FINAL

REVISION 2.0

CORRECTIVE ACTION PLAN FOR GROUNDWATER

FOR

FORMER UNDERGROUND STORAGE TANK SITE 957/970

DEPARTMENT OF DEFENSE HOUSING FACILITY NOVATO, CALIFORNIA

Contract Number: N47408-95-D-0730
Delivery Order: 0037

Prepared for:

Naval Facilities Engineering Command
Southwest Division
1220 Pacific Highway
San Diego, California 92132-5190

and

Naval Facilities Engineering Service Center
1100 23rd Avenue
Port Hueneme, California 93043

Prepared by:

Battelle
Environmental Restoration Department
505 King Avenue
Columbus, Ohio 43201

March 1, 2002

The vendors and products, including the equipment, system components, and other materials identified in this report, are primarily for information purposes only. Although Battelle and/or the Government may have used some of these vendors and products in the past, mention in this report does not constitute Battelle's or the Government's recommendation for using these vendors or products.

CONTENTS

FIGURES vii
TABLES x
APPENDICES xii
ABBREVIATIONS AND ACRONYMS xiii
EXECUTIVE SUMMARY xvi

Section 1.0: INTRODUCTION 1
1.1 Objectives 1
1.2 Site Description 1
1.3 Site History and Background 2
1.3.1 Chronology of Events 3
1.3.2 Summary 9

Section 2.0: PREVIOUS INVESTIGATIONS 13
2.1 Source Identification and Removal 13
2.1.1 Source Removal 13
2.1.1.1 UST 957 13
2.1.1.2 UST 970-3 14
2.1.1.3 Tank 970-Waste Oil 14
2.1.1.4 UST 970-1 and UST 970-2 15
2.1.1.5 Building 970 Hydraulic Lift Investigation and Removal Activities 16
2.1.1.5.1 Building 970 Hydraulic Lift Investigations 16
2.1.1.5.2 Building 970 Hydraulic Lift and Oil/Water Separator Removal Activities 17
2.2 Site Characterization 18
2.2.1 Preliminary Site Characterization 18
2.2.2 MTBE Plume Delineation 19
2.2.3 Remedial Investigation 20
2.2.3.1 Task 1 21
2.2.3.2 Task 2 21
2.2.3.3 Task 3 21
2.2.3.4 Task 4 22
2.2.4 Continuous Coring and Soil Lithology 22
2.3 Groundwater and Surface Water Monitoring Program 23
2.3.1 Groundwater 23
2.3.2 Surface Water 24
2.4 Human Health Risk Assessments 25
2.4.1 Tier 3 RBCA Assessment 26
2.4.2 Revised Risk Assessment 26
2.4.2.1 Potential Exposure Scenarios 27
2.4.2.2 Methodology 27
2.4.2.3 Results 28
2.4.2.4 Conclusions 28
2.5 Ecological Risk Assessment 28

Section 3.0: INTERIM REMEDIAL ACTION 80
3.1 Air Sparging and Soil Vapor Extraction Technology Description 80
3.2 Implementation 81
3.3 Results 82

Section 4.0: CONCEPTUAL SITE MODEL AND NATURE AND EXTENT 93
4.1 Conceptual Site Model Development 93
4.1.1 Description of Conceptual Site Model Region 93
4.1.2 Primary Soil Layer Units 94
4.1.3 Groundwater Flow System Description 97
4.2 Current Nature and Extent of Gasoline Constituents 99
4.2.1 Soil 99
4.2.1.1 Building 970 Hydraulic Lift Excavation and Removal 99
4.2.1.2 Remedial Investigation 100
4.2.2 Groundwater 101
4.2.2.1 MTBE 101
4.2.2.2 Benzene 102
4.2.2.3 Other Gasoline Constituents 103
4.2.2.4 Gasoline Constituents in Wells Installed During the Remedial Investigation 103

Section 5.0: EVALUATION OF SITE CONDITIONS 173
5.1 Regulatory Framework 173
5.2 Site Assessment 175
5.2.1 Assessment of Source 175
5.2.1.1 Former UST Removal 175
5.2.1.2 Presence of Free Product 176
5.2.2 Assessment of Adequacy of Site Characterization 176
5.2.3 Assessment of Plume Stability 178
5.2.3.1 Evaluation of BTEX Plume Stability 179
5.2.3.1.1 Time-Series Data 179
5.2.3.1.2 Monitored Natural Attenuation Summary 180
5.2.3.2 Evaluation of MTBE Plume Stability 180
5.2.3.2.1 Time-Series Data 181
5.2.3.2.2 Center of Mass 182
5.2.4 Assessment of Impact to Water Resources or Other Sensitive Receptors 183
5.2.5 Assessment of Risk to Human Health 184
5.2.6 Assessment of Risk to the Environment 186
5.3 Remedial Action Objectives 186

Section 6.0: IDENTIFICATION AND ANALYSIS OF REMEDIAL ALTERNATIVES 200
6.1 Remedial Technology Screening 200
6.1.1 Alternatives Considered 200
6.1.1.1 Closure With No Further Action 200
6.1.1.2 In Situ Aerobic Biodegradation by Circulating Oxygen-Bearing Solutions 201
6.1.1.3 In Situ Aerobic Biodegradation Using Oxygen Release Compounds 201
6.1.1.4 In Situ Biosparging/Air Sparging 202
6.1.1.5 Interception/Aeration Trench 203
6.1.1.6 Collection Trench and Wells With Groundwater Pump and Treat and SVE 203
6.1.1.7 Monitored Natural Attenuation 204
6.1.1.8 Organic Soil Modification 204
6.1.1.9 Phytoremediation 205
6.1.1.10 Excavation and Dewatering 205

