change in values of degradation half-life was assumed to be similar for all remedial alternatives. Therefore, sensitivity analysis results corresponding to Alternative G-1 were to estimate the remediation durations for the remaining alternatives.
3.	Model Layers appear to be continuous and of uniform thickness (e.g., the bottom of Layer 2 is set 10 feet below Layer 1). It is unclear how the model addressed the issue of discontinuity (or absence) of some hydrostratigraphic units as depicted in OU 2B cross-sections. Please clarify how the model addressed the discontinuity or absence of hydrostratigraphic units.	The model layers were initially set up based on the average thicknesses and soil type of the site stratum, Layer 1 for the fill, Layer 2 for the shallow bay mud, Layer 3 for the Merritt Sand and associated alluvial fan sediments, and Layer 4 for the Yerba Buena Aquitard. The model layers serve as a generalization of the type of deposits. During model setup, the hydraulic conductivity (k) values were initially based on the geology encountered within a given model grid. These initial k values were representative of the discontinuous nature of the deposits within model layers and were then adjusted during calibration as part of matching the observed hydraulic heads. The spatial variability of calibrated hydraulic conductivity values based on the calibrated hydraulic heads within different layers of the model account for heterogeneity of geologic deposits.

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Comment No.	*Comment*	*Response*
4.	The information on General Head Boundary (GHB) and Constant Head (CH) boundary is missing. The text should discuss how the GHB for the Seaplane Lagoon was set up (e.g., the conductance for the boundary condition). Also, it is unclear why the CH boundary was established only for Layer 1. Please explain how the GHB for the Seaplane Lagoon was set up and why the CH boundary was only established for Layer 1. Please provide the water level map that was used to establish the CH boundary.	The Constant Head (CH) boundary was set in Layer 1 only to represent the groundwater table on the upgradient side (east) of the flow model. This boundary was subdivided into four segments to allow lateral variation of the specified head to better reflect groundwater elevations downgradient in the flow model. The head elevation in the CH was initially set to groundwater surface contours extrapolated east from nearby wells, since there was only one layer 1 well located along the CH boundary. These heads were adjusted during the calibration process to improve the flow model heads calibration. The auto sensitivity (AS) feature in Groundwater Vistas was used to vary the CH head elevation by +/- specified head elevation. The results from each AS run were evaluated for improvement to calibration as well as whether the head adjustment made hydrogeologic sense. The General Head Boundaries were setup in a similar fashion as the CH cells. There were six GHB segments in each model layer, for a total of 24 in the flow model. There were GHBs set in each layer on the downgradient sides of the flow model since the monitoring wells showed head variation with depth. Seaplane Lagoon was set up as a single GHB 'zone' with its initial head elevation set to the average tidal elevation. The head elevation in the other GHB segments were initially set to groundwater surface contours extrapolated north, west, and south from nearby wells. These heads were adjusted during the calibration process to improve the flow model heads calibration. The AS feature in Groundwater Vistas was used to vary the GHB head elevation by +/- specified head elevation. The results from each AS run were evaluated for improvement to calibration as well as whether the head adjustment made hydrogeologic sense. The conductance terms in the GHB were initially sent to approximately the K value of the nearby K-zones in the layer. Where there were two or more K-zones along a GHB segment the average of the K values was used. The AS feature was also used to evaluate the GHB conductance terms in a similar fashion as with the head terms. The above explanation and a potentiometric map of the

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		average groundwater elevations at the Layer 1 wells will be provided in a revised modeling summary report.
5.	The hydraulic conductivity (K) distribution appears to be the result of the calibration process rather than the actual geology (the bullseye distribution). Some of the K values (e.g., 80 feet per day [ft/day] in Layer 3; zones 40, 41, and 42) are not supported by the site geology, much of which consists of clayey sands and silty sands with finer grained units. Areas with poorly graded sands that may have elevated hydraulic conductivities do not appear to be laterally extensive. Further, site-specific hydraulic conductivity values listed under Section 3.1.2.3 and Table 4 of the final FS are: 2.2E-04 ft/day, and 5.6 ft/day for Site 4; 2.1 ft/day for Site 11; and 2.4 to 7.3 ft/day with an average of 4.4 ft/day for Sites 11/21, which do not support the high hydraulic conductivities used in the model. The rationale for the K-distribution in Layers 3 and 4 must be provided and this distribution should be based on site lithology and site-specific hydraulic conductivities. Please provide the rationale for the K-distribution in Layers 3 and 4 and explain how these values are related to site lithology and site-specific hydraulic conductivities.	The hydraulic conductivities reported in Section 3.1.2.3 and Table 4 of the Final OU-2B FS generally represent data collected in a discrete zone less than 42 feet below ground surface (bgs). Layer 3 extends from approximately 30 feet to 70 feet bgs; therefore, the values in Table 4 may not be representative of Layers 3 and 4 hydraulic conductivities. Layer 3 contains poorly graded sands, silty sands, and clayey sands. The calibrated hydraulic conductivity values for Layer 3 used in the model are within the estimated values range reported in literature for sands, silty sands, and clayey sands (see hydraulic conductivity values in Attachment 1 for fine and medium sands; this table (transmitted previously) was extracted from USEPA Method 9100: Saturated Hydraulic Conductivity, Saturated Leachate Conductivity, and Intrinsic Permeability [USEPA 1986]). There are no K values for the mud of the Yerba Buena Aquitard but it was assumed to be low (0.1 foot per day for majority of the model domain).
6.	It is unclear how the calibration targets were selected and what the "average" water level map is for the site. Also, most of the 266 targets used in the calibration are in Layer 1 and the calibration statistics for Layers 3 and 4 are rather poor. More importantly, in addition to the statistical results, the model report should include other evidence to support the model calibration. For example, a graph showing the observed vs. computed heads for each model layer is a standard way of showing whether there is a bias in the calibration results. The observed and computed hydraulic gradients (both horizontal and vertical) should be compared. In addition, spatial bias should be evaluated by plotting the residual head differences. Please clarify how the calibration targets were selected, why they are primarily in Layer 1, and provide an “average” water level map for OU 2B. Also, please provide a graph showing the observed vs. computed heads for each model layer and plot residual heads to evaluate spatial bias.	The calibration targets were assigned to model layers based on the geologic stratum in which the screen is located. The calibration target values were based on average water levels from 1991 to 2006 and as reported there were more values available for Layer 1. The water level data from 1991 through 2006 included measured water levels for every month of the year. The depth distribution of the well screens was based on site investigation priorities and thus controlled the distribution of potential head calibration targets. As stated above, a potentiometric map of the average groundwater elevations at the Layer 1 wells will be provided. A graph of observed vs. simulated heads for each model layer will be provided in the revised modeling summary report. Maps showing the spatial distribution of residuals are already provided as Figures 8, and 9A through D. In addition, contours will be added to these maps to show simulated gradient directions. The vertical gradients will be qualitatively evaluated by comparing the simulated and observed for the individual

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		model layers.
7.	Recharge rates are important for the model. It is unclear whether recharge rates vary over the model area (the land use). Further, a sensitivity analysis for this and other parameters should have been conducted. Please explain how recharge rates vary over the model area and conduct a sensitivity analysis.	There are three recharge zones in the flow model. There is a lower recharge rate (6.3 inches/year) over the runway area approximately 1.5 miles west of OU-2B, which is surrounded by open grass fields where runoff would collect; There is a higher recharge area (10.4 inches/year) around the elliptical-shaped grass area in the northern part of OU2B where it is assumed the flat grassy area allows a higher recharge rate; The majority of the flow model domain has a recharge rate of 9.8 inches per year. Most of the domain has buildings and parking lots with surrounding flat grass, dirt, or gravel areas. It is assumed that the flat non-impervious areas allow recharge from the direct precipitation and runoff from adjacent impervious areas. Sensitivity analysis will be performed and the results will be presented to the BCT in the revised modeling summary report.
8.	The water budget results are missing. Please provide a water budget for each model layer.	A water budget [flow mass balance report] will be provided in the revised modeling summary report.
9.	The effective porosity is assumed to be equal to the total porosity (30 percent). Considering the type of the geologic material, this is unlikely. Please correct this in the model.	The report does not equate total porosity to effective porosity. The effective porosity value selected was based on literature values for the type of geologic material encountered (see Attachment 2). MODFLOW uses effective porosity only in the transport model and not in the flow model.
10.	The dispersivity values for Layers 1, 2, and 3 are 25.29, 26.32, and 26.41 feet, respectively. These are rather precise numbers for a parameter which is usually determined by model calibration. It is unclear why the dispersivity in Layer 2 (an aquitard) is practically the same as in Layers 1 and 3. Please explain why the dispersivity of Layer 2 is nearly the same as those of Layers 1 and 3. Also, please explain how the dispersivity values were obtained.	Dispersivity was calculated using the equation for 'alpha-x' cited in the report by Xu, Moujin and Y. Eckstein, 1995, as explained in Section F3 of Appendix F of OU-2B Final FS. This equation is based on the plume length and since the plume in all three layers are of similar length (see Figures 10, 11, and 12 in Appendix F) the dispersivity values are similar.
11.	It is unclear if degradation rates for other volatile organic compounds (VOCs) other than trichloroethene (TCE) were considered and whether TCE represents the worst case scenario. Please discuss whether degradation rates for VOCs other than TCE were considered and whether TCE represents the worst case	TCE is the predominant VOC reported in groundwater at OU-2B. As such its fate and transport characteristics (including biodegradation) were used to represent the entire VOC plume. The degradation of other VOCs was not simulated since their

Comment No.	*Comment*	*Response*
	scenario.	mass was included in the total VOC mass (see Section F3.1 - *Model Assumptions and Uncertainties* in Appendix F of the Final OU-2B FS. To analyze the uncertainty in the degradation rates, a sensitivity analysis was performed by varying the biodegradation rate by a half order of magnitude lower and higher than the calculated site-specific rate. The results of this analysis are presented in Table 2 of Appendix F of the Final OU-2B FS. Total VOC mass was modeled for OU-2B using fate and transport characteristics of TCE. This represents a reasonable and conservative scenario since TCE is the predominant VOC in OU-2B groundwater. There are less likely scenarios where this approach may not represent a worst-case scenario, e.g. where degradation of other VOCs occurs at a considerably slower rate. Therefore, the sensitivity analysis performed as part of OU-2B groundwater modeling presents ranges of predicted time-frames corresponding to changes in values of degradation rates for the remedial alternatives.
12.	The procedure for determining the retardation factor was not fully explained. It is unclear if the total organic carbon (TOC) values were for the aquifer material (the text suggests that TOCs were based on groundwater sampling results) or how these the foc values were obtained. Specifically, the values for the retardation factors for TCE and other constituents should be specified. Please discuss this issue.	Retardation factor was not specified by input but calculated by the model software based on the parameters such as bulk density, sorption coefficient, and porosity. The retardation factor is calculated using the following equation: $R = 1+ [Bd * Kd] / Porosity$ which includes the following terms: Kd [sorption coefficient] is calculated based on the values of foc (fraction organic carbon) and Koc (organic carbon partitioning coefficient); The foc was based on TOC values from soil samples taken below the groundwater table at OU-2B from October through December 2007 and reported in the OU-2B Remedial Investigation Report. The average of the TOC values for the OU2B area was converted to foc value. The Koc value was the literature-reported value (Montgomery 2000). The bulk density was calculated using the porosity value using the equation Bd = 2.65(1- porosity).
13.	The text did not explain how the concentration source(s) was/were implemented in the transport model. For example, the geometry of the sources should be	The current site plume in the transport model was simulated as a dissolved plume for alternatives that have active source zone

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	specified. Please clarify.	treatments and simulated using initial VOC concentrations for alternatives that do not have active source zone treatments (i.e., G-1 and G-4). No continuous/depleting secondary sources (therefore no specific geometry) were simulated. Three of the transport simulations (i.e. simulations for Alternatives G-2, G-3a, and G-3b) were setup with the plume zones greater than 10 ppm being significantly reduced by various active source zone treatments to 1 ppm.
14.	The sensitivity analysis on the model predictions (once the model is calibrated and validated) should be included in the report. Please ensure that the sensitivity analysis is included in the model report.	Please see response to Comment #1. A sensitivity analysis for flow model parameters including hydraulic conductivity, recharge, and boundary conditions will be conducted and the results will be presented to USEPA in a revised modeling summary report.
15.	Please provide rationale for using +/- 50% range for the predicted clean up times from modeling simulations. For example, why it is not +/-30% or +/- 65% etc. etc.	The +/- 50% range (in years) represents an approximate average variation in predicted remediation time-frames corresponding to 0.5 times and 5 times the site-specific degradation rate.

References:

Montgomery, John, H. 2000. Groundwater Chemicals - Desk Reference, Third Edition, CRC Press LLC

U.S. Environmental Protection Agency (USEPA). 1986. Method 9100: Saturated Hydraulic Conductivity, Saturated Leachate Conductivity, and Intrinsic Permeability. http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/9100.pdf.

U.S. Environmental Protection Agency (USEPA). 1988. Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites. EPA/540/G-88/003. December.

United States Environmental Protection Agency (U.S. EPA). 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. Office of Research and Development. EPA/600/R-98/128. September.

Attachment 1

Table of Hydraulic Conductivity Values USEPA Method 9100: Saturated Hydraulic Conductivity, Saturated Leachate Conductivity, and Intrinsic Permeability (USEPA 1986)

TABLE C

HYDRAULIC CONDUCTIVITIES ESTIMATED FROM GRAIN-SIZE DESCRIPTIONS
(In Feet Per Day)

Grain-Size Class or Range From Sample Description	Degree of Sorting			Silt Content		
	Poor	Moderate	Well	Slight	Moderate	High
Fine-Grained Materials						
Clay	Less than .001					
Silt, clayey	1 - 4					
Silt, slightly sandy	5					
Silt, moderately sandy	7 - 8					
Silt, very sandy	9 - 11					
Sandy silt	11					
Silty sand	13					
Sands and gravels(1)						
Very fine sand	13	20	27	23	19	13
Very fine to fine sand	27	27	-	24	20	13
Very fine to medium sand	36	41-47	-	32	27	21
Very fine to coarse sand	48	-	-	40	31	24
Very fine to very coarse sand	59	-	-	51	40	29
Very fine sand to fine gravel	76	-	-	67	52	38
Very fine sand to medium gravel	99	-	-	80	66	49
Very fine sand to coarse gravel	128	-	-	107	86	64
Fine sand	27	40	53	33	27	20
Fine to medium sand	53	67		48	39	30
Fine to coarse sand	57	65-72	-	53	43	32
Fine to very coarse sand	70	-	-	60	47	35
Fine sand to fine gravel	88	-	-	74	59	44
Fine sand to medium gravel	114	-	-	94	75	57
Fine sand to coarse gravel	145	-	-	107	87	72
Medium sand	67	80	94	64	51	40
Medium to coarse sand	74	94	-	72	57	42
Medium to very coarse sand	84	98-111	-	71	61	49
Medium sand to fine gravel	103	-	-	84	68	52
Medium sand to medium gravel	131	-	-	114	82	66
Medium sand to coarse gravel	164	-	-	134	108	82
Coarse sand	80	107	134	94	74	53
Coarse to very coarse sand	94	134	-	94	75	57
Coarse sand to fine gravel	116	136-156	-	107	88	68
Coarse sand to medium gravel	147	-	-	114	94	74
Coarse sand to coarse gravel	184	-	-	134	100	92

(1) Reduce by 10 percent if grains are subangular.
Source: Lappala (1978).

(continued)

TABLE C (Continued)

Grain-Size Class or Range From Sample Description	Degree of Sorting Poor	Moderate	Well	Silt Content Slight	Moderate	High
Sands and Gravels(1)						
Very coarse sand	107	147	187	114	94	74
Very coarse sand to fine gravel	134	214	-	120	104	87
Very coarse sand to medium gravel	1270	199-227	-	147	123	99
Very coarse sand to coarse gravel	207	-	-	160	132	104
Fine gravel	160	214	267	227	140	107
Fine to medium gravel	201	334	-	201	167	134
Fine to coarse gravel	245	289-334	-	234	189	144
Medium gravel	241	231	401	241	201	160
Medium to coarse gravel	294	468	-	294	243	191
Coarse gravel	334	468	602	334	284	234

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(1) Reduce by 10 percent if grains are subangular.
Source: Lappala (1978).

Attachment 2

Representative Porosity Values

Representative Porosity Values

Material	Total Porosity, p_t		Effective Porosity, p_e	
	Range	Arithmetic Mean	Range	Arithmetic Mean
Sedimentary material				
Sandstone (fine)	-	-	0.02 - 0.40	0.21
Sandstone (medium)	0.14 - 0.49	0.34	0.12 - 0.41	0.27
Siltstone	0.21 - 0.41	0.35	0.01 - 0.33	0.12
Sand (fine)	0.25 - 0.53	0.43	0.01 - 0.46	0.33
Sand (medium)	-	-	0.16 - 0.46	0.32
Sand (coarse)	0.31 - 0.46	0.39	0.18 - 0.43	0.30
Gravel (fine)	0.25 - 0.38	0.34	0.13 - 0.40	0.28
Gravel (medium)	-	-	0.17 - 0.44	0.24
Gravel (coarse)	0.24 - 0.36	0.28	0.13 - 0.25	0.21
Silt	0.34 - 0.51	0.45	0.01 - 0.39	0.20
Clay	0.34 - 0.57	0.42	0.01 - 0.18	0.06
Limestone	0.07 - 0.56	0.30	~0 - 0.36	0.14
Wind-laid material				
Loess	-	-	0.14 - 0.22	0.18
Eolian sand	-	-	0.32 - 0.47	0.38
Tuff	-	-	0.02 - 0.47	0.21
Igneous rock				
Weathered granite	0.34 - 0.57	0.45	-	-
Weathered gabbro	0.42 - 0.45	0.43	-	-
Basalt	0.03 - 0.35	0.17	-	-
Metamorphic rock				
Schist	0.04 - 0.49	0.38	0.22 - 0.33	0.26

A hyphen indicates that no data are available.

Source: McWorter, D.B., and D.K. Sunada, 1977, Groundwater Hydrology and Hydraulics, Water Resources Publications, Fort Collins, Colo. (1977) as reported in the following: Loureiro et. al. 1993. Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.

Subject: U.S.EPA/Tech Law Comments Made During the Conference Call with AECOM dated 19 June 2012. Conference Call discussion matter was Groundwater Modeling performed as part of the *Final Feasibility Study, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point, Alameda, California.*

Note to the Reviewer: The following table presents the clarifications requested by U.S. EPA/TechLaw during the subject conference call. This table is not intended to provide responses to all U.S. EPA comments or resolve all the issues discussed during the conference call.

Commenters: Dr. Milovan Beljin and Ms, Karla Brasaemle, TechLaw, Inc.