6.1.2 Selection of Alternatives for Detailed Evaluation 205
6.2 Detailed Evaluation of Alternatives 206
6.2.1 Common Elements 206
6.2.1.1 Monitored Natural Attenuation 206
6.2.1.2 Monitoring 207
6.2.1.3 Institutional Controls 208
6.2.1.4 Land Use Covenant 209
6.2.2 Characteristics of Candidate Alternatives 209
6.2.2.1 Alternative 1 – Excavation and Dewatering 209
6.2.2.1.1 Description 209
6.2.2.1.2 Implementability 210
6.2.2.1.3 Effectiveness 210
6.2.2.1.4 Benefits 210
6.2.2.1.5 Impact on Public Health and Welfare and the Environment 210
6.2.2.1.6 Cost 210
6.2.2.2 Alternative 2 – Interception/Aeration Trench 211
6.2.2.2.1 Description 211
6.2.2.2.2 Implementability 212
6.2.2.2.3 Effectiveness 212
6.2.2.2.4 Benefits 213
6.2.2.2.5 Impact on Public Health and Welfare and the Environment 214
6.2.2.2.6 Cost 214
6.2.2.3 Alternative 3 – Collection Trench and Wells with Groundwater Pump and Treat and SVE 214
6.2.2.3.1 Description 214
6.2.2.3.2 Implementability 216
6.2.2.3.3 Effectiveness 216
6.2.2.3.4 Benefits 216
6.2.2.3.5 Impact on Public Health and Welfare and the Environment 217
6.2.2.3.6 Cost 217
6.2.2.4 Alternative 4 – Biosparging 218
6.2.2.4.1 Description 218
6.2.2.4.2 Implementability 219
6.2.2.4.3 Effectiveness 219
6.2.2.4.4 Benefit 221
6.2.2.4.5 Impact on Public Health and Welfare and the Environment 221
6.2.2.4.6 Cost 221
6.3 Selection of Corrective Action 222

Section 7.0: DESCRIPTION OF RECOMMENDED REMEDY 241
7.1 Objective and Scope 241
7.2 Recommended Corrective Action Alternative 241
7.2.1 Biosparging With System Monitoring 241
7.2.1.1 Design 242
7.2.1.1.1 Design Objectives 242
7.2.1.1.2 General System Design 243
7.2.1.1.3 Sparge Wells 243

7.2.1.1.4 Vapor Migration Control/Soil Vapor Extraction 243
7.2.1.1.5 Soil-gas Monitoring Probes..... 244
7.2.1.1.6 Performance Goal Groundwater Monitoring Wells 244
7.2.1.2 Installation..... 244
7.2.1.2.1 Drilling..... 244
7.2.1.2.2 Assembly..... 245
7.2.1.3 Operations and Monitoring 245
7.2.1.3.1 Shakedown..... 246
7.2.1.3.2 Routine Operations 246
7.2.1.4 Performance Goals..... 247
7.2.1.5 SVE Contingency..... 250
7.2.2 MNA..... 250
7.2.3 Institutional Controls..... 251
7.3 Schedule..... 252

Section 8.0: REFERENCES 263

ATTACHMENT 1: California Regional Water Quality Control Board Order No. 00-064
ATTACHMENT 2: DTSC Approval Letter for July 13, 2001 on Draft Revised Risk Assessment for Former UST Site 957/970, Department of Defense Housing Facility, Novato, California, Dated June 8, 2001
ATTACHMENT 3: US Navy Summary Findings on Bedrock Groundwater Conditions at the Former Underground Storage Tank Site 957/970 Department of Defense Housing Facility Novato, California
ATTACHMENT 4: Response to Comments Table [Dated November 30, 2001] for Draft Proposed Final Revision 1.0 Corrective Action Plan for Groundwater for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California

FIGURES

Figure 1-1. Regional Location Map 10
Figure 1-2. Site Location Map 11
Figure 1-3. Future Land Use Map 12
Figure 2-1. Tank Site 957 Sample Locations and Results 30
Figure 2-2. Site 970 Tank, Piping, and Sampling Locations 31
Figure 2-3. Site 970 – Tank 970-Waste Oil Tank Sampling Locations, UST 970-1, and UST 970-2 32
Figure 2-4. Sampling Locations for Hydraulic Lift Investigation in Building 970 33
Figure 2-5. Hydrocarbon Concentrations (mg/kg) in Soil at 5 ft bgs at Site 957/970 34
Figure 2-6. Hydrocarbon Concentrations (mg/kg) in Soil between 8 and 10 ft bgs at Site 957/970 35
Figure 2-7. Localized Areas of Elevated Soil Hydrocarbon Concentrations at Site 957/970 36
Figure 2-8. Hydrocarbon Concentrations (µg/L) in Groundwater at Site 957/970 37
Figure 2-9. Localized Areas of Elevated Groundwater Hydrocarbon Concentrations at Site 957/970 38
Figure 2-10. CPT/Geoprobe™ Investigation Locations at Site 957/970 (1998) 39
Figure 2-11. Location of Monitoring Wells Installed Near the Former 970 Complex During the Remedial Investigation 40
Figure 2-12. Location of Bedrock Wells Installed During the Remedial Investigation 41
Figure 2-13. Location of Replacement Wells and Network Augmentation Wells 42
Figure 2-14. Shallow Soil (<8 ft bgs) Sampling Locations at Site 957/970, September 2000 43
Figure 2-15. Deep Soil (>8 ft bgs) Sampling Locations at Site 957/970, September 2000 44
Figure 2-16. CPT Investigation Locations at Site 957/970, September 2000 45
Figure 2-17. Cross-Section Tracer Lines From CPT Investigation at Site 957/970, September 2000 46
Figure 2-18. Well Location Map 47
Figure 2-19. MTBE Concentrations in Surface Water 48
Figure 2-20. Surface Water MTBE Concentrations at Culvert Outlet Locations 49
Figure 2-21. Surface Water Sampling Location, Streambed Elevation and Water Elevation in Nearby Monitoring Wells, February, 2001 50
Figure 3-1. Air Sparging and SVE Well Locations in Areas A, B, and DE at Former UST Site 957/970 84
Figure 3-2. IAS/SVE Process Flow Diagram for DoDHF Novato 85
Figure 3-3. Influent TPH-G, BTEX, and MTBE Concentration Over Time 86
Figure 3-4. Area A (Former UST 970 Tank Complex Source Area) Benzene and MTBE Time Series Graphs for Transect Wells 87
Figure 3-5. Area B Benzene and MTBE Time Series Graphs for Transect Wells 88
Figure 3-6. Area DE (Former UST 957 Source Area) Benzene and MTBE Time Series Graphs for Transect Wells 89
Figure 4-1. Conceptual Site Model of Former UST Site 957/970 105
Figure 4-2. Perspective View of 3-D Block Diagram Looking Northeast at Former UST Site 957/970 106
Figure 4-3. North-South Cross-Sectional View through 3-D Block Conceptual Site Model Diagram (at easting -5") 107
Figure 4-4. East-West Cross-Sectional View Looking North at Former UST Site 957/970 108
Figure 4-5. Perspective View of 3-D Block Diagram Looking Northeast at Former UST Site 957/970 Showing Slope of Water Table Downward Toward the North With Color-Filled Contours 109
Figure 4-6. Subsurface Installation Location Map 110