Comment No.	*Requested Clarifications*	*Response*
1.	Will the proposed active treatment of the hot-spot areas under Alternatives G-2, G-3, GM-2, and GM-3 extend to depths greater than 30 feet below ground surface?	Yes, the proposed active hot-spot treatment (in-situ thermal treatment, in-situ chemical oxidation, and/or in-situ bioremediation, as appropriate) under Alternatives G-2, G-3, GM-2, and GM-3 will extend to depths greater than 30 feet below ground surface in the hot-spot areas where concentrations of total volatile organic compounds (VOCs) greater than 10,000 micrograms per liter are reported at depths greater than 30 feet.
2.	What are the values of total and effective porosities used in the model?	The OU-2B model used only one porosity value (30 percent) as input parameter. This porosity value is equivalent to the effective porosity and is reasonable based on literature values for the type of geologic material encountered (see Attachment 1). The predominant soil types for OU-2B aquifer include poorly-graded sands, silty sands, and clayey sands (see Figures 8 through 11 of the Final OU-2B Feasibility Study). The table in Attachment 1 shows that the arithmetic mean values of effective porosity for sands range from 30 percent to 33 percent.
3.	What value of porosity was used in the retardation factor calculation? Was this value total porosity or effective porosity?	The equation for the calculation of retardation factor uses effective porosity value as input parameter as recommended by the following two references: (1) the attached paper from Groundwater journal (downloaded from http://info.ngwa.org/gwol/pdf/910655328.PDF), and (2) the U.S. EPA guidance document on partition coefficient (U.S. EPA 1999). The OU-2B model used an effective porosity value of 30 percent for retardation factor calculation.
4.	What is the value of retardation factor used in the model?	The calculated retardation factor is 1.67. The retardation factor is calculated using the following equation: R = 1+ [Bd * Kd] / Porosity which includes the following terms: • Bd (bulk density) = 100 pounds per cubic feet (lb/ft^3). • Kd (sorption coefficient) = 0.001999 lb/ft^3 [calculated using foc value of 0.0014; Koc value of 1.3975 lb/ft^3] • Effective porosity = 0.3

Subject: U.S.EPA/Tech Law Comments Made During the Conference Call with AECOM dated 19 June 2012. Conference Call discussion matter was Groundwater Modeling performed as part of the *Final Feasibility Study, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point, Alameda, California.*

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Commenters: Dr. Milovan Beljin and Ms, Karla Brasaemle, TechLaw, Inc.

References:

United States Environmental Protection Agency (U.S. EPA). 1999. Understanding Variation in Partition Coefficient, Kd, Values. EPA 402-R-99-004A. August. http://www.epa.gov/rpdweb00/docs/kdreport/vol1/402-r-99-004a.pdf

Attachment 1

Representative Porosity Values

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Representative Porosity Values

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	Range	Arithmetic Mean	Range	Arithmetic Mean
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Sand (fine)	0.25 - 0.53	0.43	0.01 - 0.46	0.33
Sand (medium)	-	-	0.16 - 0.46	0.32
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Wind-laid material				
Loess	-	-	0.14 - 0.22	0.18
Eolian sand	-	-	0.32 - 0.47	0.38
Tuff	-	-	0.02 - 0.47	0.21
Igneous rock				
Weathered granite	0.34 - 0.57	0.45	-	-
Weathered gabbro	0.42 - 0.45	0.43	-	-
Basalt	0.03 - 0.35	0.17	-	-
Metamorphic rock				
Schist	0.04 - 0.49	0.38	0.22 - 0.33	0.26

A hyphen indicates that no data are available.

Source: McWorter, D.B., and D.K. Sunada, 1977, Groundwater Hydrology and Hydraulics, Water Resources Publications, Fort Collins, Colo. (1977) as reported in the following: Loureiro et. al. 1993. Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.

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Attachment 2

Research Paper – Groundwater Journal

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Simple Derivation of the Retardation Equation and Application to Preferential Flow and Macrodispersion

by Herman Bouwer[a]

Abstract

The equation to calculate the retardation factor of sorbing chemicals moving in aqueous solution through aquifers and vadose zones is derived using a linear sorption isotherm and a mass-balance approach. The procedure is very simple and clearly illustrates the roles of porosity and water content, including those for saturated flow, unsaturated flow, and preferential flow or other systems with both mobile and immobile phases of the water. Applications of the equation to preferential flow in the vadose zone and macrodispersion in a layered aquifer are illustrated with numerical examples for hypothetical cases.

Introduction

The formula most often found in the literature for calculating the retardation factor from the distribution coefficient and aquifer properties is (see, for example, Freeze and Cherry, 1979)

$$R_t = 1 + \frac{\rho_b}{n} K_d \tag{1}$$

where R_t = retardation factor (linear actual velocity of water divided by linear transport velocity of chemical in solution; dimensionless); ρ_b = dry bulk density of aquifer or vadose zone (g/cm^3); n = porosity (volume fraction, dimensionless); and K_d = distribution coefficient (cm^3/g). The parameter K_d is the slope of the linear portion of the adsorption isotherm (Freeze and Cherry, 1979). Use of K_d assumes a low enough water velocity for sorption to be at equilibrium. Because $\rho_b K_d$ must be dimensionless, the dimension of K_d is the reciprocal of that of bulk density. The common unit of K_d is cm^3/g or ml/g. Values of K_d range from 0 for nonsorbing solutes to more than 1,000 cm^3/g for strongly sorbing (hydrophobic) solutes and fine soils with substantial organic carbon (Freeze and Cherry, 1979).

Equation (1) is for saturated flow. According to Freeze and Cherry (1979), equation (1) was developed on an "empirical basis" by Vermeulen and Hiester (1952) for use in chemical engineering and was first applied to ground-water situations by Higgins (1959) and Baetslé (1967, 1969). Roberts et al. (1980 and 1982), McCarty et al. (1981), and Bear and Veruijt (1987) derived equation (1) from the general transport equation, which is the differential equation describing solute concentration changes in relation to time, distance, dispersion coefficient, water velocity, soil bulk density, porosity, mass of solute per unit dry mass of soil, and degradation of solute. The equation is applicable to one-dimensional, horizontal, single-phase flow in saturated, unconsolidated, homogeneous porous media. For unsaturated flow, it is common practice to replace n in equation (1) by the volumetric water content θ. In the following paragraphs, equation (1) is derived with a simple mass-balance approach that clearly illustrates the roles of n and θ, and how the equation should be used for unsaturated flow and preferential flow or other systems with both mobile and immobile water, or relatively fast and slow-moving water. Where preferential flow is caused by spatial variability or other heterogeneity, soil properties in the dominant flow paths may differ from those in the rest of the soil. In those cases, downward flow in the vadose zone may have to be treated as flow through a number of vertical columns, each with its own values of retardation factor, effective water content, hydraulic conductivity, and other pertinent characteristics.

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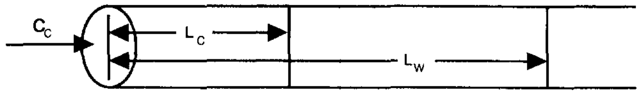

Fig. 1. Geometry and symbols for water and chemical movement.

Derivation of Retardation Equation

Figure 1 depicts a flow tube of unit cross-sectional area in an aquifer or vadose zone (vertical or horizontal) with pure water flowing through it. Water with a dissolved sorbing chemical at concentration C_c then starts flowing through the flow tube, entering at the left. After a certain time t, the water introducing the chemical into the flow tube has advanced a distance L_w and the chemical a distance L_c (piston flow or point of half concentration on breakthrough curve). Thus, the retardation coefficient R_t is L_w/L_c. The volume of water that has entered the flow tube in time period t is $L_w\theta$, where θ is the volumetric water content of the porous material. If the material is saturated, $\theta = n$; if it is unsaturated, $\theta < n$. If there is mobile and immobile water, θ is the volume fraction of the mobile water only.

The total amount of chemical transported into the flow tube at time t is $L_w\theta C_c$. All of this chemical is stored in the L_c-section of the flow tube. Of this total, $L_c\theta C_c$ is in solution in the water phase, and the rest, or $L_w\theta C_c - L_c\theta C_c$, is adsorbed to the solid phase. The mass of the solid phase in section L_c is $(1 - n) L_c\rho$, where n is the porosity of the material, and ρ is the mass density of the solid phase (sand, gravel, rock, etc.). For unconsolidated materials, ρ is about 2.65 g/cm^3. Because the distribution coefficient K_d is the mass of chemical adsorbed to the solid phase per unit mass of solid phase divided by the concentration of the chemical in the water, K_d can be expressed as

$$K_d = \frac{(L_w\theta C_c - L_c\theta C_c)/(1 - n) L_c\rho}{C_c} \qquad (2)$$

Solving this equation for L_w yields

$$L_w = \frac{K_d (1 - n) L_c\rho + \theta L_c}{\theta}$$

Dividing this equation by L_c gives the retardation factor $R_t = L_w/L_c$ or

$$R_t = 1 + K_d \frac{(1 - n)\rho}{\theta} \qquad (3)$$

Because $(1 - n)\rho$ is the dry bulk density of the solid phase, and $\theta = n$ for saturated and full-matrix flow, equation (3) is identical to equation (1). Since equation (3) is applicable to flow in any direction, it can be used for downward flow in the vadose zone as well as for horizontal flow in the aquifer. If there is no interaction between the solute and the soil, $K_d = 0$ and $R_t = 1$, meaning that the solute moves as fast as the water. Anion exclusion can produce an "acceleration" of the pore flow. This can lead to observed "effective" values of R_t of less than one.

Equation (3) illustrates that the use of actual water content θ instead of porosity n in equation (1) is correct when applying equation (1) to unsaturated flow. As a matter of fact, the preferred way to write the equation for R_t is with θ rather than n in the denominator, as in equation (3). The derivation of equation (3) also illustrates that where there is preferential flow or other flow with mobile and immobile phases of the water, θ should include only the water that is moving, or the "effective" water content. Diffusion of the chemical from the mobile into the immobile water may then have to be taken into account (Bear and Verruijt, 1987). Use of the effective θ would also allow better distinction between retardation effects due to sorption, and acceleration effects due to preferential flow or anion exclusion (van Genuchten and Wierenga, 1986). For unsaturated flow, the only variable in equation (3) is θ. Assuming that there is enough film flow and other contact between the liquid and the solid phase for K_d to remain constant, R_t thus is essentially inversely proportional to θ. The underlying assumption for equation (3) is, of course, ideal sorption. This includes instantaneous sorption and equilibrium between the chemical sorbed to the solid phase and that still remaining in solution, isotherm linearity and sorption-desorption singularity. These assumptions are not always met, and sorption nonideality may have to be considered (Brusseau and Rao, 1989). More knowledge of the effects of θ, mobile and immobile water, and sorption on K_d is needed.

Application to Preferential Flow

Preferential flow can be caused by many factors, including macropores (cracks, rootholes, wormholes, structural development), instability of flow (fingering), and micro spatial variability (Amoozegar-Fard et al., 1982; Beven and Germann, 1982; Bowman and Rice, 1986a, b; Bowman et al., 1987; Dao et al., 1979; Germann and Beven, 1985; Hagerman et al., 1989; Jaynes et al., 1988; Kanchanasut et al., 1978; Rice et al., 1986; Scotter, 1978; Thomas and Phillips, 1979; Tyler and Thomas, 1977; White, 1985a, b). Reference is also made to the entire December 1988 issue of *The Journal of Contaminant Hydrology,* which under the editorship of Peter F. Germann, presents 15 articles on "rapid and far-reaching hydrologic processes in the vadose zone" (Germann, 1988). Sometimes, preferential flow occurs in soils without obvious macropores. In that case, preferential flow may be caused by micro spatial variability. Instability of downward flow and "fingering" (Figure 2) can occur in permeable soil that is overlain by much less permeable soil (Samani et al., 1989). Because the fingering type of preferential flow is not caused by macropores or micro spatial variability, the underlying permeable soil can actually be quite uniform. For such a uniform soil, the effect of fingering on the rate of chemical movement through the vadose zone can be calculated readily, as shown in the following numerical example for a hypothetical situation.

The flow through the less permeable top layer is assumed to be uniformly distributed at a rate of 40 cm/yr (Figure 2), which is a reasonable order of magnitude of annual downward movement of water below irrigated soils in hot, dry climates and below nonirrigated soils in humid climates. The flow in the underlying, more permeable material, then, can be unstable and can be concentrated in fin-

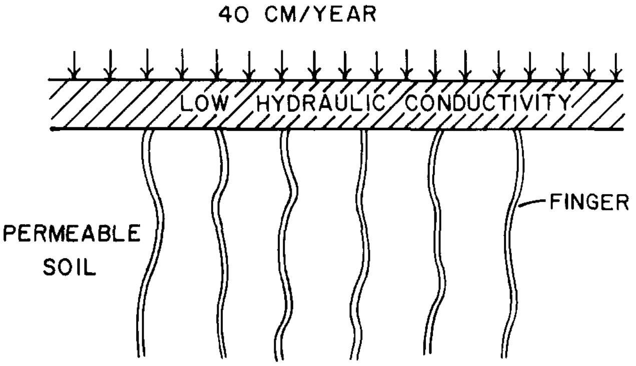

Fig. 2. Preferential flow or fingering in unsaturated permeable soil underlying much less permeable material.

gers. Assuming that the cross-sectional area of the fingers is 0.1 of the total horizontal area ("fingering ratio"), the Darcy flow in the fingers thus is 400 cm/yr. To calculate the rate of downward movement of a solute through the fingers, the value of K_d and the relation between (unsaturated) hydraulic conductivity K and volumetric water content θ for the underlying permeable soil must be known. In this example, K_d will be taken as 10 cm^3/g, and the relation between K and θ will be taken as the one for Rubicon sandy loam presented by Topp (1969) (see also Bouwer, 1978), and shown as Figure 3. The dry bulk density of the underlying permeable soil will be taken as 1.56 g/cm^3, based on a solid density of 2.6 and a porosity of 40%.

The flow in the fingers will be considered as entirely due to gravity, so that the hydraulic gradient is 1, and K in the fingers is equal to the Darcy flow, in this case 400 cm/yr or 7.6×10^{-4} cm/min. Figure 3 shows that the value of θ corresponding to this K-value is 0.24. Thus, the actual downward velocity of water in the fingers is $400/0.24 = 1{,}667$ cm/yr. R_t for $K_d = 10$ is calculated with equation (3) as $1 + 10 \times 1.56/0.24 = 66$, so that the chemical moves downward in the fingers at a rate of $1{,}667/66 = 25.2$ cm/yr.

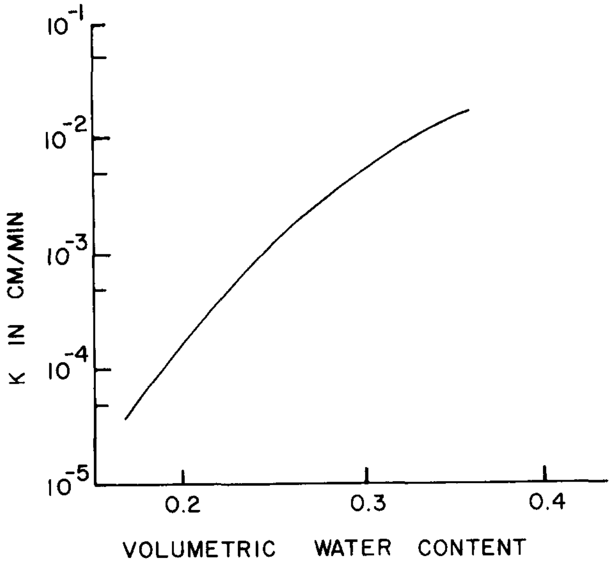

Fig. 3. Relation between K and θ for permeable soil in Figure 2.

Without fingering (fingering ratio of 1), the Darcy flow in the permeable soil would be 40 cm/yr, for which the corresponding θ is 0.18. R_t would then be 87.7, and the rate of chemical movement 2.53 cm/yr. This shows that a fingering ratio of 0.1 increases the rate of downward chemical movement by a factor of 10 compared to no fingering (complete matrix flow). Similar calculations show that for a fingering ratio of 0.01, the rate of chemical movement is 251 cm/yr, or about 100 times faster than for no fingering. A fingering ratio of 0.5 gives a chemical movement of 5.06 cm/year, or about twice the rate for no fingering. Thus, for this case, the rate of chemical transport to ground water is essentially inversely proportional to the fingering ratio. This shows that compounds with high K_d can still be relatively mobile in the underground environment. Models to predict downward movement of chemicals to ground water must take preferential flow into account. This poses a severe challenge (Glass et al., 1988). A simple approach would be to consider preferential flow as a combination of fast and slow transport (through the preferential flow paths and the rest of the soil matrix, respectively) with a diffusion link between the two.

Macrodispersion

Transport of solutes in ground water often is complicated by heterogeneity of the aquifer and dominated by the most permeable materials which also tend to have the lowest retardation factors. This is a form of macropreferential flow, causing macrodispersion of the chemicals transported by the ground water. Dispersion coefficients then tend to be scale-dependent, increasing with increasing distance between the point where the chemicals enter the ground water and the location of the well where ground-water quality is monitored and breakthrough curves are determined. This scale dependency is caused by the fact that heterogeneity in the system increases with increasing distance between the pollution source and the point where the breakthrough is monitored (Kahn and Jury, 1990). As always, the main difficulty in dealing with heterogeneous media is characterization of underground conditions and simplification to manageable systems.

If the system is layered, the hydraulic conductivity, thickness, hydraulic gradient, porosity or effective water content, and retardation factor for the chemical in question must be known for each layer. The breakthrough curve for the chemical a certain distance away can then be estimated by assuming piston flow transport in each layer. This produces a step breakthrough curve, through which a smooth curve can be drawn. This procedure will be illustrated for a hypothetical, four-layered aquifer system (Figure 4). The hydraulic gradient is taken as 0.01 for all layers, and full matrix flow is assumed in each layer so that the pore velocity is equal to the Darcy velocity divided by the porosity. The breakthrough curve is calculated for a completely penetrating well at 1,000 m from the pollution source.

In Table 1, the four layers of the aquifer in Figure 4 are listed in decreasing order of hydraulic conductivity. The first column of Table 1 shows the values of the hydraulic conductivity in m/day for each layer. The second column shows the thickness D of each layer in m, and the third column the

Table 1. Parameters of Hypothetical, Four-Layered Aquifer and Calculation of Step Breakthrough Curve

K *m/day*	D *m*	T *m^2/day*	R_t	n	v_D *m/day*	v_p *m/day*	v_c *m/day*	t *days*	q *m^3/day*	Σq	C/C_0
										0	0
20	2	40	5	0.30	0.2	0.667	0.133	7.5×10^3	0.4		
										0.4	0.23
10	10	100	10	0.25	0.1	0.4	0.04	25×10^3	1		
										1.4	0.8
5	5	25	15	0.20	0.05	0.25	0.0167	60×10^3	0.25		
										1.65	0.94
1	10	10	20	0.15	0.01	0.0667	0.00333	300×10^3	0.1		
										1.75	1

transmissivity T of each layer (T = KD). Values of R_t (fourth column) were selected so that they increase with decreasing K to account for greater adsorption in the less permeable and, hence, finer materials. Porosities (n, fifth column) were selected smaller for the less permeable (and presumably more graded) materials. Assuming a hydraulic gradient of 0.01 in all layers, Darcy velocities v_D are calculated in the sixth column. These values are divided in the seventh column by n to give the pore velocities, which, in turn, are divided in the eighth column by the retardation factor, to give the velocities of the chemical in solution. Travel times for 1,000 m are calculated in column 9. Volume rates of flow in each layer per unit width of layer ($q = 0.01$ T) are calculated in column 10. The sum of these values is 1.75 m^3/day (column 11), which is the total flow q_t per unit width in the four layers. Assuming a fully penetrating well, 1,000 m downgradient from the pollution source, the first arrival of the chemical occurs after 7,500 days or 20.5 years (top layer). At that point, the chemical-laden flow q_c makes up $0.4/1.75 = 0.23$ of the actual flow q_t through the aquifer (column 11 in Table 1). Thus, the relative concentration of the chemical (concentration C in water from well divided by concentration C_0 of chemical in ground water at pollution source) in the well water is then also 0.23 (column 12, Table 1). This concentration remains constant until the chemical from the second layer arrives at the well. This happens after 25,000 days (68 years) when the flow of contaminated water q_c at the well increases to $0.4 + 1 = 1.4$ m/day (column 11, Table 1), or 0.8 of the total flow q_t in the four layers. Thus, at this time, C/C_0 in the well water also increases to 0.8 (column 12, Table 1). Similarly, it can be calculated that C/C_0 in the well increases to 0.94 after 60,000 days (164 years) when the chemical in the third layer arrives at the well site, and to 1 after 300,000 days (822 years), when the chemical from the fourth layer also arrives at the well. The resulting step breakthrough function is shown in Figure 5. A smooth curve was sketched through the center points of each vertical step.

The curve resembles a parabola with pronounced tailing and no longer shows the typical symmetrical sigmoid shape for dispersion in homogeneous materials. Also, the point of $C/C_0 = 0.5$, which theoretically is reached after one pore volume has passed through a homogeneous medium without adsorption and retardation of the chemical, now occurs when 7.2 pore volumes have moved through the system. This took about 23,000 days. One pore volume is $1{,}000(2 \times 0.3 + 10 \times 0.25 + 5 \times 0.2 + 10 \times 0.15) = 5{,}600\ m^3$. As can be expected, the value of 7.2 is relatively close to the R_t of 5 of the most permeable layer, which dominates the transport process and initial arrival of the chemical at the well site. As a matter of fact, the number of pore volumes necessary to produce a C/C_0 value of 0.5 on the breakthrough curve for a certain solute could be used in field studies to estimate the average retardation factor of the more permeable formations in the aquifer system. Tailing of

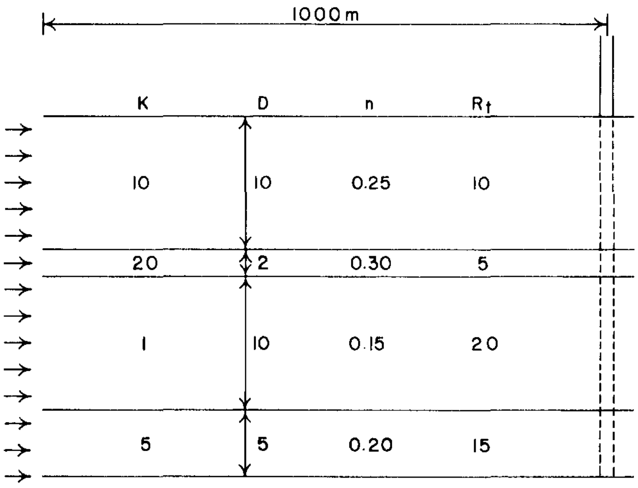

Fig. 4. Hypothetical four-layered aquifer system with plane entry of chemical on left and breakthrough in completely penetrating well on right.

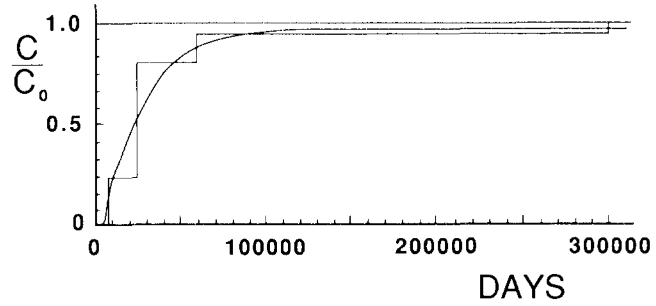

Fig. 5. Step breakthrough curve for arrival times and concentration increases calculated in Table 1, and smooth curve sketched through step increases.

breakthrough curves for more strongly sorbing compounds has also been observed in field studies (Roberts et al., 1990).

When the number of pore volumes for $C/C_0 = 0.5$ is much larger than 1, retardation is significant, and an "overall" dispersion coefficient for the entire system cannot be calculated from the breakthrough curve because the resulting value is meaningless where there is heterogeneity and retardation. If, however, the number of pore volumes at $C/C_0 = 0.5$ appears to be essentially one, there is little or no adsorption and retardation in the system, and the observed breakthrough curve can be used to calculate "the" dispersion coefficient of the layered aquifer system, using, for example, the simple equation developed by Kirkham and Powers (1972). The equation (see also Bouwer and Rice, 1984) is

$$D_c = \frac{v_p L}{4\pi s^2} \tag{4}$$

where D_c = dispersion coefficient; v_p = pore velocity; L = length of travel through porous medium; and s = slope (tangent of angle with horizontal) of breakthrough curve at relative concentration of 0.5 and one pore volume (relative concentration on ordinate, pore volumes on abscissa for evaluation of tangent).

When the breakthrough curve for the system in Table 1 is calculated with R_t values of one, equation (4) yields a dispersion coefficient of 36 m^2/day for the four-layered aquifer system.

Restoration

Preferential flow in aquifers and vadose zones increases the number of pore volumes of clean water that must be passed through the system before contaminants are sufficiently removed from the plume or other affected area. This is because of the long time required to pass the desired number of pore volumes through the less permeable zones while all the time water keeps flowing through the more permeable zones. The total volume of water that then flows through the system is well in excess of the desired number of pore volumes. Assuming, for example, that for the system of Table 1, two pore volumes of clean water must pass through each layer in order to remove the contaminants, the volume of pore water per unit width of system that must flow through the top layer of Table 1 is $2 \times 2 \times 0.3 \times 1{,}000 = 1{,}200$ m^3. The volumes for the other layers are calculated similarly (Table 2, first column). Assuming that the flow rates in the four layers are the same as in Table 1 (column 10), the number of days for two pore volumes to move through each layer is calculated in column 3 of Table 2. As can be expected, the least permeable layer requires the longest time for two pore volumes to move through it, i.e., 30,000 days. Thus, the entire flow through all four layers must be maintained for 30,000 days. Since the flow rate through all four layers is 1.75 m^3/day, $30{,}000 \times 1.75$ or 52,500 m^3 must move through the aquifer before the least permeable layer is sufficiently cleaned up. This corresponds to $52{,}500/5{,}600 = 9.4$ pore volumes, which is almost five times as much as the two required to remove the contaminants. While two pore volumes passed through the least permeable layer, 20 pore volumes passed through the most permeable layer! Preferential flow and macrodispersion thus can cause the volume of water that must flow through an aquifer for restoring a contaminated zone to be much higher than originally estimated.

Conclusions

The equation for the retardation factor can be derived with a simple mass-balance approach, which clearly shows the roles of water content and porosity. The porosity normally shown in the equation is correct only for full matrix flow in saturated porous media. In all other situations, the porosity should be replaced by the effective volumetric water content. This is the content of the water that is actually moving and is dominating the chemical transport process. Application of the retardation equation to preferential flow or "fingering" in the vadose zone shows that the rate of downward movement of chemicals is inversely proportional to the fingering ratio (total cross-sectional area of fingers per unit horizontal area). Mobile and immobile fractions of pore water may occur in saturated and unsaturated porous media, and they should be taken into account when dealing with underground transport of chemicals.

In aquifers, macropreferential flow occurs when the aquifer consists of various layers or zones with different hydraulic conductivity, thickness, texture, porosity, retardation factor, and other properties affecting the movement of water and chemicals. This leads to macrodispersion where convective transport of chemicals and breakthrough curves are dominated by "preferential" flow through the most permeable and least sorbing materials. Resulting breakthrough curves then tend to be more parabolic than sigmoid, and evaluating "the" dispersion coefficient for the whole system with conventional approaches is futile. Breakthrough curves for layered systems with different hydraulic conductivities, porosities, retardation coefficients, etc., for each layer can be estimated rather simply by assuming a piston flow in each layer, as illustrated with a numerical example. This produces a step breakthrough curve, through which a smooth curve can be drawn. The resulting curve tends to be parabolic rather than sigmoid and, when determined in the field, can be used to estimate the average retardation factor of the more permeable formations of the aquifer. Preferential flow in vadose zones and aquifers also can cause the volume of clean water that must be passed through the system to

Table 2. Calculation of Time Required for Two Pore Volumes to Move Through Each Layer Per Unit Width of System in Table 1

Two pore volumes, m^3	*Flow rate q in each layer, m^3/day*	*Time for two pore volumes, days*
1,200	0.4	3,000
5,000	1	5,000
2,000	0.25	8,000
3,000	0.1	30,000
11,200	1.75	

reduce contaminant concentrations to acceptable levels to be much higher than the number of pore volumes theoretically sufficient to clean up each zone or layer.

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* * * * *

Herman Bouwer received B.S. and M.S. degrees in 1949 and 1952 in drainage, reclamation, and irrigation from the National Agricultural University at Wageningen, The Netherlands, and a Ph.D. degree in 1955 in Soil and Water Management from Cornell University, New York. He was associated with the Agricultural Engineering Department of Auburn University, Alabama, from 1955 to 1959, before joining the U.S. Water Conservation Laboratory, Agricultural Research Service, U.S. Department of Agriculture (4331 E. Broadway, Phoenix, Arizona 85040) where he became Director in 1972. In 1970, he also was appointed adjunct professor at Arizona State University in Tempe where he taught ground-water hydrology in the Geology and Civil Engineering Departments. He is also an adjunct professor at the University of Arizona in Tucson.

Memo

Date: 8 August 2012

To: Curtis Moss

From: Joe Harrigan, Harvinder Singh and Crispin Wanyoike

Subject: Data Package, Groundwater Flow Model Sensitivity Analysis and Validation, Operable Unit-2B, Alameda Point, Alameda, California

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1. Introduction

Groundwater flow and transport modeling was conducted as part of the feasibility study (FS) for groundwater at Operable Unit-2B (OU-2B), Alameda Point, Alameda, California. The modeling methodology and results were documented in the Final OU-2B FS Report (OTIE 2011). As part of review of the Draft OU-2B FS Addendum (OTIE 2012), the United States Environmental Protection Agency (U.S. EPA) requested the Navy to perform sensitivity analysis and validation of the flow model. A brief summary of conclusions of the sensitivity analysis and validation for the OU-2B flow model is presented below, and the detailed methodology and results are presented in Attachment A.

2. Conclusions

2.1 FLOW MODEL SENSITIVITY ANALYSIS

A sensitivity analysis was conducted for the OU-2B flow model for hydraulic conductivity (K) zones, the three recharge zones, the four Constant Head (CH) zones, and the twenty-eight General Head Boundary (GHB) zones. The major conclusions include:

- More than half of the K-zones for the entire model domain and within OU-2B area fall into the low sensitivity category with less than one-third of the horizontal hydraulic conductivity (K_h) zones spread across the high to very high sensitivity categories (see Figure 1). Most of the vertical hydraulic conductivity (K_v) zones fall into the low sensitivity category (see Figure 2). This indicates that the model K-zones are more sensitive horizontally than it is vertically.
- U.S.EPA has previously provided comments regarding the use of 80 feet/day K_h zones in the groundwater model. Based on the sensitivity analysis, the two 80 feet/day K_h zones in the OU-2B area have low sensitivity so that their K value could be reduced to 8 ft/day (0.1x the current K_h value) with little impact to the calibration and the flow field.
- As expected, any increase or decrease in the recharge values currently used in the model will adversely impact the flow model calibration.
- The majority of the GHB-K zones for the entire model domain and within OU-2B area are in low sensitivity category (see Figure 3). Most of the GHB-Ft zones fall into the low sensitivity category for the whole model and the OU2B area (see Figure 4).

2.2 FLOW MODEL VALIDATION

The groundwater flow model for OU-2B was calibrated using the average water level data from 1991 through 2005 (hereinafter referred to as “Data Set #1” or “Period 1 Data Set”). Data Set #1 contains groundwater level data for 295 wells within and outside the boundary of OU-2B. The flow model validation was performed using a more recent water level data (2006 through 2011) (herinafter referred to as “Data Set #2” or “Period 2 Data Set”) for wells located within the boundary of or in the immediate vicinity of OU-2B. Data Set #2 contains groundwater level data for 123 wells.

Consistent with the recommendations of the U.S. EPA, prior to performing the flow model validation, a comparison of water level data collected from 1991 through 2005 (Period 1) with the data collected from 2006 through 2011 (Period 2), was conducted for 41 wells located within and in the immediate vicinity of OU-2B that have groundwater elevation data in both data sets. The results of this comparison are shown on Figure 5.

The vertical bars on Figure 5 depict the ranges of groundwater levels for Periods 1 and 2, and triangular symbols indicate the average groundwater elevation for each period. The bars on Figure 5 indicate that there is a significant overlap between the ranges of water levels for Period 1 and Period 2 Data Sets for OU-2B wells.

Following comparison of Period 1 and Period 2 Data Sets, calibration residuals were calculated for the groundwater model by substituting average water level data based on Period 2 for 41 wells located within OU-2B. These calibration residuals are shown in Table 1 and in general show improved calibration statistics with lower ARM and percentage compared to calibration residuals using just Period 1 data. This demonstrates that the flow model calibration is reasonable.

3. References:

OTIE 2011. *Final Feasibility Study Report for Operable Unit (OU) 2B Installation Restoration Sites 3, 4, 11, and 21, Alameda Point. Alameda, California*. December.

OTIE 2012. *Draft Feasibility Study Report Addendum, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point. Alameda, California*. February.

Tetra Tech (Tetra Tech). 2009. *Final Technical Memorandum for Data Gap Sampling at Operable Units 2A and 2B.* July 17.

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Figures

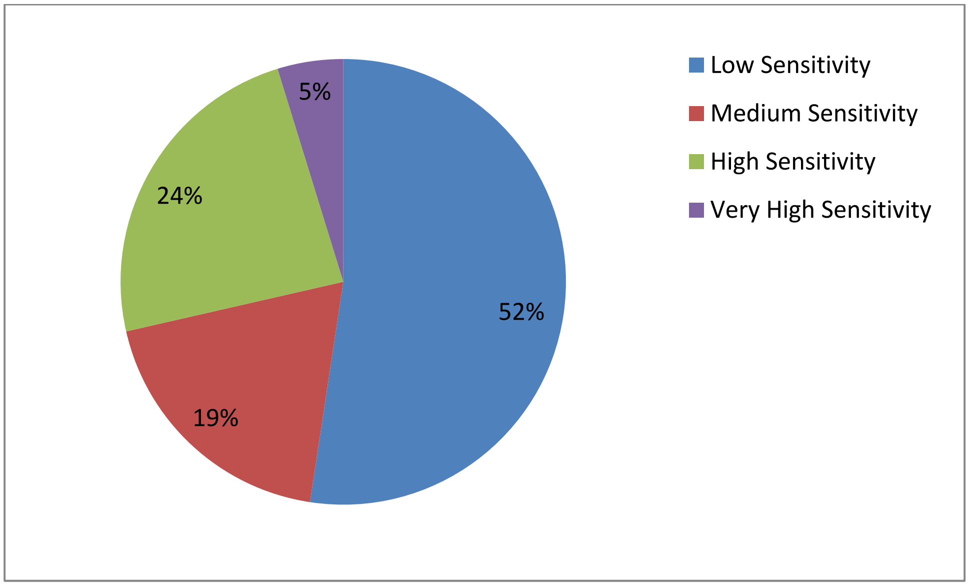


Figure 1: Summary of Sensitivity Analysis Results for Kh Values -- OU-2B Area (All Model Layers)

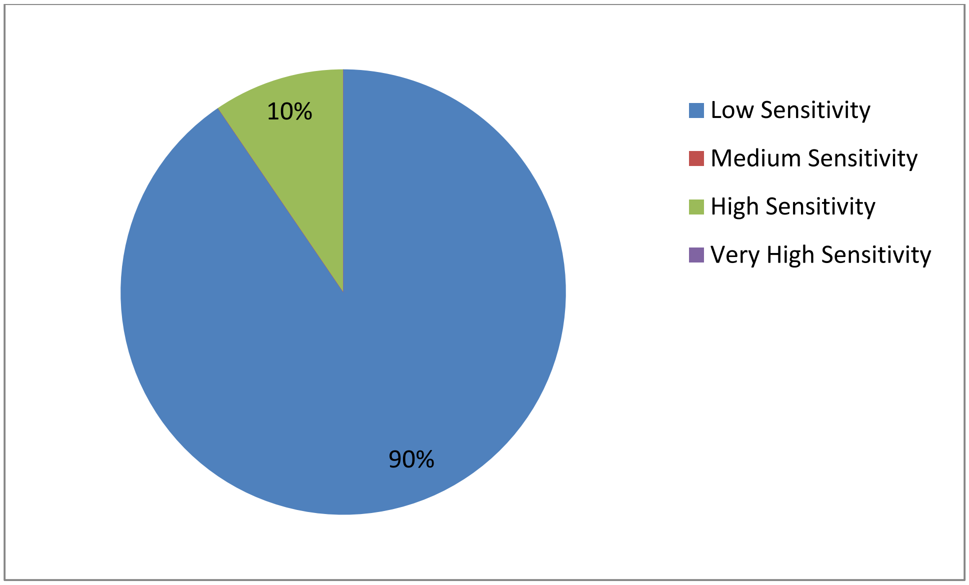


Figure 2: Summary of Sensitivity Analysis Results for Kv Values -- OU-2B Area (All Model Layers)

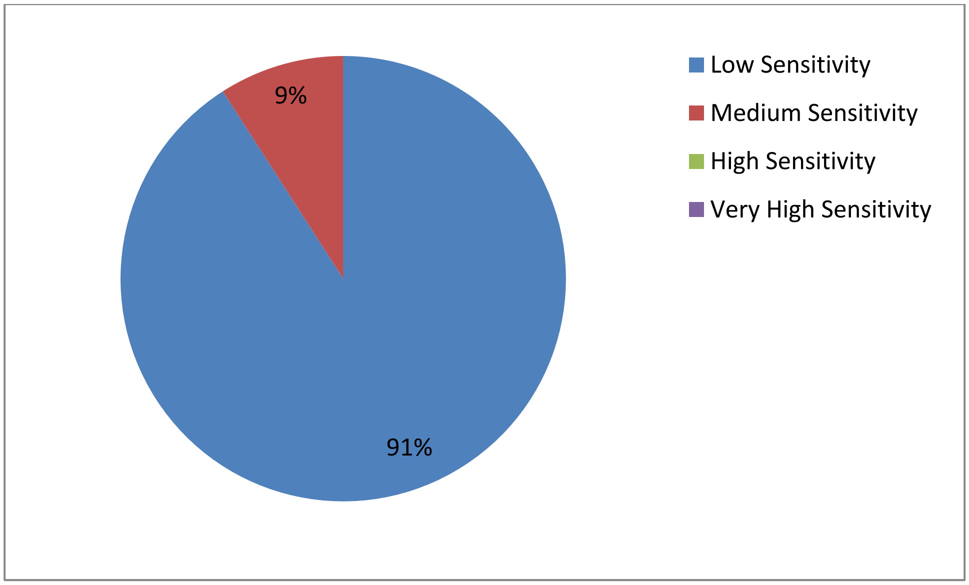


Figure 3: Summary of Sensitivity Analysis Results for GHB-K Values -- OU-2B Area (All Model Layers)