Figure 4-7. Cross Section A-A' 111
Figure 4-8. Cross Section B-B' 112
Figure 4-9. Cross Section C-C' 113
Figure 4-10. Cross Section D-D' 114
Figure 4-11. Cross Section E-E' 115
Figure 4-12. Cross Section F-F' 116
Figure 4-13. Cross-Section Tracer Lines from September 2000 CPT Investigation 117
Figure 4-14. Cross Section A-A' From September 2000 CPT Investigation 118
Figure 4-15. Cross Section B-B' From September 2000 CPT Investigation 119
Figure 4-16. Cross Section C-C' From September 2000 CPT Investigation 120
Figure 4-17. Cross Section D-D' From September 2000 CPT Investigation 121
Figure 4-18. Cross Section E-E' From September 2000 CPT Investigation 122
Figure 4-19. Cross Section F-F' From September 2000 CPT Investigation 123
Figure 4-20. Cross Section G-G' From September 2000 CPT Investigation 124
Figure 4-21. Water Table Elevation (ft msl) Map in Unconfined Aquifer Zone (May 1999) 125
Figure 4-22. Saturated Thickness of Unconfined Aquifer, May 1999 126
Figure 4-23. Elevation Map of Top of Weathered Bedrock Surface 127
Figure 4-24. Water Levels and Rainfall Along Center Line 128
Figure 4-25. Concentrations of TPH-O in Soil at Building 970 129
Figure 4-26. Concentrations of TPH-G and Benzene in Soil at Building 970 130
Figure 4-27. Concentrations of TPH-D and TOG in Soil at Building 970 131
Figure 4-28. Concentrations of Lead and Chromium in Soil at Building 970 132
Figure 4-29. Conceptual Extent of Residual Petroleum Hydrocarbons in Soil at Building 970 133
Figure 4-30. Shallow Soil (<8 ft bgs) Sampling Locations, September 2000 134
Figure 4-31. Deep Soil (>8 ft bgs) Sampling Locations, September 2000 135
Figure 4-32. TPH-G Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 136
Figure 4-33. Benzene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 137
Figure 4-34. Toluene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 138
Figure 4-35. Ethylbenzene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 139
Figure 4-36. Xylene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 140
Figure 4-37. MTBE Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000 141
Figure 4-38. TPH-G Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 142
Figure 4-39. Benzene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 143
Figure 4-40. Toluene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 144
Figure 4-41. Ethylbenzene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 145
Figure 4-42. Xylene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 146
Figure 4-43. MTBE Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the Sale Area, September 2000 147
Figure 4-44. TPH-G Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 148

Figure 4-45. Benzene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 149
Figure 4-46. Toluene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 150
Figure 4-47. Ethylbenzene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 151
Figure 4-48. Xylene Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 152
Figure 4-49. MTBE Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 153
Figure 4-50. TPH-D Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000 154
Figure 4-51. TPH-G Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 155
Figure 4-52. Benzene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 156
Figure 4-53. Toluene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 157
Figure 4-54. Ethylbenzene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 158
Figure 4-55. Xylene Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 159
Figure 4-56. MTBE Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 160
Figure 4-57. TPH-D Concentrations (mg/kg) in Deep Soil (>8 ft bgs) Within the PBC Area, September 2000 161
Figure 4-58. February 2001 Contour Maps at Former UST Site 957/970 DoDHF Novato 162
Figure 5-1. Area A (Former UST 970 Tank Complex Source Area) Benzene and MTBE Time Series Graphs for Transect Wells 189
Figure 5-2. Time-Series Benzene Contour Maps at Former UST 957/970 DoDHF Novato 190
Figure 5-3. Benzene Mass Estimates in Groundwater Over Time 191
Figure 5-4. Contour Maps of Toluene, Ethylbenzene, and Xylenes at Former UST 957/970 DoDHF Novato 192
Figure 5-5. Time-Series MTBE Contour Maps at Former UST 957/970 DoDHF Novato 193
Figure 5-6. MTBE Mass Estimates in Groundwater Over Time 194
Figure 5-7. MTBE Center of Mass for First Quarter 1999 and First Quarter 2001 at Former UST Site 957/970 DoDHF Novato 195
Figure 5-8. Well Survey, Former UST Site 957/970 and Surrounding Area 196
Figure 5-9. Longitudinal Cross Section and Groundwater Levels Near Pacheco Creek 197
Figure 6-1. Conceptual Diagram for Excavation and Dewatering 224
Figure 6-2. Conceptual Diagram for Interception/Aeration Trench 225
Figure 6-3. Conceptual Diagram for Collection Trench and Wells With Groundwater Pump and Treat 226
Figure 6-4. Conceptual Diagram for Bio Sparging/Air Sparging 227
Figure 7-1. Conceptual Diagram for Biosparging at Former UST Site 957/970 253
Figure 7-2. Typical Sparge Well Construction 254
Figure 7-3. Typical SVE Well Construction 255
Figure 7-4. Typical Soil-Gas Monitoring Probe Construction 256
Figure 7-5. Typical Monitoring Well Construction 257
Figure 7-6. Estimated MTBE Concentration Trends in Performance Goal Monitoring Wells Resulting from Biosparging Operation 258

Figure 7-7. Flowchart Depicting SVE Contingency 259
Figure 7-8. Tentative CAP Schedule 260

TABLES

Table ES-1. Summary Comparison of Remedial Alternatives xxviii
Table 2-1. Analytical Results From UST 957 Removal Activities in 1992 51
Table 2-2. Analytical Results from Groundwater and Tank Content Samples Collected During UST 970-3 Removal Activities in 1995 52
Table 2-3. Analytical Results from Soil Samples Collected During UST 970-3 Removal Activities in 1995 52
Table 2-4. Analytical Results from Soil, Groundwater, and Tank Content Samples Collected During Tank 970-Waste Oil Removal Activities in 1995 53
Table 2-5. Analytical Results from Soil and Groundwater Samples Collected During UST 970-1 and UST 970-2 Removal Activities 54
Table 2-6. Analytical Results from Soil Samples Collected from Pump Island During UST 970-1 and UST 970-2 Removal Activities 54
Table 2-7. Hydraulic Lift Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs) 55
Table 2-8. Hydraulic Lift Soil Analytical Data (Metals) 56
Table 2-9. Oil/Water Separator Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs) 57
Table 2-10. Oil/Water Separator Soil Analytical Data (Metals) 60
Table 2-11. OWS2 Product Analytical Data (Petroleum Hydrocarbons) 62
Table 2-12. OWS2 Water Analytical Data (Petroleum Hydrocarbons, SVOCs and VOCs) 63
Table 2-13. OWS2 Water Analytical Data (Metals) 63
Table 2-14. Waste Oil Line Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs) 64
Table 2-15. Waste Oil Line Soil Analytical Data (Metals) 65
Table 2-16. Analytical Results of Groundwater Collected During the SCAPS Investigation at the NEX Service Station 65
Table 2-17. Analytical Results of Soil Samples Collected During the SCAPS Investigation at the NEX Service Station 65
Table 2-18. Analytical Results of Groundwater Samples Collected During the March 1998 Geoprobe™ Investigation 66
Table 2-19. Analytical Results of Groundwater Samples Collected During the 66
Table 2-20. Analytical Results of Groundwater Samples Collected During the August 1998 CPT Investigation 67
Table 2-21. Analytical Results of Groundwater Samples Collected from Permanent Monitoring Wells Located on Former Hamilton Army Airfield Property 68
Table 2-22. Soil Sampling Results from the Sale Area, September 2000 69
Table 2-23. Soil Sampling Results for BTEX and MTBE in the PBC Area, September 2000 70
Table 2-24. Soil Sampling Results for TPH Constituents in the PBC Area, September 2000 71
Table 2-25. Sampling and Analytical Methods for Periodic Monitoring 72
Table 2-26. Laboratory Practical Quantitation Limits Based on Clean Matrices for Periodic Monitoring 72
Table 2-27. QC Samples 72
Table 2-28. Groundwater Monitoring Network and Decision Criteria by Objective 73
Table 2-29. Surface Water Monitoring Network and Decision Criteria 75
Table 2-30. Surface Water Sampling Analytical Results 76

Table 2-31. Total Risks to Potential Receptors in the Sale Area and PBC Area for Former UST Site 957/970 77
Table 2-32. Summary of Excavation Worker Risks from Exposure to Impacted Soil 78
Table 2-33. Conceptual Site Model for Ecological Risk Assessment 79
Table 3-1. Construction Details for Air Sparging and SVE Wells at Former UST Site 957/970 90
Table 3-2. Soil Vapor Extraction System Summary 91
Table 3-3. MTBE and Benzene Concentration in Sparge Wells – Initial and Following One Year of Operation 92
Table 4-1. Depth to Primary Soil Layers 163
Table 4-2. Grain-Size Distribution 166
Table 4-3. Hydraulic Gradients and Groundwater Flow Velocities at Former UST Site 957/970 167
Table 4-4. Hydraulic Conductivity (K) from Slug Tests, in ft/day 167
Table 4-5. Total Dissolved Solids Concentrations 167
Table 4-6. Soil Characterization Data 168
Table 4-7. Range in Values of Porosity 169
Table 4-8. Applicable Screening Levels and Maximum Detections for Soil Samples Collected During Hydraulic Lift Removal Activities at Building 970, April/May 2000 170
Table 4-9. Estimated Unsaturated Soil Volume Exceeding Screening Criteria and Total Mass of Gasoline Constituents in the Sale Area and the PBC Area After IAS/SVE Treatment 171
Table 4-10. Bedrock Well and Nearby Monitoring Well Sampling Results 171
Table 4-11. Nested Well Sampling Results 172
Table 5-1. Dissolved MTBE and Benzene Mass Estimates 198
Table 5-2. Historical Maximum and Average Concentrations of Contaminants 198
Table 5-3. Location of MTBE Plume Center of Mass in Various Portions of the Site 199
Table 6-1. Advantages and Limitation of Options for Remediation of MTBE in Groundwater at the Former UST Site 957/970 228
Table 6-2. Basis of Selecting Options for Remediation of MTBE in Groundwater at the Former UST Site 957/970 232
Table 6-3. MNA Sampling Approach 233
Table 6-4. Monitoring Approach for Each Candidate Alternative 234
Table 6-5. Summary of Costs for Alternative 1: Excavation and Dewatering 235
Table 6-6. Summary of Costs for Alternative 2: Interception/Aeration Trench 235
Table 6-7. Summary of Costs for Alternative 3: Collection Trench and Wells With Groundwater Pump and Treat and SVE 236
Table 6-8. Summary of Costs for Alternative 4: Biosparging 236
Table 6-9. Air Sparging Performance 237
Table 6-10. Summary Comparison of Remedial Alternatives 238
Table 7-1. Summary of Biosparging Subsurface Installations 261
Table 7-2. Biosparging Operational Monitoring Parameters 262
Table 7-3. Safety Threshold Hydrocarbon Soil-gas Concentrations[(a)] and Sampling Information for Shallow Soil-Gas Monitoring Points 262