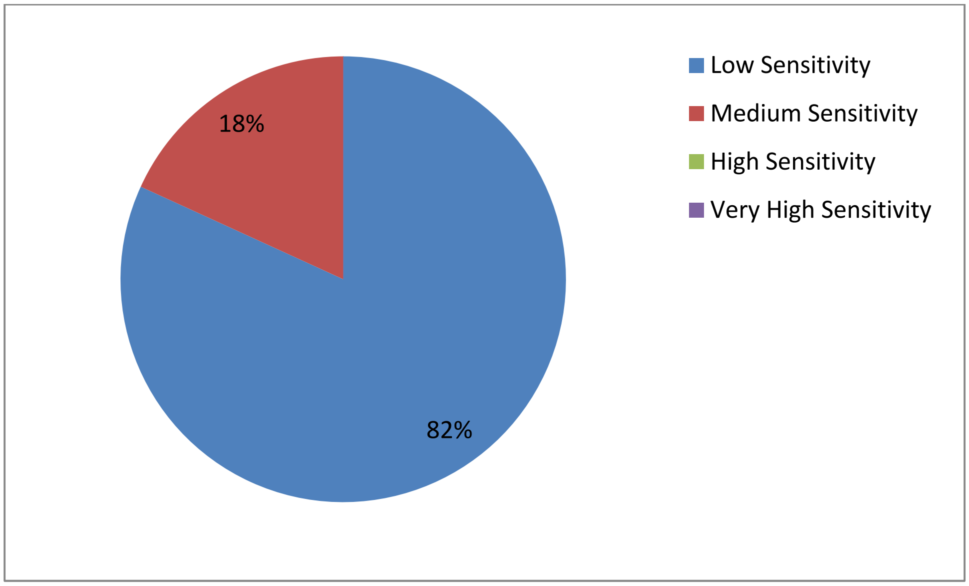
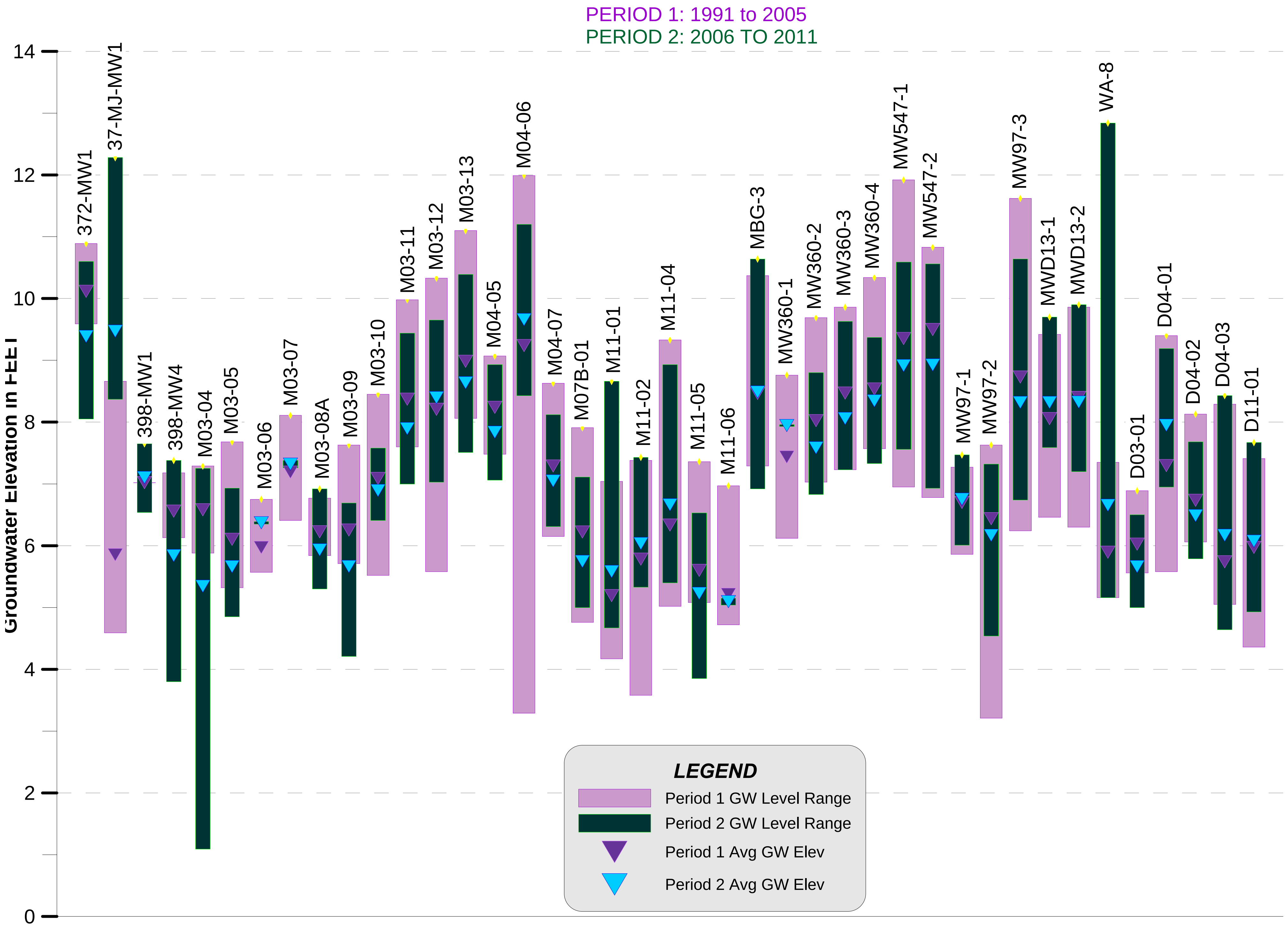


Figure 4: Summary of Sensitivity Analysis Results for GHB-Ft Values -- OU-2B Area (All Model Layers)

FIGURE 5. ALAMEDA POINT - OU2B GROUNDWATER LEVEL COMPARISON



Tables

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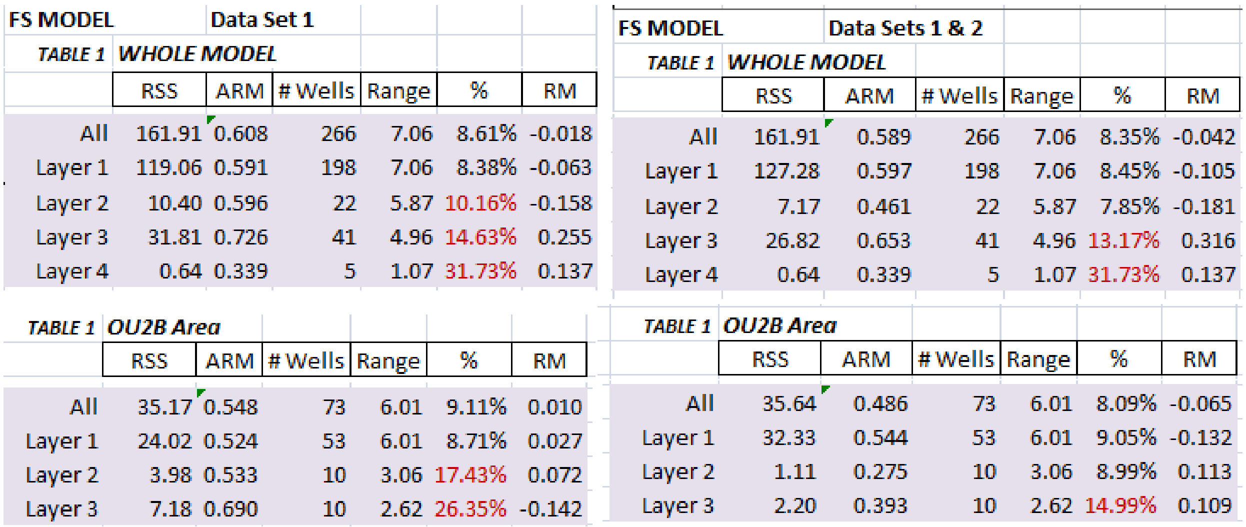
Table 1: Calibration Statistics Comparison



FS MODEL **Data Set 1**

TABLE 1 ***WHOLE MODEL***

	RSS	ARM	# Wells	Range	%	RM
All	161.91	0.608	266	7.06	8.61%	-0.018
Layer 1	119.06	0.591	198	7.06	8.38%	-0.063
Layer 2	10.40	0.596	22	5.87	10.16%	-0.158
Layer 3	31.81	0.726	41	4.96	14.63%	0.255
Layer 4	0.64	0.339	5	1.07	31.73%	0.137

TABLE 1 ***OU2B Area***

	RSS	ARM	# Wells	Range	%	RM
All	35.17	0.548	73	6.01	9.11%	0.010
Layer 1	24.02	0.524	53	6.01	8.71%	0.027
Layer 2	3.98	0.533	10	3.06	17.43%	0.072
Layer 3	7.18	0.690	10	2.62	26.35%	-0.142

FS MODEL **Data Sets 1 & 2**

TABLE 1 ***WHOLE MODEL***

	RSS	ARM	# Wells	Range	%	RM
All	161.91	0.589	266	7.06	8.35%	-0.042
Layer 1	127.28	0.597	198	7.06	8.45%	-0.105
Layer 2	7.17	0.461	22	5.87	7.85%	-0.181
Layer 3	26.82	0.653	41	4.96	13.17%	0.316
Layer 4	0.64	0.339	5	1.07	31.73%	0.137

TABLE 1 ***OU2B Area***

	RSS	ARM	# Wells	Range	%	RM
All	35.64	0.486	73	6.01	8.09%	-0.065
Layer 1	32.33	0.544	53	6.01	9.05%	-0.132
Layer 2	1.11	0.275	10	3.06	8.99%	0.113
Layer 3	2.20	0.393	10	2.62	14.99%	0.109

Attachment A
Flow Model Sensitivity Analysis and Validation

1. Introduction

Groundwater flow and transport modeling was conducted as part of the feasibility study (FS) for groundwater at Operable Unit-2B (OU-2B), Alameda Point, Alameda, California. The modeling methodology and results were documented in the Final OU-2B FS Report (OTIE 2011). As part of review of the Draft OU-2B FS Addendum (OTIE 2012), the United States Environmental Protection Agency (U.S. EPA) requested the Navy to perform sensitivity analysis and validation of the flow model. The following subsections present a summary of methodology and results for the OU-2B flow model sensitivity analysis and flow model validation.

1.1 FLOW MODEL SENSITIVITY ANALYSIS

The sensitivity tests were conducted for each of the 60 hydraulic conductivity zones, the three recharge zones, the four Constant Head (CH) zones, and the 28 General Head Boundary (GHB) zones, and the results are shown in Table 1. The calibration statistic used for reporting the results is the sum of squared residuals (SSR). The SSR for the calibrated flow model is 161 square feet (ft^2), and was considered the "base SSR" value for all comparisons. The maximum, minimum, and range between the two statistics were calculated and are listed below the SSR results for each tested parameter (see Table 1). The magnitude of the range of SSR was selected to rate the sensitivity of the flow model parameter as low (0 square feet [ft^2] to 10 ft^2), moderate (10 ft^2 to 50 ft^2), high (50 ft^2 to 161 ft^2), and very high (greater than 161 ft^2). In general, low SSR values indicated that a good calibration could be slightly impacted if particular K_h or K_v values were changed. High SSR values, assumed to be greater than 50 ft^2, indicate that a particular K-value is sensitive to change. Since the OU-2B area covers approximately 20 percent of the entire flow model domain, notations are made in Table 1 indicating which model parameters occur within OU-2B.

For hydraulic conductivity, the model was run with a single value of either horizontal hydraulic conductivity (K_h) or vertical hydraulic conductivity (K_v) multiplied by a set value (multipliers varying between 0.1 and 10 for both K_h and K_v). These simulations were repeated for each model K_h or K_v zone with all applicable multipliers. The resulting K_h SSR values range between 153.65 ft^2 and 7,325 ft^2. The lowest K_h SSR value is 153.65 ft^2 which is 8.57 ft^2 (4.7 percent) below the base SSR value. Plots of the K_h SSR results versus the multipliers are shown on Figures 1 through 4. These plots show results for the OU-2B area with low sensitivity K zones on Figure 1, moderate sensitivity K zones on Figure 2, and high sensitivity K zones on Figure 3, and very high sensitivity K zones on Figure 4. In general, the greatest SSR values are associated with the greatest and lowest multipliers.

The K_v SSR values showed a larger range, between 152.11 ft^2 and 10,714 ft^2. Plots of the K_v SSR results versus the multipliers are shown on Figures 5 through 7. These plots show results for the OU-2B area with low sensitivity K zones on Figure 5, moderate sensitivity K zones on Figure 6, and high sensitivity K zones on Figure 7. In general, the greatest SSR values are associated with the greatest and lowest multipliers. In several cases there are SSR values that are slightly lower than the base SSR which could indicate an improved model calibration. However, the K_h SSR and the associated K_v SSR needs to be considered together if the 10:1(K_h:K_v) ratio is to be maintained. The SSR for a particular K_h multiplier may be less than the base SSR but the SSR for the K_v value for the same multiplier many times is higher than the corresponding base SSR. The net result is degraded SSR. Another issue to be considered with the lower SSR value is the resulting K value if the multiplier is applied. For instance, as shown on Figure 2, the best SSR value (+1.43 ft^2) for K-zone 40 (80 ft/day) is with the 10x multiplier. The resulting K value would be 800 ft/day which is well above the acceptable range of K for the site.

There are two 80 feet/day K zones in the OU-2B area, zones 40 and 41. As can be seen in Table 1, both of these zones have low sensitivity so that their K value could be reduced to 0.1x (8 ft/day) with little impact to the calibration and the flow field. Both of the 80 feet/day K zones are relatively small zones which are surrounded by lower K zones which isolate these high K zones.

Table 2 summarizes the number of K-zones, both K_h and K_v, whose SSR Range values fall into the four sensitivity categories, by model layer and for those zones within or near the OU-2B area. There is a mix of sensitivity with the majority of the K-zones falling into the low sensitivity category. However, nearly half of the K_h zones are spread across the moderate to very high categories. Most of the K_v zones fall into the low sensitivity category. This indicates that the model K-zones are more sensitive horizontally than it is vertically.

The sensitivity test for the three recharge zones across the Alameda Point model domain had their values, in feet/day, multiplied by a set value varying between 0.5 and 1.5, or between 50-percent to 150-percent, and the SSR values are reported in Table 1. Period of record precipitation recorded at the Oakland Museum gauge site is 44 percent to 179 percent of normal precipitation. The 50 percent to 150 percent multiplier used is a reasonable approximation of the range. All three recharge zones had minimum SSRs at either 1x (two zones) or 0.9x (one zone) the current setting. The SSR Range varied between 3.7 ft2 to 1,632 ft2. Recharge zone 2 covers most of the OU-2B area has the minimum SSR at 1x and has the largest SSR range at both 0.5x and 1.5x. The resultant SSR show clear trends of degrading SSR at both multiplier end-points (0.1x and 10x) so any continued decrease or increase in multiplier for precipitation should show continuation of the trends. This indicates that almost any increase or decrease in recharge will adversely impact the flow model calibration.

The sensitivity test for the four CH zones located along the eastern (upgradient) side of the model were run for the head value ranging between -1.0 feet and +1.0 feet of the set value with the SSR values reported as results. The CH zones are oriented north to south, with zone 1 on the north and zone 4 on the south. The SSR Range varied between 0.483 ft^2 to 2.956 ft^2, all in the low sensitivity range.

The sensitivity test for the 28 GHB zones located along the northern, western, and southern sides of the model were run for two settings with each GHB, head and conductivity settings. There are 10 GHB zones in layer 1, and six each in layers 2, 3, and 4. In layer 1, zone 12 represents Seaplane Lagoon, and zones 2 to 5 are the GHB zones, positioned in order from north to south, along the eastern edge of Seaplane Lagoon, i.e., the western edge of OU-2B. GHB zone 11, located along the southeast edge of the flow model, is the closest of the other five layer 1 GHB zones to OU-2B area. The GHB zones in lower layers are positioned and labeled similarly as in layer 1; for instance, below layer 1 GHB zone 11 is GHB zone 21 in layer 2, GHB zone 31 in layer 3, and GHB zone 41 in layer 4.

The conductivity values (GHB-K) were multiplied by a set value varying between 0.1 and 10 and the GHB head (GHB-Ft) values were adjusted between -1.0 and +1.0 feet of the set value, with the SSR values reported as results. The median range of historic groundwater levels for the 296 wells at the site is 3.14 feet. The +/-1 feet results in 2 feet of range, or 64% of the range. That is reasonable range for these groundwater levels. The resulting GHB-K SSR range values were between 442.87 square feet (ft^2) and 0.003 ft^2, with two K_h -zones being greater than 200 ft^2. Plots of the GHB-K SSR results versus the multipliers are shown on Figures 8 and 9. These plots show results for the OU-2B area with low sensitivity K zones in Figure 8 and low and high sensitivity K zones on Figure 9. In general, the greatest SSR values are associated with the greatest and lowest multipliers.

The resulting GHB-Ft SSR range values were between 40.97 and 0.005ft^2, with the five highest SSR values of the GHB-Ft zones being only of moderate sensitivity. Table 3 summarizes the number of GHB-K and GHB-Ft zones, whose SSR Range values fall into the four categories, by model layer and for those zones in or near the OU-2B area. The majority of the GHB-K zones fall into the low sensitivity category although approximately a third of the GHB-K zones are spread across the moderate to very high categories. In the OU-2B area, all but one of the GHB-K zones are in the low sensitivity category. Most of the GHB-Ft zones fall into the low sensitivity category for the whole model and the OU-2B area. This indicates that the GHB-K settings in the flow model are more sensitive than the GHB-Ft settings.

1.2 FLOW MODEL VALIDATION EVALUATION

The groundwater flow model for OU-2B was calibrated using the average water level data from 1991 through 2005 (hereinafter referred to as "Data Set #1" or "Period 1 Data Set"). Data Set #1 contains groundwater level data for 295 wells within and outside the boundary of OU-2B. The flow model validation was performed using a more recent water level data (2006 through 2011) (herinafter referred to as "Data Set #2" or "Period 2 Data Set") for wells located within the boundary of or in the immediate vicinity of OU-2B. Data Set #2 contains groundwater level data for 123 wells.

Consistent with the recommendations of the U.S. EPA, prior to performing the flow model validation, a comparison of water level data collected from 1991 through 2005 (Period 1) with the data collected from 2006 through 2011 (Period 2), was conducted for 41 wells located within and in the immediate vicinity of OU-2B that have groundwater elevation data in both data sets. The results of this comparison are shown on Figure 10.

The vertical bars on Figure 1 depict the ranges of groundwater levels for Periods 1 and 2, and triangular symbols indicate the average groundwater elevation for each period. The bars on Figure 1 indicate that there is a significant overlap between the ranges of water levels for Period 1 and Period 2 for OU-2B wells.

The groundwater levels are subject to the known tidal influences and fluctuations in water levels (minimum/maximum) are likely temporal conditions. Therefore, the use of average water levels computed using Period 2 Data Set for validation is appropriate. Following comparison of Period 1 and Period 2 data sets, calibration residuals were calculated for the groundwater model by substituting average water level data based on Period 2 for 41 wells located within OU-2B. These calibration residuals are shown in Table 4 and in general show improved calibration statistics with lower ARM and percentage compared to calibration residuals using just Period 1 data

In addition, as a first step to evaluate the effect of including water level data collected from wells installed after 2004-2005, average water levels were computed for Layers 1, 2, and 3 of the groundwater model based on the Period 2 Data Set. These average values were compared with corresponding averages for Layers 1, 2, and 3 computed for wells within and in the immediate vicinity of OU-2B using Period 1 Data Set. As shown in Table 5, the differences in Layers 1, 2, and 3 average water levels computed based on Period 1 and Period 2 data sets range from 0.29 feet to 1.89 feet.