APPENDICES

APPENDIX A: HYDRAULIC LIFT REMOVAL LABORATORY ANALYTICAL REPORTS AND CHAIN-OF-CUSTODY DOCUMENTATION

APPENDIX B: CPT/GEOPROBE™ INVESTIGATION LABORATORY ANALYTICAL REPORTS – MARCH 1998, APRIL/MAY 1998, AND AUGUST 1998

APPENDIX C: CPT BORING LOGS - APRIL/MAY 1998 AND AUGUST 1998

APPENDIX D: REMEDIAL INVESTIGATION LABORATORY ANALYTICAL REPORTS AND CHAIN-OF-CUSTODY DOCUMENTATION

APPENDIX E: REMEDIAL INVESTIGATION CPT BORING LOGS

APPENDIX F: SOIL BORING LOGS FOR SUBSURFACE INSTALLATIONS

APPENDIX G: TABULATED SOIL ANALYTICAL DATA PRECEDING REMEDIAL INVESTIGATION

APPENDIX H: SOIL LABORATORY ANALYTICAL REPORTS PRECEDING REMEDIAL INVESTIGATION

APPENDIX I: QUARTERLY GROUNDWATER LEVEL DATA AND POTENTIOMETRIC MAPS

APPENDIX J: QUARTERLY GROUNDWATER AND SURFACE WATER MONITORING PURGE LOGS

APPENDIX K: MONITORING WELL CONSTRUCTION DETAILS

APPENDIX L: CUMULATIVE QUARTERLY GROUNDWATER MONITORING RESULTS

APPENDIX M: QUARTERLY GROUNDWATER AND SURFACE WATER LABORATORY ANALYTICAL REPORTS AND CHAIN-OF-CUSTODY DOCUMENTATION

APPENDIX N: IAS/SVE PROCESS VAPOR ANALYTICAL RESULTS

APPENDIX O: DETAILED STATISTICAL ANALYSIS SUMMARY FOR EVALUATION OF MNA OF BTEX COMPOUNDS

APPENDIX P: COST DETAIL FOR REMEDIAL ALTERNATIVES

ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
asml	above mean sea level
BAAQMD	Bay Area Air Quality Management District
Basin Plan	Water Quality Control Plan for the San Francisco Bay Basin
bgs	below ground surface
BRAC	Base Realignment and Closure
BTEX	benzene, toluene, ethylbenzene, and xylene
Cal-EPA	California Environmental Protection Agency
CAP	Corrective Action Plan
cfm	cubic feet per minute
CMEHS	County of Marin Environmental Health Services
CPT	cone penetrometer test
DIPE	di-isopropyl ether
DO	dissolved oxygen
DoD	Department of Defense
DoDHF	Department of Defense Housing Facility
DON	Department of Navy
DTSC	(California) Department of Toxic Substances Control
DWR	(California) Department of Water Resources
EBS	Environmental Baseline Survey
EFD	Engineering Field Division
EQM	Environmental Quality Management, Inc.
ETBE	ethyl tertiary-butyl ether
GAC	granular activated carbon
GMP	groundwater monitoring plan
GPR	ground-penetrating radar
GSA	General Services Administration
GW	groundwater
HAAF	Hamilton Army Airfield
HDTMA	hexadecyltrimethyl ammonium
HERD	Human and Ecological Risk Division
hp	horsepower
HSA	hollow-stem auger
IAS	in situ air sparging
IC	institutional controls
ICE	internal combustion engine
LNAPL	light, nonaqueous phase liquid
LUFT	Leaking Underground Fuel Tanks
MCL	maximum contaminant levels

MNA	monitored natural attenuation
MOA	memorandum of agreement
msl	mean sea level
MTBE	methyl-*tert*-butyl ether
MP	monitoring point
MW	monitoring well
NA	not analyzed
ND	not detected
NEX	Naval Exchange
NFA	no further action
NFESC	Naval Facilities Engineering Service Center
NPDES	National Pollutant Discharge
NPWC	Navy Public Works Center
NUSD	Novato Unified School District
ORC®	Oxygen Release Compound
ORP	oxidation-reduction potential
OSB	operation support building
OSWER	Office of Solid Waste and Emergency Response
OWS	oil/water separator
P	point
PBC	public benefit conveyance
PCB	polychlorinated biphenyls
PID	photoionization detector
ppb	parts per billion
ppmv	parts per million, volume
PQL	practical quantitation limits
PRG	preliminary remediation goal
psi	pounds per square inch
PVC	polyvinyl chloride
PWC	Public Works Center
PZ	piezometer
QA/QC	quality assurance/quality control
RAO	Remedial Action Objective
RBCA	Risk-Based Corrective Action
RBSL	risk-based screening levels
RCRA	Resource Conservation and Recovery Act
RWQCB	Regional Water Quality Control Board, San Francisco Bay Area
SCAPS	Site Characterization and Analysis Penetrometer System
scfm	standard cubic feet per minute
STP	standard temperature and pressure
SVE	soil vapor extraction
SVOC	semivolatile organic compounds
SWRCB	California State Water Resources Control Board
TAME	*tertiary*-amyl methyl ether

TBA	*tertiary*-butyl alcohol
TBF	*tertiary*-butyl formate
TeMB	tetramethyl benzene
TMB	trimethylbenzenes
TOC	total organic carbon
TOG	total oil and grease
TPH	total petroleum hydrocarbons
TPH-D	total petroleum hydrocarbons quantified as diesel
TPH-G	total petroleum hydrocarbons quantified as gasoline
TPH-JF	total petroleum hydrocarbons quantified as jet fuel
TPH-MO	total petroleum hydrocarbons motor oil
TSDF	treatment, storage and disposal facility
TTLC	total threshold limit of concern
TRPH	total recoverable petroleum hydrocarbons
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOA	volatile organic analysis
VOC	volatile organic compound
WQO	water quality objective

EXECUTIVE SUMMARY

This Corrective Action Plan (CAP) provides a thorough review of site history at Former Underground Storage Tank (UST) Site 957/970, describes the current conditions of site property, and recommends a corrective action strategy to ensure protection of human health and the environment in compliance with Regional Water Quality Control Board, San Francisco Bay Area (RWQCB) Order No. 00-64, Task 6.

Site Description and History

Former UST Site 957/970 (the Site) on Department of Defense Housing Facility (DoDHF) Novato, California, is located approximately 20 miles north of San Francisco in Marin County, California, and comprises an area of approximately 13 acres. The Site is the location of a former Navy Exchange (NEX) gas station and a former Naval Public Works Center (PWC) gas station that were in use from the mid-1970s to the early 1990s and operated USTs that stored gasoline. At the time the gas stations were closed, the three (3) USTs that had supported the NEX gas station (UST 970-1, UST 970-2, and UST 970-3) and the single UST (UST 957) that had supported the PWC gas station were removed. Because groundwater at the site was thought to be impacted by fuel releases from both the NEX gas station and the PWC gas station, the respective site designations were merged and the label "Former UST Site 957/970" was adopted.

The Site geology is heterogeneous, with sands and clay encountered in different proportions and at varying depths across the site. Bedrock is typically encountered at 15 to 20 ft below ground surface (bgs) and underlies a shallow, thin aquifer encountered at about 9 ft bgs. A small creek, Pacheco Creek, flows northward on former Hamilton Army Airfield (HAAF) property after it discharges from piped culverts into a concrete-lined culvert just north of Navy property.

Future Land Use

DoDHF Novato is scheduled for transfer of ownership under the Base Realignment and Closure (BRAC) program. As described in the *Hamilton Army Airfield Reuse Plan: Final Reuse Plan*, a portion of the site, referred to as the "Sale Area", will be sold to the City of Novato, California, for commercial/industrial use, and other portions will be transferred to the Novato Unified School District (NUSD) as an educational public benefit conveyance (PBC).

Continuing north of Navy property onto former HAAF property, an area referred to as "Hamilton Meadows Subdivision" exists, and is currently being developed for residential use and recreational areas. The area northwest of Hamilton Meadows Subdivision is open land that is not currently in use, and is planned for recreational purposes or open space. The area northeast of Hamilton Meadows Subdivision is Landfill 26.

Regulatory Oversight

The U.S. Navy is the lead agency administrating the remediation and closure of the Site, and it is Department of Defense (DoD) policy to achieve site closure with the agreement of local regulatory authorities. Because the source of gasoline constituents was a UST hydrocarbon release, the RWQCB is the local regulatory authority with which this project has been coordinated. The California Department of Toxic Substances Control (DTSC) is involved as the lead state agency for closing former military installations and has oversight concerning risk assessment activities at the Site.

Groundwater underlying the Former UST Site 957/970 is located within the Novato Valley Groundwater Basin. The RWQCB has designated all groundwater in the Novato Valley Groundwater Basin to be a potential source for use as domestic or municipal supply. Municipal and domestic supplies, including sources of drinking water, require the most protective standards for groundwater. Therefore, groundwater that is considered a potential source of drinking water is not to contain contaminant concentrations in excess of the Maximum Contaminant Levels (MCLs) and/or taste and odor thresholds outlined in the RWQCB's Basin Plan.

On July 19, 2000, the RWQCB adopted Order No. 00-064 establishing a series of tasks to be performed at the Site and a schedule by which those tasks would be performed. This CAP was prepared to comply with Task 6 of Order 00-064. Note that the compliance date has been postponed with the agreement of the RWQCB because of the need for additional risk assessment work requested by the DTSC. The rationale for the delay was based on having a clear understanding of the risk presented by site conditions prior to selecting a corrective action remedy to ensure protection of human health and the environment, including the water resources of the State of California.

Site Assessment

This section evaluates various aspects of site conditions that are relevant to establishing remedial action objectives (RAOs) for the Site. The categories of conditions evaluated are taken from RWQCB Guidance on Cleanup of Fuel UST Sites (RWQCB, 1996) and are standards used by the RWQCB to determine whether a UST site is low risk. Order No. 00-064 is the ruling guidance for the Site and states that it is consistent with other RWQCB guidance; therefore, the purpose of evaluating site conditions against these low-risk benchmarks is to establish the reasonable time frame within which RAOs can be achieved in compliance with Resolution 92-49. The RWQCB UST Guidance uses six standards to evaluate the relative risk a site presents to human health and the environment:

- ***Have releases been stopped, and have ongoing sources, including free product, been removed or remediated?***
- ***Has the site been adequately characterized?***
- ***Is the dissolved hydrocarbon plume migrating?***
- ***Are any water wells, deeper drinking water aquifers, surface water, or other sensitive receptors likely to be impacted?***
- ***Does the site present any significant risk to human health?***
- ***Does the site present any significant risk to the environment?***

The information presented in the following subsections answers these questions and forms the basis for establishing a time frame within which RAOs must be achieved to comply with Order No. 00-064 and Resolution 92-49, and to protect human health and the environment.

Assessment of Source *(Have releases been stopped, and have ongoing sources, including free product, been removed or remediated?)*

Releases have been stopped; USTs, hydraulic lifts, and oil/water separators have been removed; and multiple investigations gave shown that free product no longer exists at the Site.

Assessment of Adequacy of Site Characterization (*Has the site has been adequately characterized?)*

Extensive site characterization activities have been conducted at the Site. Multiple Geoprobe and Cone Penetrometer (CPT) investigations have supplemented the lithological examination of over 75 soil cores to characterize soil deposits. Quarterly groundwater sampling has been conducted since March of 1998. The extent and distribution of gasoline constituents in soil and groundwater have been fully defined. Air quality samples have been collected and analyzed outdoors and in buildings. Soil gas concentrations have been monitored in locations overlying the highest concentrations of gasoline constituents in groundwater and soil. Other soil gas samples were collected to characterize the vertical concentration profile of gasoline constituent vapors in the subsurface. Surface water samples have been collected in Pacheco Creek at multiple locations over greater than a seasonal cycle. The Site has been adequately characterized.

Assessment of Plume Stability *(Is the dissolved hydrocarbon plume migrating?)*

The stability of gasoline constituents in groundwater can be evaluated by various means based on the type of gasoline constituent (i.e., benzene, toluene, ethylbenzene, and total xylenes [BTEX] versus MTBE) and quantity and type of data and analytical tools available. Based on BTEX plume maps, which are provided in the main text of this CAP, the general shape and downgradient extent of the BTEX plumes have remained constant since the third quarter sampling event in 1998. The maximum and average BTEX concentrations measured during each quarterly monitoring event are both generally decreasing over time. BTEX constituent plumes are shrinking at the Site.

MTBE plume contour maps (provided in the main text of this CAP) based on groundwater analytical data collected from November 1998 through February 2001 show that the overall shape and downgradient extent of the MTBE plume has remained relatively constant over time with the exception of an advance of low-level MTBE concentrations in groundwater on the northeastern tip of the plume. In general, the overall maximum and average MTBE concentrations and estimated dissolved mass of MTBE have declined over time.

Using quarterly estimates of the dissolved mass of MTBE, it was possible to approximate the center of mass of MTBE over the entire Site, on Navy property, and on former HAAF property in January/February 1999 and February 2000. Over the two-year period of time, the estimated center of mass of MTBE dissolved in groundwater over the entire Site (Navy and former HAAF property) has receded nearly 300 ft upgradient (south).

Based on the MTBE plume maps provided in the main text of this CAP and the center of mass of estimated MTBE dissolved in groundwater at the Site, the greatest uncertainty appears to be related to the elevated MTBE concentration area at the northern end of the Navy property just upgradient of former HAAF property. Natural attenuation processes currently appear to be closely balanced with the tendency of advective groundwater flow to carry MTBE downgradient. The Navy has identified a natural channel or preferential pathway through which the bulk of groundwater seems to be flowing from the Navy property onto former HAAF property. This feature can be exploited for remedy selection as well as monitoring purposes.