2. Conclusions

A sensitivity analysis was conducted for the OU-2B flow model for hydraulic conductivity zones, the three recharge zones, the four CH zones, and the 28 GHB zones. In addition, validation of OU-2B model was performed using a more recent water level data (2006 through 2011) for wells located within the boundary of or in the immediate vicinity of OU-2B. The following conculsions may be derived based on the results of the flow model sensitivity analysis and validation:

- More than half of the K-zones in the entire model fall into the low sensitivity category with less than one-third of the K_h zones spread across the high to very high sensitivity categories. Most of the K_v zones fall into the low sensitivity category. This indicates that the model K-zones are more sensitive horizontally than it is vertically.

- The two 80 feet/day K zones in the OU-2B area have low sensitivity so that their K value could be reduced to 8 ft/day (0.1x the current K value) with little impact to the calibration and the flow field.

- As expected, any increase or decrease in the recharge values currently used in the model will adversely impact the flow model calibration.

- The majority of the GHB-K zones fall into the low sensitivity category although approximately a third of the GHB-K zones are spread across the moderate to very high categories. In the OU-2B area all but one of the GHB-K zones are in the low sensitivity category. Most of the GHB-Ft zones fall into the low sensitivity category for the whole model and the OU-2B area. This indicates that the GHB-K settings in the flow model are more sensitive than the GHB-Ft settings.

- The flow model validation exercise showed that calibration statistics are improved if the most recent groundwater elevation data (2006 through 2011) were used for the wells within or the immediate vicinity of OU-2B. This demonstrates that the flow model calibration is reasonable.

3. References:

OTIE 2011. *Final Feasibility Study Report for Operable Unit (OU) 2B Installation Restoration Sites 3, 4, 11, and 21, Alameda Point. Alameda, California*. December.

OTIE 2012. *Draft Feasibility Study Report Addendum, Operable Unit 2B, Installation Restoration Sites 3, 4, 11, and 21, Alameda Point. Alameda, California*. February.

Tetra Tech (Tetra Tech). 2009. *Final Technical Memorandum for Data Gap Sampling at Operable Units 2A and 2B.* July 17.

_______. 2011. *Final Supplemental Data Gaps Sampling at Operable Units 2A And 2B, Alameda Point, Alameda, California.* September 19.

Tables

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TABLE 1

ALAMEDA POINT - OU2B: SENSITIVITY ANALYSIS RESULTS SUMMARY

Horizontal Conductivity Zones

Layer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1, 2	1, 3	2	2	2	2	2	2	2	2	2	3	3
K: Ft/D	0.10	0.10	8.00	8.00	10.00	5.00	7.50	10.00	0.13	0.13	0.10	1.00	0.10	0.02	0.10	0.05	0.10	10,000.0	0.25	0.24	2.00	0.11	0.10	1.00	1.00	0.25	2.00	1.00	12.46	14.00
Multiplier	Kx2	Kx3	Kx4	Kx5	Kx6	Kx7	Kx8	Kx9	Kx23	Kx24	Kx25	Kx26	Kx34	Kx43	Kx44	Kx45	Kx47	Kx19	Kx1	Kx10	Kx11	Kx12	Kx20	Kx21	Kx30	Kx31	Kx35	Kx48	Kx13	Kx14
0.1	165.84	164.36	194.35	166.77	161.24	165.00	**161.03**	**161.16**	161.27	161.76	161.92	162.30	161.50	187.48	**159.79**	**158.50**	162.41	162.47	162.50	162.98	163.91	161.61	161.31	161.24	161.23	161.46	161.52	164.85	1,022.56	325.43
0.3	164.37	163.51	178.30	164.70	161.21	163.50	161.10	161.18	161.27	161.53	161.57	162.10	161.40	164.36	160.19	159.28	161.92	161.49	161.99	162.27	163.08	161.51	161.29	161.24	161.23	161.40	161.45	162.44	345.11	203.58
0.5	163.23	162.76	170.30	163.35	161.20	162.62	161.14	161.20	161.26	161.40	161.41	161.85	161.33	161.12	160.59	159.94	161.62	161.33	161.68	161.82	162.43	161.42	161.27	161.23	161.23	161.35	161.38	161.71	223.12	178.04
0.7	162.31	162.10	165.47	162.35	**161.20**	161.97	161.18	161.21	161.24	161.31	161.32	161.59	161.28	**160.74**	160.89	160.51	161.42	161.26	161.46	161.52	161.89	161.34	161.25	161.23	161.22	161.30	161.31	161.40	181.72	167.84
0.85	161.73	161.64	163.02	161.74	161.21	161.57	161.20	161.22	161.23	161.26	161.26	161.40	161.25	160.92	161.07	160.88	161.31	161.24	161.33	161.35	161.54	161.28	161.24	161.23	161.22	161.26	161.27	161.28	168.05	163.77
1	161.22	161.22	**161.22**	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	**161.22**	161.22	161.22	**161.22**	**161.22**	161.22
2	159.02	159.05	157.81	159.03	161.40	159.69	161.31	161.25	161.15	161.09	161.05	160.27	161.07	163.26	161.79	162.87	**161.04**	161.20	160.76	160.73	**160.00**	160.88	161.13	161.20	161.22	161.01	160.97	161.35	166.91	**157.60**
4	157.35	156.55	166.58	157.45	162.00	158.25	161.41	161.27	161.04	**161.03**	160.87	159.28	160.86	165.29	162.19	164.62	161.38	**161.19**	160.31	160.30	161.08	160.35	160.96	161.16	161.23	160.65	160.57	162.04	208.83	163.22
6	**157.00**	155.15	180.92	**157.31**	162.71	157.57	161.47	161.28	160.97	161.03	160.75	**159.00**	160.70	166.21	162.35	165.56	161.92	437.97	160.09	160.04	165.57	159.97	160.81	161.13	161.26	160.37	160.26	162.56	242.98	169.84
8	157.16	154.26	196.46	157.77	163.45	157.18	161.50	161.28	160.92	161.06	160.66	159.12	160.58	166.72	162.43	166.15	162.47	468.63	159.98	159.91	172.50	159.68	160.68	161.10	161.30	160.12	160.01	162.94	269.88	175.69
10	157.57	**153.65**	211.89	158.55	164.17	**156.95**	161.53	161.29	**160.90**	161.11	**160.59**	159.51	**160.48**	167.06	162.49	166.56	162.99	7,486.84	**159.94**	**159.88**	181.24	**159.45**	**160.56**	**161.07**	161.34	**159.92**	**159.81**	163.22	291.84	180.71
Max:	165.84	164.36	211.89	166.77	164.17	165.00	161.53	161.29	161.27	161.76	161.92	162.30	161.50	187.48	162.49	166.56	162.99	7,486.84	162.50	162.98	181.24	161.61	161.31	161.24	161.34	161.46	161.52	164.85	1,022.56	325.43
Min:	157.00	153.65	157.81	157.31	161.20	156.95	161.03	161.16	160.90	161.03	160.59	159.00	160.48	160.74	159.79	158.50	161.04	161.19	159.94	159.88	160.00	159.45	160.56	161.07	161.22	159.92	159.81	161.22	161.22	157.60
Range:	8.839	10.713	**54.08**	9.467	2.971	8.048	0.500	0.131	0.369	0.725	1.324	3.303	1.019	26.745	2.695	8.061	1.950	**7,325.7**	2.565	3.102	21.237	2.153	0.749	0.176	0.114	1.542	1.717	3.633	**861.3**	**167.8**
Notes			OU2B		OU2B					OU2B		OU2B		OU2B	OU2B			open water			OU2B				OU2B		OU2B			

Vertical Conductivity Zones

Layer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1, 2	1, 3	2	2	2	2	2	2	2	2	2	3	3
K: Ft/D	0.01	0.01	0.80	0.80	1.00	0.50	0.75	1.00	0.01	0.01	0.01	0.10	0.01	0.00	0.01	0.01	0.01	10,000	0.03	0.02	0.20	0.01	0.01	0.10	0.10	0.03	0.20	0.10	12.46	1.40
Multiplier	Kz2	Kz3	Kz4	Kz5	Kz6	Kz7	Kz8	Kz9	Kz23	Kz24	Kz25	Kz26	Kz34	Kz43	Kz44	Kz45	Kz47	Kz19	Kz1	Kz10	Kz11	Kz12	Kz20	Kz21	Kz30	Kz31	Kz35	Kz48	Kz13	Kz14
0.1	2825.99	10865.79	**159.21**	**160.97**	**161.00**	162.98	**161.20**	161.22	1055.40	244.42	631.28	313.47	1612.02	**160.80**	**160.80**	**156.43**	253.01	161.22	758.68	2079.95	236.33	1657.43	477.758	161.368	**161.026**	1200.435	170.705	164.032	161.76	162.28
0.3	504.58	1237.04	160.50	161.08	161.15	161.68	161.21	161.22	261.15	176.93	224.91	176.59	306.60	160.87	160.91	156.95	177.10	161.22	208.91	347.08	169.08	347.37	197.953	161.272	161.079	290.935	161.808	161.850	161.37	161.48
0.5	234.78	363.46	160.90	161.15	161.19	161.42	161.22	161.22	174.74	164.49	172.82	165.91	192.71	160.95	161.01	158.28	165.93	161.22	170.65	199.78	163.41	208.73	168.959	161.245	161.142	198.287	161.245	161.482	161.28	161.33
0.7	178.68	211.90	161.08	161.19	161.21	161.31	161.22	161.22	161.62	161.73	163.04	162.89	168.12	161.05	161.10	159.61	162.78	161.22	163.33	168.94	161.92	174.26	162.511	161.232	161.184	173.359	**161.186**	161.331	161.25	161.27
0.85	166.02	176.60	161.16	161.21	161.22	161.26	161.22	161.22	**160.43**	161.25	161.39	161.85	163.03	161.13	161.16	160.48	161.78	161.22	161.75	162.65	161.46	165.14	161.285	161.226	161.205	165.508	161.198	161.267	161.23	161.24
1	**161.22**	161.22	161.22	161.22	161.22	161.22	161.22	**161.22**	161.22	**161.22**	**161.22**	**161.22**	**161.22**	161.22	161.22	161.22	161.22	161.22	**161.22**	**161.22**	**161.22**	**161.22**	**161.222**	161.222	161.222	161.222	161.222	161.222	161.22	161.22
2	164.15	**152.11**	161.39	161.26	161.24	161.12	161.22	161.22	170.52	162.64	165.24	159.88	162.85	161.87	161.53	164.08	160.25	**161.22**	162.26	172.39	160.98	162.35	165.892	161.210	161.286	**154.801**	161.362	161.098	161.19	161.17
4	173.81	163.31	161.48	161.28	161.25	161.08	161.22	161.22	178.91	164.17	169.86	159.44	166.87	163.11	161.90	166.00	160.10	161.22	164.14	188.06	161.29	170.61	172.144	161.202	161.329	154.979	161.476	161.037	161.18	161.14
6	178.12	169.00	161.51	161.29	161.25	161.06	161.23	161.22	182.24	164.77	171.80	159.31	168.62	164.09	162.10	166.71	**160.09**	161.22	164.96	195.11	161.56	174.66	175.175	161.200	161.347	155.580	161.520	161.017	161.17	161.13
8	180.47	172.18	161.52	161.29	161.25	**161.05**	161.22	161.22	184.00	165.08	172.84	159.26	169.56	164.83	162.24	167.08	160.10	161.22	165.41	199.03	161.76	176.95	176.948	161.199	161.355	155.987	161.545	161.008	**161.17**	161.13
10	181.94	174.19	161.53	161.29	161.25	161.05	161.22	161.22	185.09	165.27	173.49	159.23	170.15	165.40	162.33	167.31	160.10	161.22	165.69	201.51	161.92	178.41	178.118	**161.198**	161.361	156.267	161.559	**161.002**	161.17	**161.13**
Max:	2,825.99	10,865.79	161.53	161.29	161.25	162.98	161.23	161.22	1,055.40	244.42	631.28	313.47	1,612.02	165.40	162.33	167.31	253.01	161.22	758.68	2,079.95	236.33	1,657.43	477.76	161.37	161.36	1,200.44	170.71	164.03	161.76	162.28
Min:	161.22	152.11	159.21	160.97	161.00	161.05	161.20	161.22	160.43	161.22	161.22	159.23	161.22	160.80	160.80	156.43	160.09	161.22	161.22	161.22	160.98	161.22	161.22	161.20	161.03	154.80	161.19	161.00	161.17	161.13
Range:	**2,664.8**	**10,713.7**	2.323	0.320	0.254	1.930	0.027	0.007	**895.0**	**83.20**	**470.1**	**154.2**	**1,450.8**	4.603	1.522	10.873	**92.92**	0.004	**597.5**	**1,918.7**	**75.35**	**1,496.2**	**316.5**	0.170	0.335	**1,045.6**	9.519	3.029	0.592	1.155
Notes			OU2B		OU2B					OU2B		OU2B		OU2B	OU2B			open water			OU2B				OU2B		OU2B			

Horizontal Conductivity Zones

Layer	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
K: Ft/D	44.52	80.0	6.08	5.00	44.52	28.00	25.00	3.04	37.84	14.00	5.00	80.0	80.0	80.0	0.10	14.00	80.0	6.08	6.08	44.52	24.96	12.46	12.46	12.46	12.46	0.10	0.50	0.10	2.50	0.25
Multiplier	Kx15	Kx16	Kx17	Kx22	Kx27	Kx28	Kx29	Kx36	Kx37	Kx38	Kx39	Kx40	Kx41	Kx42	Kx46	Kx51	Kx52	Kx53	Kx54	Kx55	Kx56	Kx57	Kx58	Kx59	Kx60	Kx18	Kx32	Kx33	Kx49	Kx50
0.1	360.72	875.24	395.64	171.07	1,374.21	179.79	234.96	162.67	439.99	171.75	161.31	166.17	161.32	226.11	**159.76**	163.14	351.84	171.07	183.87	245.30	343.96	218.07	288.07	208.09	211.84	161.85	161.21	161.96	161.29	**160.89**
0.3	213.84	377.85	217.74	163.55	439.83	165.69	179.25	161.95	261.86	166.70	161.27	163.61	161.27	181.00	159.99	161.63	226.15	163.43	168.58	189.95	241.10	191.59	220.08	167.01	169.13	161.72	161.21	161.78	161.27	160.98
0.5	180.51	233.06	183.14	162.23	250.51	163.08	167.86	161.63	203.08	164.19	161.25	162.45	161.25	167.57	160.36	161.25	187.69	162.07	164.72	172.76	193.93	176.45	188.49	161.69	163.47	161.58	161.22	161.61	161.26	161.05
0.7	167.96	180.65	169.74	161.65	187.26	161.96	163.56	161.43	176.77	162.61	161.24	161.80	161.23	162.78	160.73	**161.15**	171.07	161.56	162.81	165.46	171.38	167.67	172.08	**160.49**	161.92	161.43	161.22	161.45	161.24	161.13
0.85	163.54	165.78	164.47	161.39	168.46	161.50	162.03	161.32	166.67	161.80	161.23	161.47	161.23	161.50	160.99	161.17	164.74	161.35	161.89	162.72	163.73	163.69	165.19	160.61	161.46	161.33	161.22	161.34	161.23	161.17
1	**161.22**	**161.22**	161.22	161.22	**161.22**	**161.22**	**161.22**	161.22	**161.22**	**161.22**	161.22	161.22	161.22	**161.22**	161.22	161.22	**161.22**	161.22	161.22	**161.22**	**161.22**	**161.22**	**161.22**	161.22	161.22	161.22	161.22	161.22	161.22	161.22
2	162.48	202.77	**157.16**	**160.91**	199.97	161.26	161.54	160.82	170.34	161.23	161.19	160.45	161.20	166.26	162.27	161.92	162.42	**160.97**	**160.12**	161.63	201.56	162.82	167.58	169.68	**161.01**	160.65	161.23	160.57	161.16	161.47
4	175.56	290.93	167.26	161.24	322.46	163.80	165.67	160.46	230.61	171.42	161.17	160.03	161.19	176.36	163.13	163.44	181.36	161.10	164.93	168.70	333.87	187.65	220.40	187.46	161.45	**160.10**	161.21	159.64	161.05	161.73
6	186.06	342.79	179.77	161.65	421.79	166.62	168.79	160.28	284.44	187.38	161.16	159.90	161.18	182.29	163.49	164.74	195.31	161.34	172.70	173.65	445.17	212.14	275.06	200.82	162.08	160.15	161.17	159.15	160.96	161.84
8	194.11	376.01	191.67	161.97	501.10	169.22	171.03	160.18	327.25	205.38	161.16	159.83	161.18	186.03	163.68	165.87	204.92	161.56	181.00	176.97	531.62	232.83	323.91	210.85	162.79	160.64	161.12	**159.01**	160.90	161.88
10	200.48	399.21	202.64	162.23	566.07	171.54	172.72	**160.12**	361.33	223.78	**161.15**	**159.79**	**161.17**	188.59	163.80	166.90	211.82	161.75	189.01	179.33	599.42	250.20	366.81	218.66	163.57	161.46	**161.07**	159.16	**160.85**	161.88
Max:	360.72	875.24	395.64	171.07	1,374.21	179.79	234.96	162.67	439.99	223.78	161.31	166.17	161.32	226.11	163.80	166.90	351.84	171.07	189.01	245.30	599.42	250.20	366.81	218.66	211.84	161.85	161.23	161.96	161.29	161.88
Min:	161.22	161.22	157.16	160.91	161.22	161.22	161.22	160.12	161.22	161.22	161.15	159.79	161.17	161.22	159.76	161.15	161.22	160.97	160.12	161.22	161.22	161.22	161.22	160.49	161.01	160.10	161.07	159.01	160.85	160.89
Range:	**199.5**	**714.0**	**238.5**	10.154	**1,213.0**	18.573	**73.74**	2.552	**278.8**	**62.559**	0.156	6.379	0.144	**64.89**	4.042	5.746	**190.6**	10.104	28.888	**84.07**	**438.2**	**88.97**	**205.6**	**58.18**	**50.83**	1.745	0.152	2.955	0.441	0.988
Notes						OU2B	OU2B	OU2B		OU2B		OU2B	OU2B						OU2B	OU2B	OU2B				OU2B	OU2B		OU2B		