Assessment of Impact to Water Resources or Other Sensitive Receptors (*Are any water wells, deeper drinking water aquifers, surface water, or other sensitive receptors likely to be impacted?*)

A well survey was performed through the County of Marin Environmental Health Services (CMEHS) and California Department of Water Resources (DWR). Results of the survey indicate that no domestic, irrigation, or agricultural wells are currently impacted by the dissolved gasoline constituents from the releases at DoDHF Novato.

Pacheco Creek, the surface water body located north of the Site, currently intersects MTBE-impacted groundwater on former HAAF property. Quarterly surface water monitoring activities performed by the Navy indicate the presence of MTBE in the surface water of Pacheco Creek. However, the fact that MTBE has been detected in the surface water does definitively establish interaction between the groundwater and Pacheco Creek during the wet season. Sampling data indicate that a possible or likely source of the MTBE in the surface water is from a storm sewer outfall located on former HAAF property that discharges laterally into Pacheco Creek near the Hamilton Parkway Bridge. During quarterly surface water sampling at the Site, MTBE concentrations have consistently been highest inside the storm sewer outlet and have decreased as the surface water travels downstream. The maximum MTBE concentration detected during all quarterly surface water monitoring events (2,400 µg/L) was found inside the storm sewer outfall; however, that level is well below the water quality objective adopted by the RWQCB to be protective of freshwater aquatic life (66,000 µg/L).

Assessment of Risk to Human Health (*Does the site present any significant risk to human health?***)**

A Tier 3 RBCA Assessment was prepared for the RWQCB to develop risk-based screening levels (RBSLs) that are protective of potential receptors that may come into contact with hydrocarbon-impacted media at the Site. After the Tier 3 RBCA Assessment was considered final, the DTSC opted to exercise their regulatory oversight for the human health risk assessment at the Site and requested the use of their preferred risk assessment method. A *Final Revised Risk Assessment* was prepared in response to DTSC comments on the Tier 3 RBCA Assessment. As part of the *Final Revised Risk Assessment*, additional health risk assessment analyses were conducted by the Navy which could be used by transferees to comply with the statutory requirements in Section 17213 of the California Education Code. DTSC concurred with the conclusions of the *Final Revised Risk Assessment* and issued a letter of approval. Results of the *Final Revised Risk Assessment* are favored over those in the Tier 3 RBCA for exposures pathways that were evaluated in both assessments.

Results of the *Final Revised Risk Assessment* indicate: (1) the cancer risk estimates to the occupational receptor in the Sale Area fall within the risk range (1×10^{-6} to 1×10^{-4}) that warrants a site-specific risk management decision regarding the suitability of the property for its intended future use; however, the total cancer risk estimates in the Sale Area are most likely overestimated and based on the results of the risk assessment, DTSC's concurrence with the risk assessment, and in accordance with EPA guidance, the Sale Area is suitable for its intended commercial/industrial use; (2) the educational PBC Area and areas outside the Sale Area and the PBC Area overlying groundwater with dissolved MTBE resulting from the former UST releases (i.e., Hamilton Meadows Subdivision) are suitable for unrestricted land use because the total cancer risk falls below 1×10^{-6} and the non-cancer risk is below 1.0; and (3) that precautionary measures should be taken by an excavation worker when working at the Site.

The results of the Tier 3 RBCA Assessment also supports that the current conditions on areas outside the Sale Area and the PBC Area overlying the MTBE plume (i.e., the former HAAF property) are not likely to be associated with adverse health effects for residential receptors that could potentially come into contact with gasoline constituents by ingesting homegrown fruits/vegetables or coming into contact with surface water in Pacheco Creek during recreational activities.

Assessment of Risk to the Environment (*Does the site present any significant risk to the environment?*)

A draft scoping level ecological risk assessment was prepared to determine if the Site poses a risk to the environment. The report focused on determining the potential ecological receptors and the potentially complete exposure pathways, according to the methodologies described by the Cal-EPA for scoping assessments and consistent with U.S. EPA guidance for problem formulation.

Because MTBE was detected in the creek, the surface water pathway is considered complete; however, risk to ecological receptors from MTBE in surface water is negligible. The maximum MTBE concentration detected inside a storm sewer outfall (2,400 μg/L) is well below the Recommended Interim Water Quality Objective (or Aquatic Life Criteria) of 66,000 μg/L MTBE for chronic exposure of freshwater organisms. The hazard quotient, calculated by dividing the exposure concentration by the Water Quality Objective is 0.04. Any hazard quotient below 1.0 is considered acceptable. Therefore, no significant risk is presented to ecological receptors at the Site.

Remedial Action Objectives

In compliance with RWQCB Order No. 00-064 and the *Water Quality Control Plan for the San Francisco Bay Basin* (the Basin Plan), the proposed ***final cleanup levels*** for Former UST Site 957/970 are background levels consistent with MCLs that completely restore the groundwater resources at the Site to their potentially most stringent domestic beneficial use. Because risk assessments performed at the Site indicate that an immediate threat to human health or the environment does not exist, in compliance with Resolution 92-49, the proposed final cleanup standards must be achieved within a reasonable time that provides the maximum benefit to the people of the State of California.

Order No. 00-064, Task 6, requires that this CAP satisfy the following requirements:

> "1. Stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site
> 2. Remediate the highest concentrations of soil pollution detected in Task B.1.
> 3. Reduce and remediate the concentrations of MTBE in Site groundwater
> 4. Reduce and remediate the concentrations of benzene in Site groundwater which exceed applicable RBSLs."

The RAOs of this CAP are to stabilize and contain the MTBE plume on Navy property as required in RWQCB Order No. 00-064 and to reduce the time to achieve the final cleanup levels (MCL concentrations) for all hydrocarbons present at the Site, including benzene and MTBE, using a remedial technology that produces the greatest benefit to the people of the State of California considering the total values involved: beneficial and detrimental, economic and social, tangible and intangible. The specific observable concentration goals will be based on performance goals which in turn are based on the most beneficial remedial alternative selected.

An evaluation of viable remedial alternatives is presented in this CAP to determine which available technology will produce the maximum benefit to the people of the State of California as measured by the feasibility study criteria given in Order No. 00-064. Specific performance goals for the proposed remedy are established. These performance goals include the estimated time to achieve stabilization and containment of the MTBE plume on Navy property as measured by observable concentrations in wells at specific proposed locations at the Site, as well as the estimated time required by each alternative to achieve MCLs as required by the Basin Plan.