Vertical Conductivity Zones

Layer	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
K: Ft/D	4.45	8.00	0.61	0.50	4.45	2.80	2.50	0.30	3.78	1.40	0.50	8.00	8.00	8.00	0.01	1.40	8.00	0.61	0.61	4.40	2.50	1.25	1.25	1.25	1.25	0.01	0.05	0.01	0.25	0.03
Multiplier	Kz15	Kz16	Kz17	Kz22	Kz27	Kz28	Kz29	Kz36	Kz37	Kz38	Kz39	Kz40	Kz41	Kz42	Kz46	Kz51	Kz52	Kz53	Kz54	Kz55	Kz56	Kz57	Kz58	Kz59	Kz60	Kz18	Kz32	Kz33	Kz49	Kz50
0.1	161.603	161.555	164.622	163.471	163.266	161.520	162.468	**161.122**	161.814	161.829	161.228	161.241	161.236	**161.069**	171.362	161.688	164.603	163.215	163.600	161.373	163.586	161.324	162.480	**158.792**	162.538	163.521	163.706	161.299	162.993	167.824
0.3	161.312	161.297	161.958	161.683	161.926	161.319	161.482	161.160	161.367	161.460	161.224	161.227	161.225	161.178	166.218	161.358	162.428	161.551	161.734	161.249	160.801	161.235	161.551	160.409	161.626	162.580	161.547	161.253	161.705	163.367
0.5	161.260	161.252	161.523	161.408	161.566	161.275	161.327	161.187	161.283	161.339	161.223	161.224	161.224	161.203	163.772	161.281	161.780	161.341	161.429	161.233	**160.737**	161.226	161.364	160.857	161.409	162.009	161.286	161.240	161.429	162.138
0.7	161.238	161.236	161.349	161.300	161.382	161.248	161.267	161.205	161.248	161.275	161.223	161.223	161.223	161.214	162.395	161.248	161.471	161.268	161.309	161.226	160.918	161.223	161.283	161.062	161.307	161.611	161.230	161.229	161.310	161.606
0.85	161.229	161.227	161.274	161.254	161.291	161.232	161.240	161.215	161.233	161.244	161.222	161.223	161.222	161.219	161.718	161.233	161.325	161.240	161.257	161.224	161.073	161.223	161.248	161.157	161.258	161.390	**161.220**	161.227	161.258	161.378
1	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222	**161.222**	161.222	161.222	161.222	161.222	161.222	161.222	161.222	161.222
2	161.204	161.207	161.079	161.136	160.989	161.177	161.173	161.247	161.192	161.156	**161.221**	161.221	**161.221**	161.231	159.774	161.191	160.915	161.176	161.126	161.218	161.949	161.222	161.151	161.414	161.107	**160.906**	161.274	161.211	161.121	160.817
4	161.194	161.200	161.009	161.095	160.834	161.141	161.150	161.262	161.177	161.126	161.221	161.222	161.221	161.238	159.110	161.176	160.755	161.159	161.080	161.215	162.651	161.222	161.116	161.513	161.032	161.991	161.339	161.199	161.072	160.646
6	161.192	161.197	160.988	161.081	160.768	161.126	161.142	161.266	161.172	161.122	161.221	**161.221**	161.221	161.239	158.921	161.171	160.701	161.153	161.066	**161.214**	162.995	161.222	161.103	161.546	161.002	163.803	161.368	161.194	161.057	160.596
8	**161.189**	161.196	160.976	161.075	160.731	161.117	161.138	161.268	161.170	**161.121**	161.221	161.221	161.220	161.240	158.836	161.168	160.674	161.151	161.056	161.214	163.201	161.223	161.098	161.562	160.985	165.825	161.387	161.190	161.048	160.573
10	161.189	**161.195**	**160.969**	**161.071**	160.707	161.112	161.136	161.270	**161.169**	161.120	161.222	161.220	161.220	161.240	**158.789**	**161.167**	**160.657**	**161.149**	**161.053**	161.215	163.341	161.223	**161.093**	161.573	**160.973**	167.880	161.396	**161.187**	**161.042**	**160.561**
Max:	161.60	161.55	164.62	163.47	163.27	161.52	162.47	161.27	161.81	161.83	161.23	161.24	161.24	161.24	171.36	161.69	164.60	163.21	163.60	161.37	163.59	161.32	162.48	161.57	162.54	167.88	163.71	161.30	162.99	167.82
Min:	161.19	161.20	160.97	161.07	160.71	161.11	161.14	161.12	161.17	161.12	161.22	161.22	161.22	161.07	158.79	161.17	160.66	161.15	161.05	161.21	160.74	161.22	161.09	158.79	160.97	160.91	161.22	161.19	161.04	160.56
Range:	0.414	0.359	3.653	2.401	2.559	0.408	1.332	0.148	0.646	0.709	0.007	0.020	0.016	0.171	12.574	0.521	3.946	2.065	2.547	0.159	2.849	0.103	1.387	2.781	1.564	6.974	2.486	0.111	1.951	7.264
Notes						OU2B	OU2B	OU2B		OU2B		OU2B	OU2B						OU2B	OU2B	OU2B				OU2B	OU2B		OU2B		

TABLE 1 Continued

ALAMEDA POINT - OU2B: SENSITIVITY ANALYSIS RESULTS SUMMARY

GHB K Parameter Sensitivity Analysis

Layer	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
K: Ft/D	2.50	2.00	2.10	2.00	1.20	1.20	2.00	3.20	0.21	2.25	2.00	1.00	4.00	1.50	1.06	1.00
Multiplier	GHB K 2	GHB K 3	GHB K 4	GHB K 5	GHB K 11	GHB K 12	GHB K 13	GHB K 14	GHB K 15	GHB K 16	GHB K 21	GHB K 22	GHB K 23	GHB K 24	GHB K 25	GHB K26
0.1	163.631	161.269	**161.131**	**161.131**	161.247	212.628	161.382	185.424	161.270	161.827	161.332	**161.212**	167.289	166.432	**161.186**	161.285
0.3	162.198	161.228	161.151	161.158	161.239	169.095	161.343	173.227	161.253	161.565	161.300	161.213	164.244	164.434	161.195	161.250
0.5	161.692	161.222	161.183	161.177	161.234	163.562	161.307	166.657	161.244	161.409	161.273	161.216	162.509	162.969	161.203	161.233
0.7	161.434	161.221	161.203	161.195	161.228	161.991	161.270	163.174	161.233	161.310	161.250	161.219	161.609	161.970	161.210	161.225
0.85	161.311	**161.221**	161.214	161.210	161.225	161.493	161.246	161.828	161.227	161.259	161.236	161.220	161.305	161.492	161.217	**161.221**
1	161.222	161.222	161.222	161.222	161.222	161.222	161.222	**161.222**	161.222	161.222	161.222	161.222	**161.222**	**161.222**	161.222	161.222
2	160.955	161.236	161.248	161.292	161.207	**160.874**	161.086	166.109	161.203	**161.130**	161.159	161.234	163.311	163.496	161.257	161.237
4	160.814	161.275	161.264	161.390	161.188	160.976	160.902	186.332	**161.195**	161.143	161.093	161.257	169.505	179.742	161.314	161.272
6	160.767	161.321	161.270	161.475	161.175	161.059	160.783	205.357	161.196	161.177	161.059	161.282	174.164	201.593	161.360	161.296
8	160.743	161.372	161.272	161.550	161.163	161.117	160.705	221.442	161.199	161.206	161.037	161.307	177.472	224.334	161.400	161.312
10	**160.729**	161.426	161.275	161.623	**161.155**	161.167	**160.649**	234.983	161.201	161.228	**161.023**	161.330	179.892	246.310	161.436	161.324
Max:	163.63	161.43	161.27	161.62	161.25	212.63	161.38	234.98	161.27	161.83	161.33	161.33	179.89	246.31	161.44	161.32
Min:	160.73	161.22	161.13	161.13	161.15	160.87	160.65	161.22	161.19	161.13	161.02	161.21	161.22	161.22	161.19	161.22
Range:	2.903	0.205	0.143	0.492	0.092	51.75	0.733	73.76	0.075	0.697	0.309	0.118	18.670	85.09	0.250	0.103
Notes	OU2B	OU2B	OU2B		OU2B	OU2B					OU2B	OU2B				

Layer	3	3	3	3	3	3	4	4	4	4	4	4
K: Ft/D	25.0	4.25	8.00	1.00	10.5	7.50	0.50	0.50	0.50	0.55	0.50	0.50
Multiplier	GHB K 31	GHB K 32	GHB K 33	GHB K 34	GHB K 35	GHB K 36	GHB K 41	GHB K 42	GHB K 43	GHB K 44	GHB K 45	GHB K 46
0.1	162.135	161.493	216.327	218.956	403.887	193.502	161.296	161.234	161.608	172.377	**161.220**	**161.208**
0.3	161.483	161.426	180.927	193.506	192.344	165.009	161.247	161.227	161.344	166.717	161.221	161.211
0.5	161.338	161.361	168.845	176.797	167.894	161.988	161.233	161.224	161.278	163.593	161.222	161.214
0.7	161.273	161.302	163.828	166.805	162.424	161.338	161.227	161.223	161.245	161.965	161.222	161.218
0.85	161.243	161.262	162.073	162.802	161.367	161.224	161.224	161.222	161.232	161.394	161.222	161.219
1	161.222	161.222	**161.222**	**161.222**	**161.222**	**161.222**	161.222	161.222	161.222	**161.222**	161.222	161.222
2	161.161	161.012	162.684	188.752	164.086	161.679	161.216	161.221	161.194	165.341	161.223	161.237
4	161.130	160.773	168.540	308.198	167.831	162.276	161.213	161.221	161.180	180.998	161.222	161.266
6	161.119	160.676	172.187	425.817	169.532	162.558	161.212	161.220	161.175	196.581	161.223	161.292
8	161.113	**160.658**	174.514	523.972	170.485	162.719	161.212	161.220	161.173	210.340	161.222	161.317
10	**161.110**	160.684	176.115	604.087	171.094	162.823	**161.211**	**161.219**	**161.171**	222.293	161.223	161.338
Max:	162.14	161.49	216.33	604.09	403.89	193.50	161.30	161.23	161.61	222.29	161.22	161.34
Min:	161.11	160.66	161.22	161.22	161.22	161.22	161.21	161.22	161.17	161.22	161.22	161.21
Range:	1.025	0.835	55.11	442.9	242.7	32.280	0.085	0.015	0.437	61.07	0.003	0.130
Notes	OU2B	OU2B					OU2B	OU2B				

GHB HEAD Parameter Sensitivity Analysis

Layer	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Head:	5	4	4	2.978	1	1.6	3	-2	2	1	1	3	-2	-2	1	1
Multiplier	GHB GW 2	GHB GW 3	GHB GW 4	GHB GW 5	GHB GW 11	GHB GW 12	GHB GW 13	GHB GW 14	GHB GW 15	GHB GW 16	GHB GW 21	GHB GW 22	GHB GW 23	GHB GW 24	GHB GW 25	GHB GW 26
-1	162.81	161.88	162.41	**161.09**	**161.20**	187.92	**161.10**	161.50	**161.20**	**161.16**	**161.05**	**161.21**	161.43	161.28	161.21	161.25
-0.8	162.44	161.68	161.86	161.12	161.20	177.16	161.12	161.35	161.20	161.17	161.08	161.22	161.35	161.24	161.21	161.24
-0.6	162.10	161.51	161.47	161.14	161.21	169.12	161.15	161.24	161.20	161.18	161.12	161.22	161.29	**161.21**	161.21	161.23
-0.4	161.78	161.37	161.23	161.17	161.21	163.78	161.17	161.19	161.21	161.19	161.15	161.22	161.25	161.20	161.21	161.22
-0.2	161.49	161.28	**161.15**	161.19	161.22	**161.15**	161.20	**161.18**	161.22	161.21	161.19	161.22	161.22	161.20	161.22	161.22
0	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	161.22	**161.22**	161.22	161.22	**161.22**
0.2	160.98	**161.20**	161.45	161.25	161.23	164.00	161.25	161.31	161.23	161.24	161.26	161.22	161.24	161.25	161.23	161.22
0.4	160.77	161.22	161.84	161.28	161.23	169.48	161.28	161.45	161.24	161.26	161.29	161.23	161.27	161.30	161.23	161.23
0.6	160.59	161.27	162.39	161.31	161.24	177.66	161.30	161.64	161.25	161.29	161.33	161.23	161.33	161.36	161.24	161.24
0.8	160.44	161.37	163.10	161.33	161.24	188.55	161.33	161.88	161.26	161.31	161.37	161.23	161.40	161.44	161.26	161.25
1	**160.31**	161.50	163.96	161.36	161.24	202.12	161.36	162.17	161.27	161.34	161.40	161.23	161.50	161.53	161.27	161.26
Max:	162.81	161.88	163.96	161.36	161.24	202.12	161.36	162.17	161.27	161.34	161.40	161.23	161.50	161.53	161.27	161.26
Min:	160.31	161.20	161.15	161.09	161.20	161.15	161.10	161.18	161.20	161.16	161.05	161.21	161.22	161.20	161.21	161.22
Range:	2.495	0.683	2.811	0.274	0.043	40.974	0.257	0.984	0.072	0.181	0.354	0.019	0.277	0.326	0.057	0.041
Notes	OU2B	OU2B	OU2B		OU2B	OU2B					OU2B	OU2B				

Layer	3	3	3	3	3	3	4	4	4	4	4	4
Head:	1.6	0	2	-2	-1	1.4	-3	-2	-3	-3	-2	-3
Multiplier	GHB GW 31	GHB GW 32	GHB GW33	GHB GW 34	GHB GW 35	GHB GW 36	GHB GW 41	GHB GW 42	GHB GW 43	GHB GW 44	GHB GW 45	GHB GW 46
-1	162.71	**161.08**	166.54	162.81	181.90	186.36	**161.16**	**161.21**	**161.07**	161.74	161.23	161.23
-0.8	160.44	161.10	163.92	162.23	174.55	177.60	161.17	161.21	161.10	161.58	161.23	161.22
-0.6	159.16	161.13	162.07	161.78	168.81	170.70	161.18	161.22	161.13	161.45	161.22	161.22
-0.4	**158.86**	161.16	161.01	161.46	164.67	165.68	161.20	161.22	161.16	161.35	161.22	161.22
-0.2	159.55	161.19	**160.73**	161.28	162.14	162.52	161.21	161.22	161.19	161.27	161.22	161.22
0	161.22	161.22	161.22	**161.22**	**161.22**	**161.22**	161.22	161.22	161.22	161.22	**161.22**	161.22
0.2	163.87	161.25	162.50	161.30	161.90	161.79	161.24	161.22	161.25	**161.20**	161.22	161.22
0.4	167.51	161.29	164.55	161.51	164.18	164.21	161.25	161.23	161.29	161.20	161.22	161.22
0.6	172.13	161.32	167.38	161.85	168.07	168.48	161.26	161.23	161.32	161.23	161.22	161.22
0.8	177.73	161.35	170.98	162.32	173.54	174.60	161.27	161.23	161.36	161.29	161.22	161.22
1	184.30	161.39	175.37	162.92	180.62	182.56	161.29	161.23	161.40	161.37	161.22	**161.22**
Max:	184.30	161.39	175.37	162.92	181.90	186.36	161.29	161.23	161.40	161.74	161.23	161.23
Min:	158.86	161.08	160.73	161.22	161.22	161.22	161.16	161.21	161.07	161.20	161.22	161.22
Range:	25.439	0.308	14.639	1.701	20.680	25.140	0.130	0.019	0.325	0.539	0.005	0.007
Notes	OU2B	OU2B					OU2B	OU2B				

RECHARGE Sensitivity Analysis

Layer	1	1	1
Ft/Day:	0.002236	0.001444	0.002362
Multiplier	Recharge2	Recharge3	Recharge4
0.5	1,443.77	249.00	163.91
0.6	964.85	210.62	162.86
0.7	595.56	182.62	162.07
0.8	337.40	165.04	161.53
0.9	192.02	**157.90**	161.25
1	**161.22**	161.22	**161.22**
1.1	246.94	175.03	161.45
1.2	451.23	199.36	161.93
1.3	776.15	234.24	162.66
1.4	1,223.47	279.69	163.65
1.5	1,793.22	335.76	164.89
Max:	1,793.22	335.76	164.89
Min:	161.22	157.90	161.22
Range:	1,632.0	177.9	3.673
Notes	OU2B		OU2B

CONSTANT HEAD Sensitivity Analysis

Layer	1	1	1	1
Head Range	4.77' to 13.68'	12.24' to 9.57'	9.45' to 6.98'	6.84' to 1.15'
Multiplier	**CH 1**	**CH 2**	**CH 3**	**CH 4**
-1	163.903	**161.022**	**160.806**	**160.689**
-0.8	163.143	161.056	160.882	160.786
-0.6	162.495	161.093	160.962	160.887
-0.4	161.957	161.133	161.044	160.994
-0.2	161.533	161.176	161.131	161.106
0	161.222	161.222	161.222	161.222
0.2	161.026	161.271	161.317	161.344
0.4	**160.947**	161.324	161.417	161.471
0.6	160.985	161.382	161.520	161.604
0.8	161.141	161.442	161.628	161.742
1	161.415	161.505	161.739	161.887
Max:	163.90	161.51	161.74	161.89
Min:	160.95	161.02	160.81	160.69
Range:	2.956	0.483	0.933	1.197
Notes				

Sensitivity Ranking

% of Base SSR (161.22)

Kx	Kz	GHB K	GHB Ft	CH	Recharge	Minimum	Maximum	Rating
(count)	(count)	(count)	(count)	(count)	(count)			
34	44	19	23	4	1	0.0	10.0	slight
7	2	2	5	0	0	10.0	50.0	moderate
8	3	5	0	0	0	50.0	161.2	high
11	11	2	0	0	2	> 161.2		very high
60	60	28						

TABLE 2 Kh and Kv Sensitivity Summary by Layer

K_H	WHOLE MODEL				OU-2B AREA			
Sensitivity:	L	M	H	VH	L	M	H	VH
Layer								
1	15	2	1	1	4	1	1	-
2	8	1	-	-	2	1	-	-
3	6	4	7	10	3	2	4	1
4	5	-	-	-	2	-	-	-
Sub-Total:	34	7	8	11	11	4	5	1

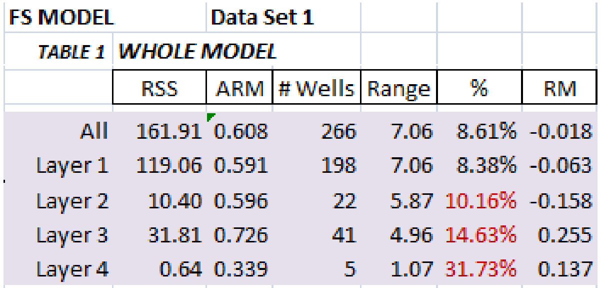
K_Z	WHOLE MODEL				OU-2B AREA			
Sensitivity:	L	M	H	VH	L	M	H	VH
Layer								
1	9	1	2	7	5	-	1	-
2	4	-	1	4	2	-	1	-
3	26	1	-	-	10	-	-	-
4	5	-	-	-	2	-	-	-
Sub-Total:	44	2	3	11	19	0	2	0

TABLE 3 General Head Boundary K and Ft Sensitivity Summary by Layer

GHB K	**WHOLE MODEL**				**OU-2B AREA**			
Sensitivity:	L	M	H	VH	L	M	H	VH
Layer								
1	8	-	2	-	4	1	-	-
2	4	1	1	-	2	-	-	-
3	2	1	1	2	2	-	-	-
4	5	-	1	-	2	-	-	-
Sub-Total:	19	2	5	2	10	1	0	0

GHB Ft	**WHOLE MODEL**				**OU-2B AREA**			
Sensitivity:	L	M	H	VH	L	M	H	VH
Layer								
1	9	1	-	-	4	1	-	-
2	6	-	-	-	2	-	-	-
3	2	4	-	-	1	1	-	-
4	6	-	-	-	2	-	-	-
Sub-Total:	23	5	0	0	9	2	0	0

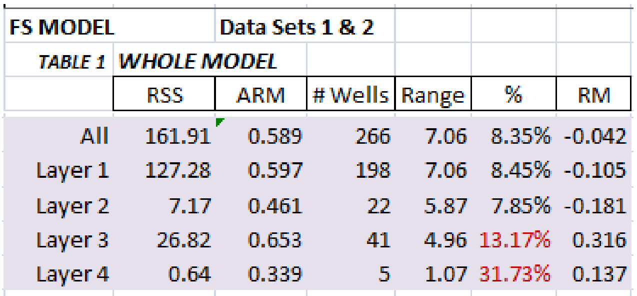
Table 4 Calibration Statistics Comparison



FS MODEL — **Data Set 1**

TABLE 1 ***WHOLE MODEL***

	RSS	ARM	# Wells	Range	%	RM
All	161.91	0.608	266	7.06	8.61%	-0.018
Layer 1	119.06	0.591	198	7.06	8.38%	-0.063
Layer 2	10.40	0.596	22	5.87	10.16%	-0.158
Layer 3	31.81	0.726	41	4.96	14.63%	0.255
Layer 4	0.64	0.339	5	1.07	31.73%	0.137



FS MODEL — **Data Sets 1 & 2**

TABLE 1 ***WHOLE MODEL***

	RSS	ARM	# Wells	Range	%	RM
All	161.91	0.589	266	7.06	8.35%	-0.042
Layer 1	127.28	0.597	198	7.06	8.45%	-0.105
Layer 2	7.17	0.461	22	5.87	7.85%	-0.181
Layer 3	26.82	0.653	41	4.96	13.17%	0.316
Layer 4	0.64	0.339	5	1.07	31.73%	0.137

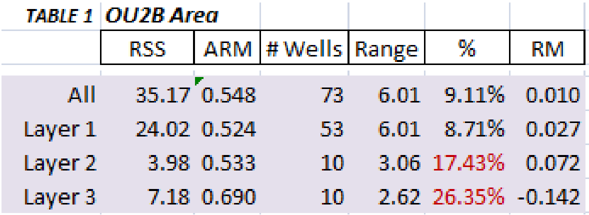


TABLE 1 ***OU2B Area***

	RSS	ARM	# Wells	Range	%	RM
All	35.17	0.548	73	6.01	9.11%	0.010
Layer 1	24.02	0.524	53	6.01	8.71%	0.027
Layer 2	3.98	0.533	10	3.06	17.43%	0.072
Layer 3	7.18	0.690	10	2.62	26.35%	-0.142

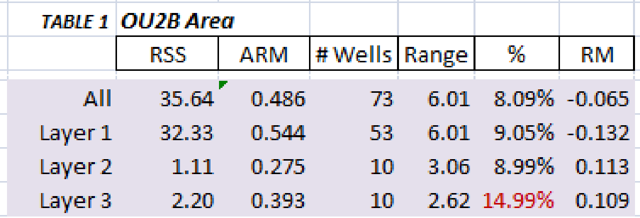


TABLE 1 ***OU2B Area***

	RSS	ARM	# Wells	Range	%	RM
All	35.64	0.486	73	6.01	8.09%	-0.065
Layer 1	32.33	0.544	53	6.01	9.05%	-0.132
Layer 2	1.11	0.275	10	3.06	8.99%	0.113
Layer 3	2.20	0.393	10	2.62	14.99%	0.109

Table 5: Comparison of Average Water Levels for Model Layers (OU-2B Area)

Layer	Average Water Levels (feet bgs)		Difference In Water Levels (feet) (Period 1 - Period 2)
	Period 1 (1991 - 2005)	Period 2 (2006 - 2011)	
1	7.06	6.77	0.29
2	8.02	6.13	1.89
3	6.85	5.34	1.51

Figures

Figure 1 - Sensitivity Analysis for OU2B, Kh Values, Layers 1, 2, and 3

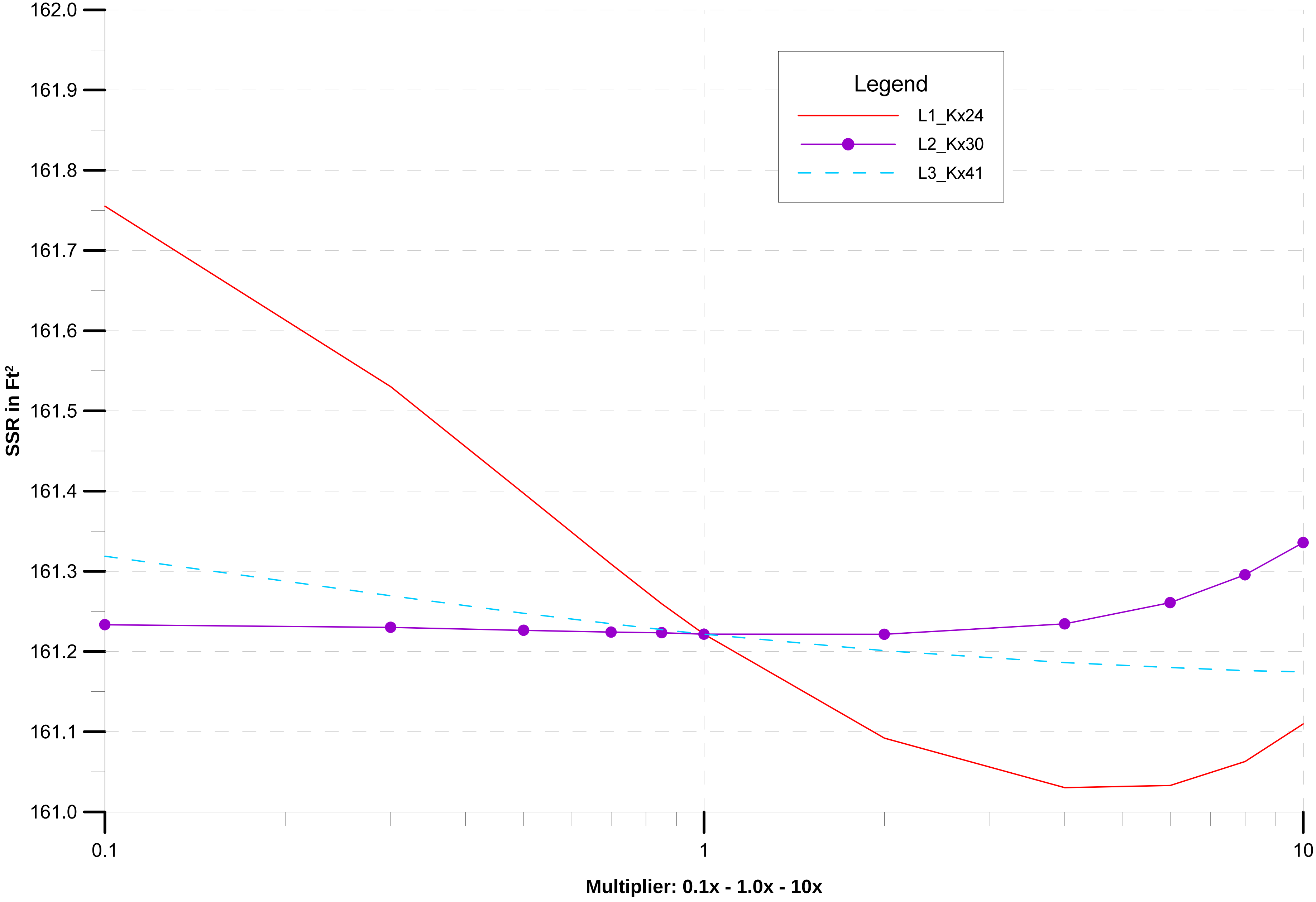


Figure 2 - Sensitivity Analysis for OU2B, KhValues, Layers 1, 2, 3, and 4

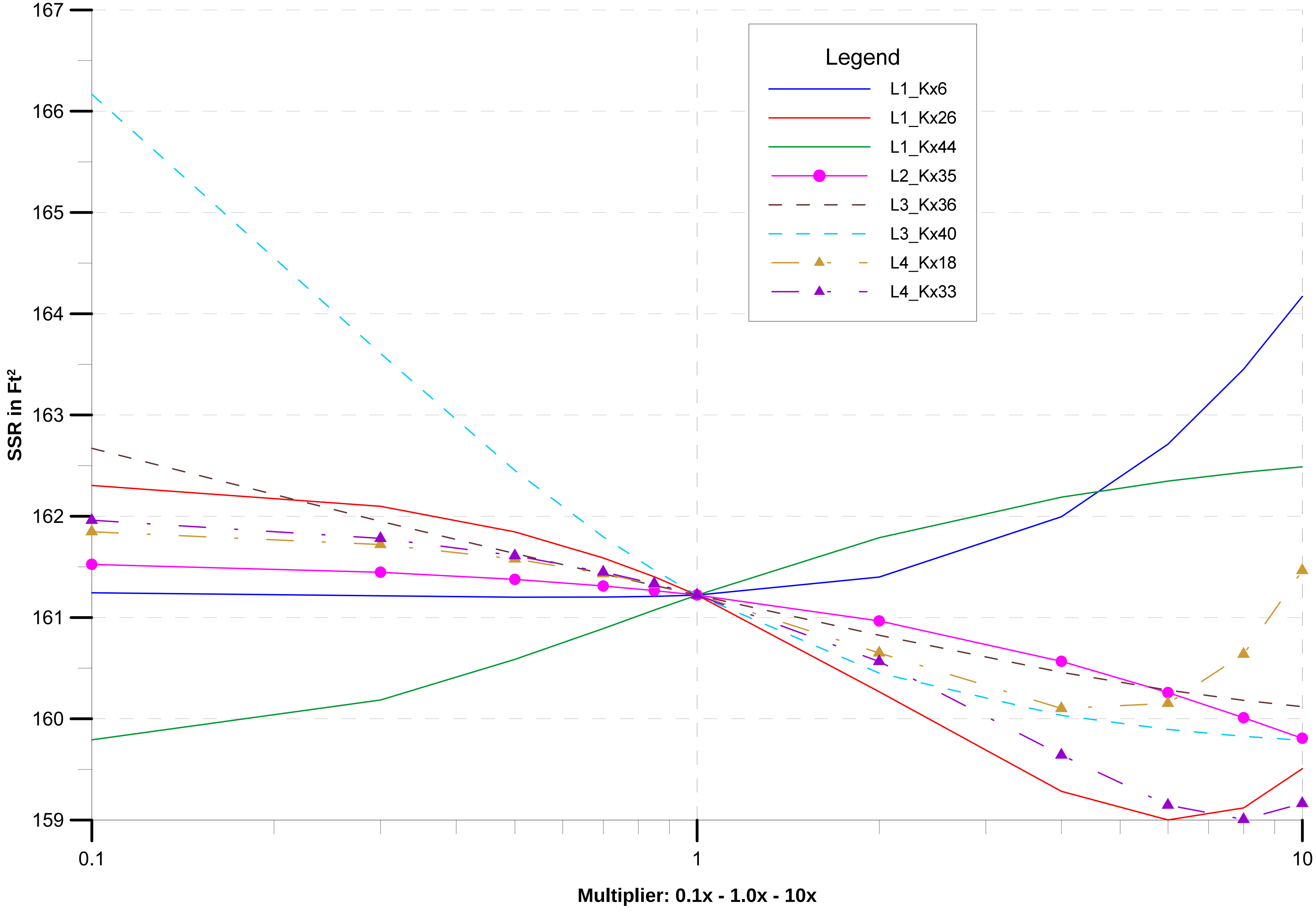


Figure 3 - Sensitivity Analysis for OU2B, Kh Values, Layers 1, 2, and 3

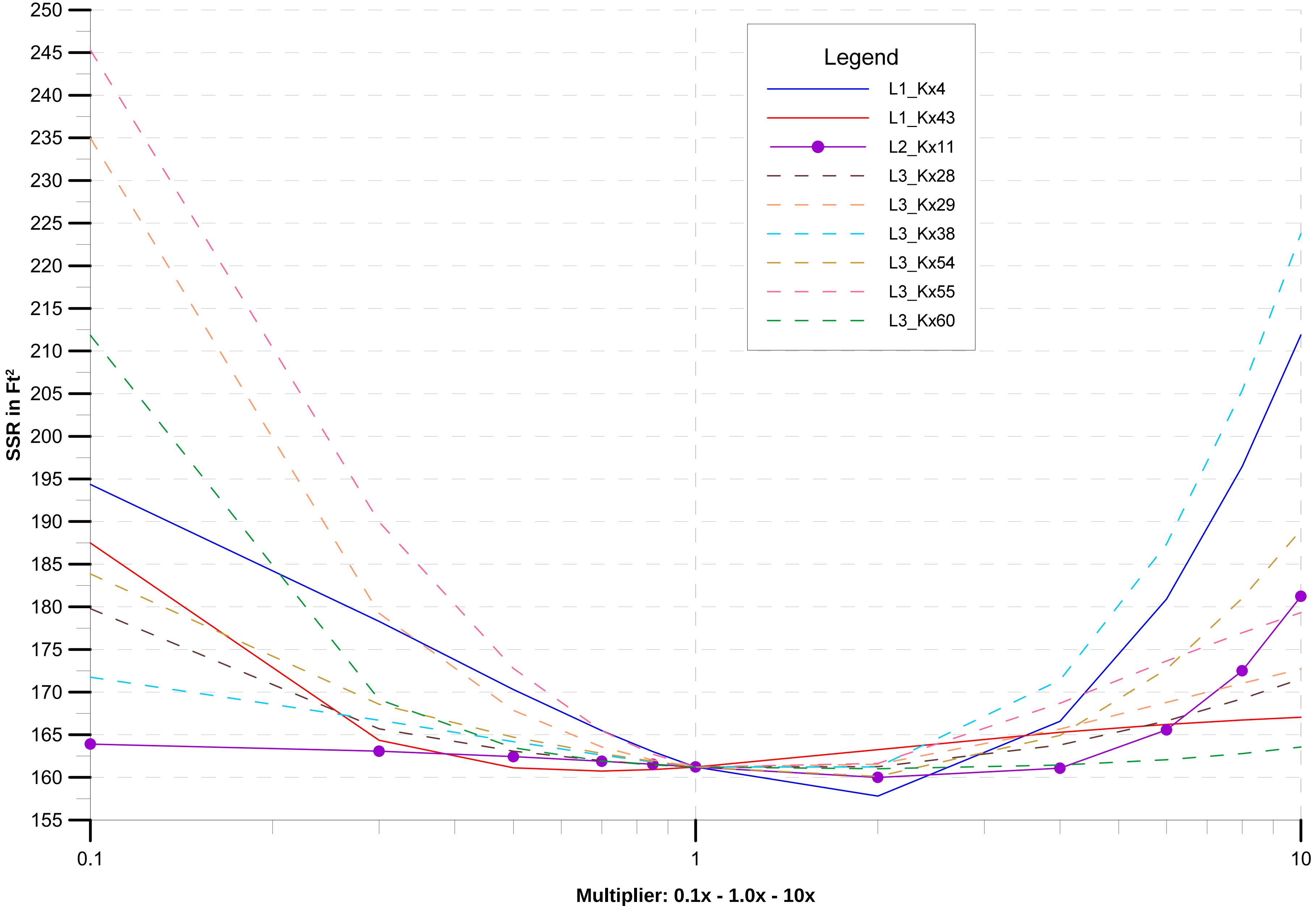


Figure 4 - Sensitivity Analysis for OU2B, Kh Values, Layer 3

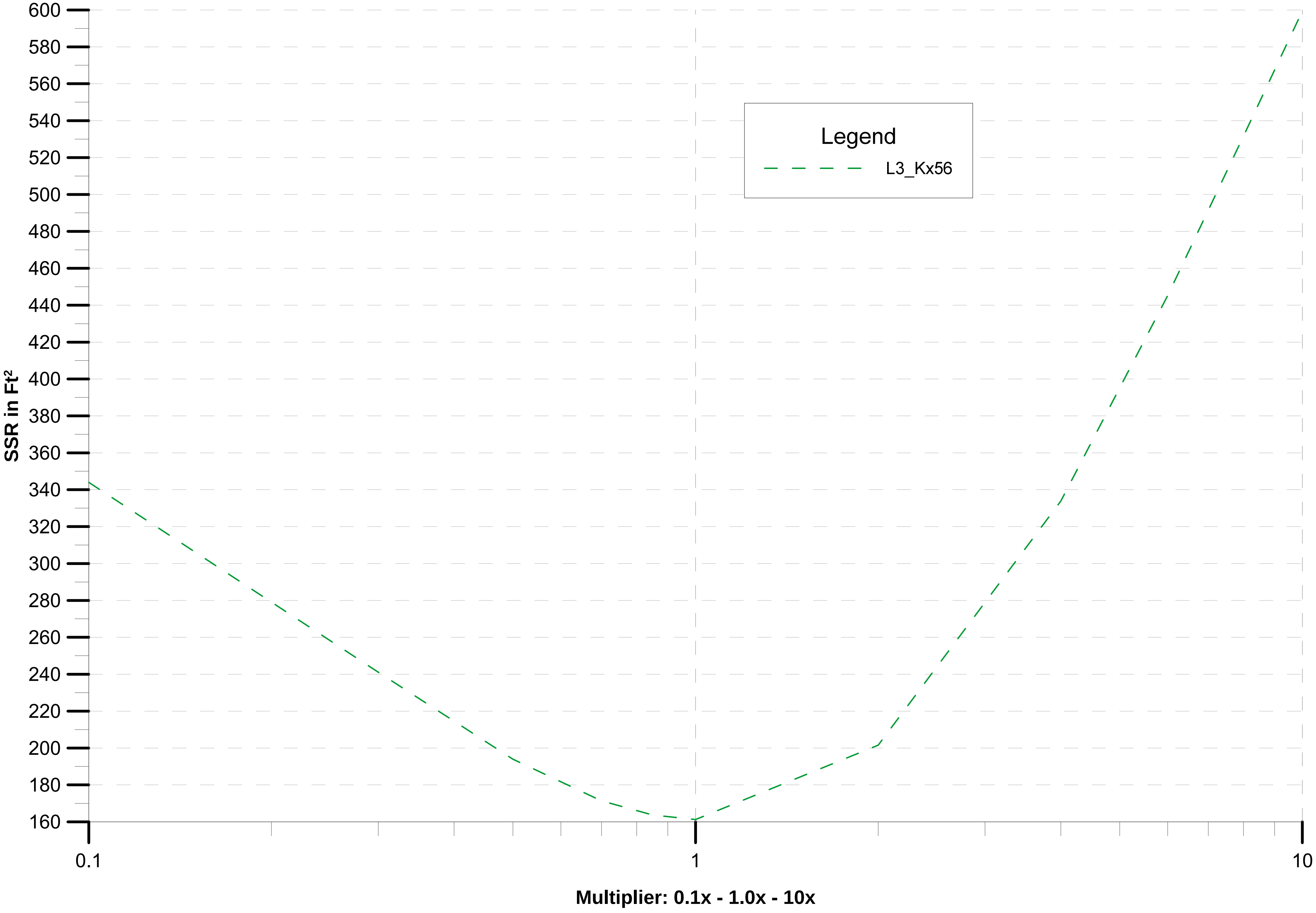


Figure 5 - Sensitivity Analysis for OU2B, Kv Values, Layers 1, 2, 3, and 4

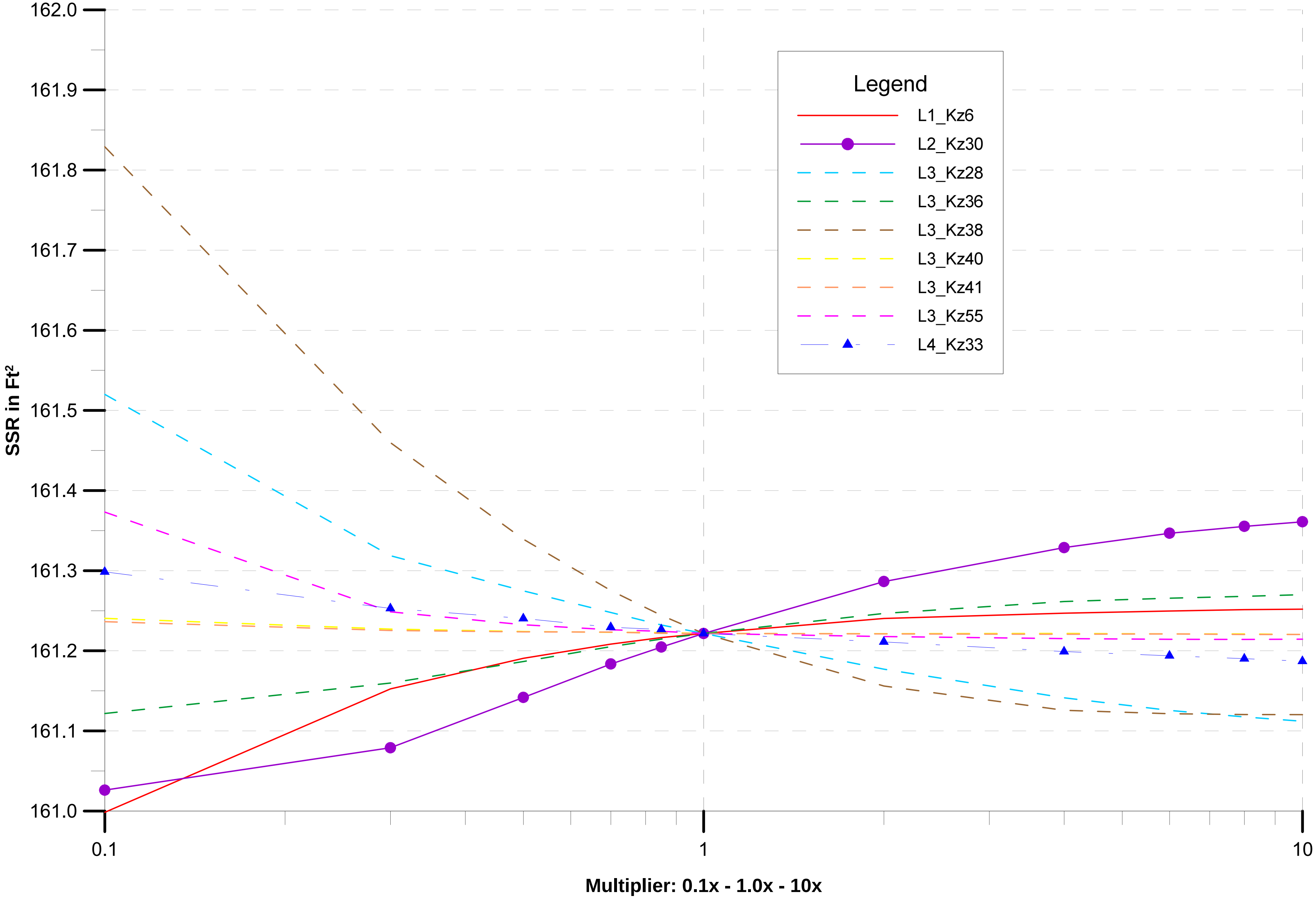


Figure 6 - Sensitivity Analysis for OU2B, Kv Values, Layers 1, 2, 3, and 4

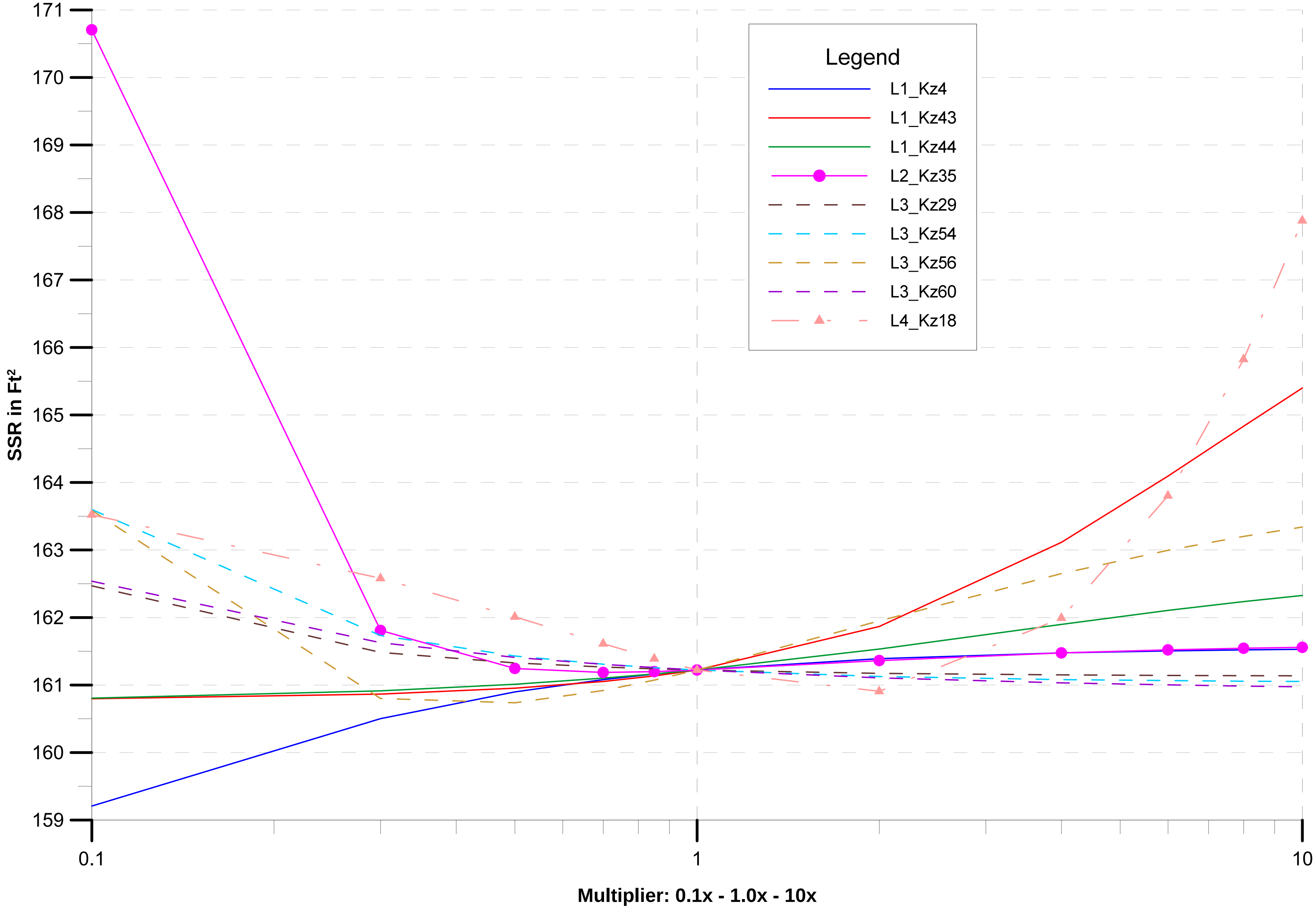
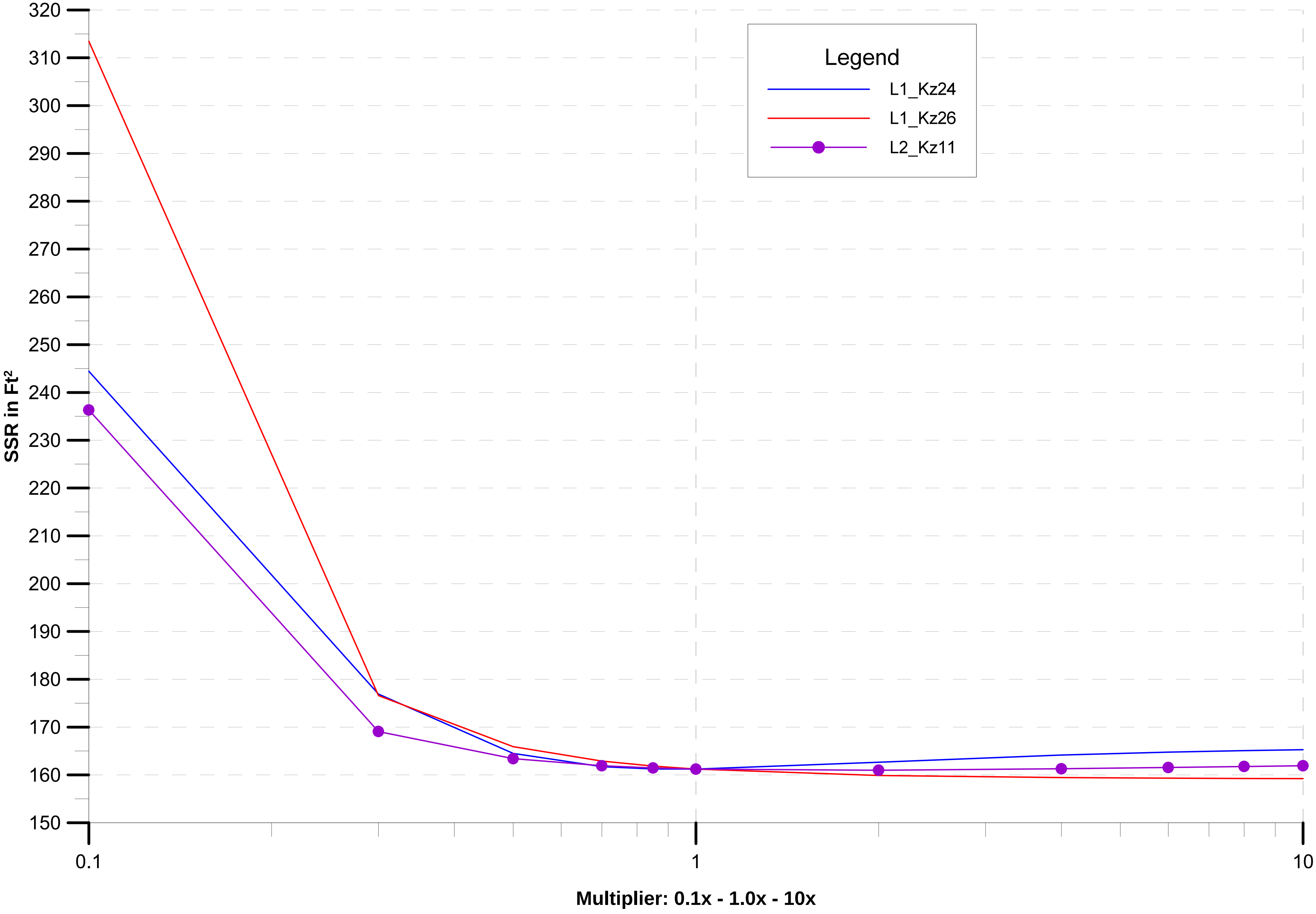


Figure 7 - Sensitivity Analysis for OU2B, Kv Values, Layers 1 and 2



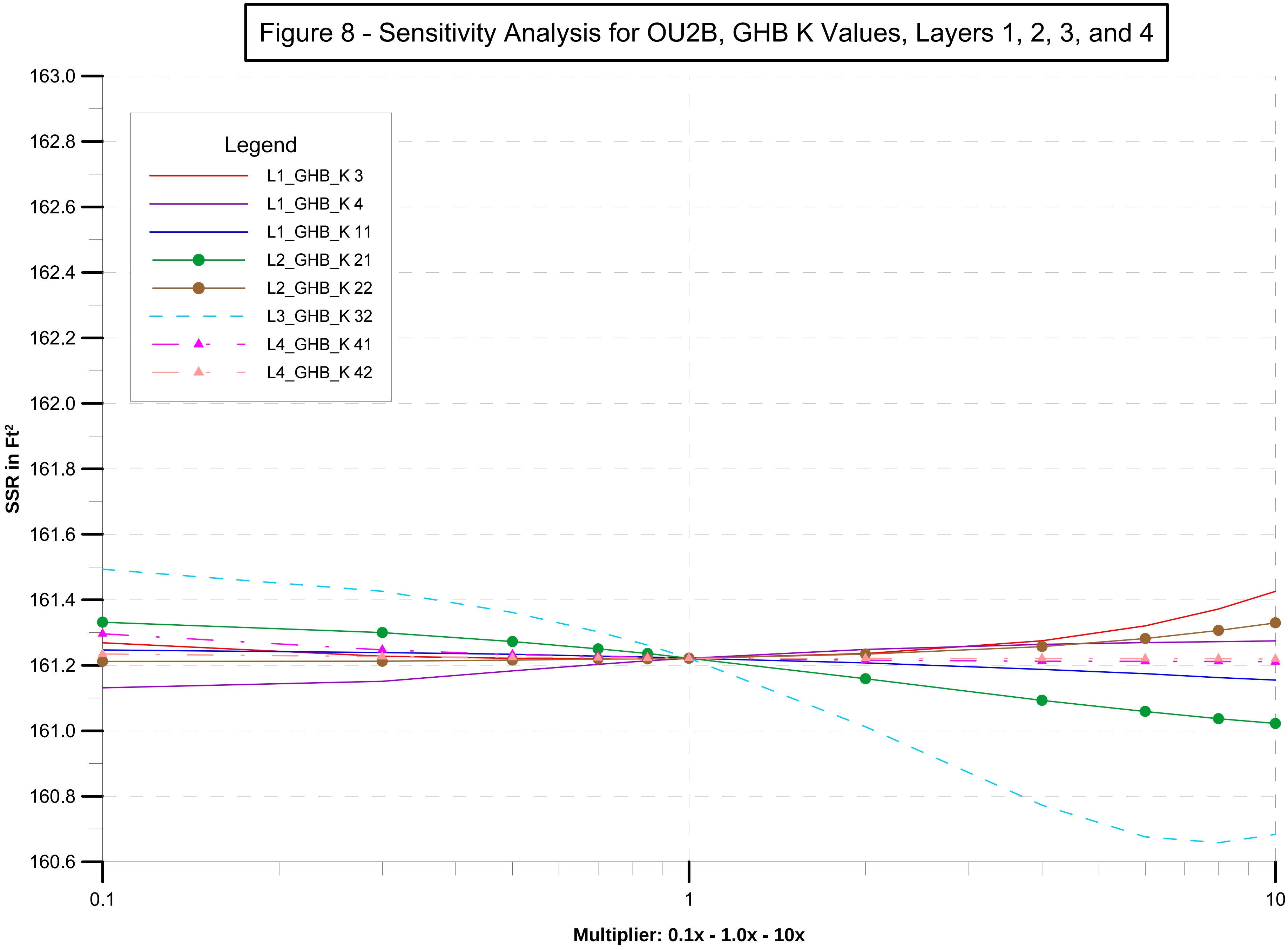


Figure 8 - Sensitivity Analysis for OU2B, GHB K Values, Layers 1, 2, 3, and 4
Legend
L1_GHB_K 3
L1_GHB_K 4
L1_GHB_K 11
L2_GHB_K 21
L2_GHB_K 22
L3_GHB_K 32
L4_GHB_K 41
L4_GHB_K 42
SSR in Ft²
163.0
162.8
162.6
162.4
162.2
162.0
161.8
161.6
161.4
161.2
161.0
160.8
160.6
0.1
1
10
Multiplier: 0.1x - 1.0x - 10x

Figure 9 - Sensitivity Analysis for OU2B, GHB K Values, Layers 1 and 3

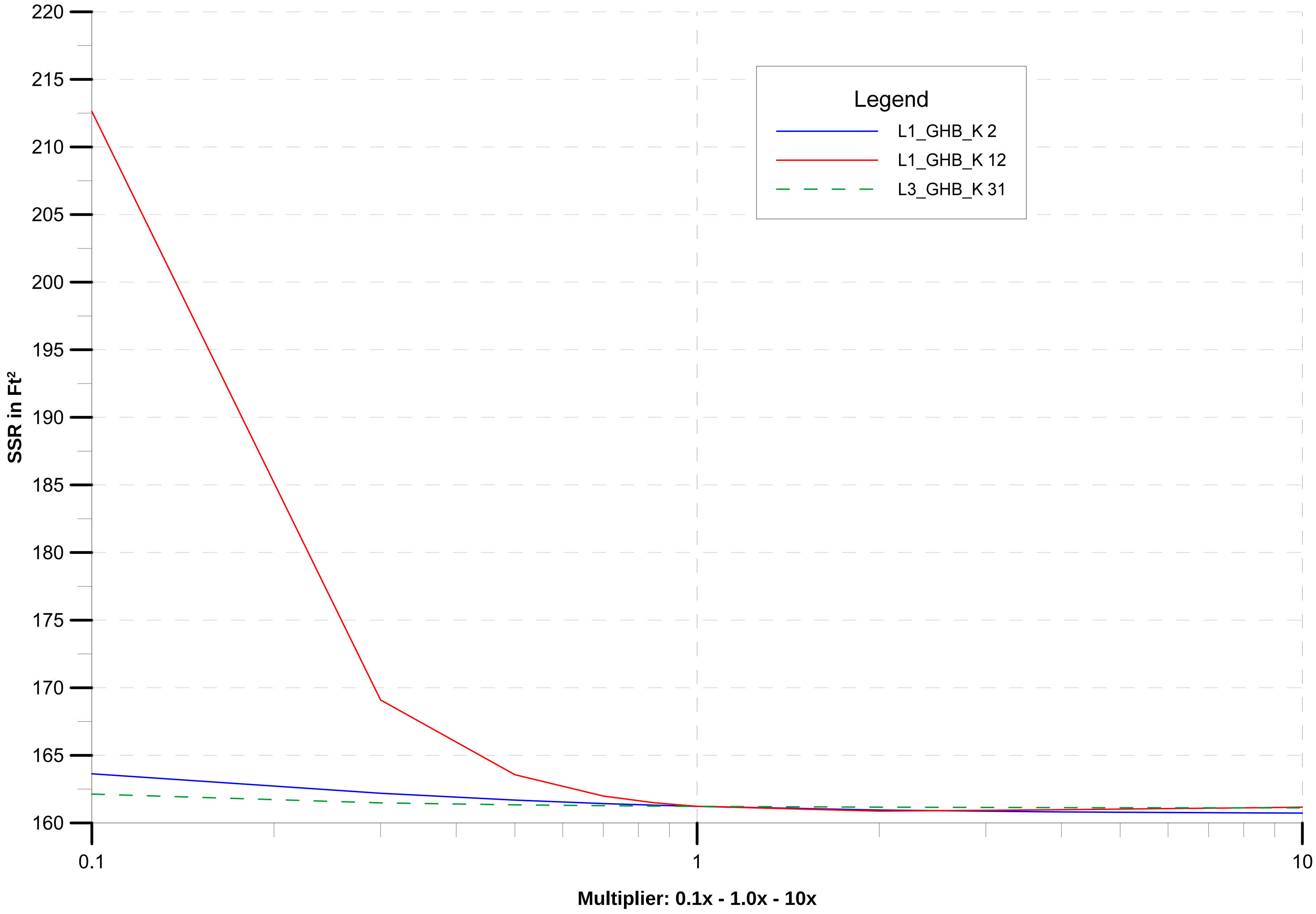


FIGURE 10. ALAMEDA POINT - OU2B GROUNDWATER LEVEL COMPARISON