All remedial alternatives considered in this CAP will include a monitoring program to ensure that the RAOs are achieved, and that concentrations of gasoline constituents are being reduced to MCLs within a reasonable time. Currently, a monitoring well protection plan and a groundwater monitoring plan are being implemented at the Site in compliance with RWQCB Order No. 00-064, Tasks 5 and 8, respectively. These plans will be modified with regulatory approval as necessary, and extended specific to the proposed remedy.

All remedial alternatives considered in this CAP will prevent nuisance conditions from occurring downgradient of the Site. All remedies considered will result in stabilization and containment of the MTBE plume on Navy property, and will therefore prevent migration of MTBE in groundwater toward Pacheco Creek or to low topography areas where surface ponding could occur.

RWQCB Order 00-064 requires that the highest concentrations of soil pollution detected in the remedial investigation as described in Order 00-064, Task 1, and performed and reported under Task 2 be addressed in the feasibility study portion of this CAP. Soil concentrations observed during the remedial investigation activities were reported in the Remedial Investigation Report submitted in compliance with Order 00-064, Task 2, and were assessed in the *Final Revised Risk Assessment* submitted June 2001. Other soil pollution was addressed in 1) the hydraulic lift removal activities that involved extensive excavation within and around Building 970, and 2) the Draft Summary Report for Hydraulic Lift and Oil/Water Separator Removal from Building 970 (July 2000) associated with those activities.

The results of the *Final Revised Risk Assessment* and the recommendations from the hydraulic lift report do not indicate that corrective action is required to protect human health and the environment from these soils. Institutional controls will be established to manage these soils and ensure that if these soils are disturbed, they will be managed properly and safely. RAOs for soil are therefore considered to have been achieved by the operation of the interim remedial action and the hydraulic lift removal activities. No further active corrective action for soils is required to satisfy Order No. 00-064 or to protect human health, the environment, or the water resources of the State of California.

Selected Corrective Action

Four remedial alternatives were selected for detailed evaluation in the feasibility study portion of this CAP and are as follows:

- **Alternative 1** – Excavation to remove soil and dewatering to remove groundwater containing elevated concentrations of gasoline constituents on currently Navy-owned property. Recovered groundwater would be treated and disposed of at an off-site facility. This active remediation method is supplemented with monitored natural attenuation (MNA) to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.
- **Alternative 2** – Interception/aeration trench at the northern boundary of the currently Navy-owned property to treat groundwater by air sparging as it moves through the trench. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.
- **Alternative 3** – Collection trench and wells with groundwater pump and treat to extract groundwater for treatment supplemented with SVE. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.
- **Alternative 4** – Biosparging to remediate groundwater migrating across the northern boundary of currently Navy-owned property and elevated concentrations of MTBE on currently Navy-owned property. A SVE system would serve as a contingency measure for off-gas control during biosparging system operation. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.

The feasibility study performed in this CAP complies with guidance provided by "Subpart F of the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), CERCLA guidance documents with respect to remedial investigation and feasibility studies, Health and Safety Code Section 25356.1(c), State Board Resolution No. 92-49 as amended, and all other applicable State Board Policies" as required by Order No. 00-064, Task 6. The remedial alternatives were evaluated with respect to the following criteria as required by Task 6 of Order No. 00-064:

- Implementability
- Effectiveness
- Benefits
- Impact on Public Health and Welfare and the Environment
- Cost.

Alternative 4, biosparging is selected in favor of the other alternatives based on the proven performance of biosparging/air sparging at the Site, the more flexible implementation options, and better cost-effectiveness of biosparging compared to the other alternatives. Selection of Alternative 4, biosparging, provides the maximum benefit to the people of the State of California. Environmental resources are protected by timely remediation of gasoline constituents in groundwater using the most cost-effective alternative. Table ES-1 provides a summary comparison of the alternatives.

Description Of Recommended Remedy

Biosparging with system monitoring, MNA, and institutional controls are recommended as the corrective action alternative to achieve the RAOs at the Site. Biosparging will be used to stabilize and contain the higher concentrations of MTBE in groundwater currently on the Navy-owned portion of the Site. System monitoring will be performed during biosparging system operation to track: (1) the removal efficiency; (2) the estimated time until RAOs are met; and (3) the biodegradation capacity of the vadose zone. After the biosparging system has met its performance goals, the system will be shut down and groundwater monitoring will be performed to verify that concentrations do not rebound. If concentrations remain stable or decrease, indicating the MTBE plume has been stabilized and contained to Navy property, MNA will be used to reach MCLs over the entire Site (Navy-owned property and Former HAAF property). During remediation activities, investigative derived wastes will be managed as outlined in the Interim Site Control Plan. After the property is transferred, institutional controls will be in place to protect human health and the environment, and to allow the corrective action to progress without the interference of site operations on the property. The following subsections provide further detail for each element of the corrective action.

Biosparging with System Monitoring

In situ biosparging is recommended to stabilize and contain the higher concentrations of MTBE and further reduce benzene concentrations in groundwater currently on the Navy-owned portion of the Site. Biosparging is the injection of pressurized air directly into the aquifer. The injected air delivers oxygen to the groundwater and strips volatile compounds from the groundwater. The air flows through permeable pathways in the saturated soil column driven toward the water table surface by buoyant forces. The shape and nature of the airflow pathways is determined by soil particle and sediment layering characteristics.

In situ biosparging removes hydrocarbons from saturated soil sediments by two primary mechanisms: (1) increased DO supports and enhances in situ biodegradation of hydrocarbons by indigenous microbes, and (2) volatile hydrocarbons partition into the vapor phase and are carried with the

air stream to the vadose zone, where additional biodegradation occurs. The relative contribution of each of these removal mechanisms are dependant on site characteristics, contaminant type and concentration, system design, and operational parameters. The operation of the sparging system will be focused on enhancing the biodegradation of hydrocarbons by injecting the air at relatively low flowrates. The vapor stream reaching the vadose zone will be a biologically reactive mixture of hydrocarbons and oxygen that microbes can utilize based on the results of aerobic treatability studies performed with Novato site-specific media. Indigenous soil bacteria aerobically respire using oxygen as an electron acceptor and the hydrocarbons as an energy and carbon source. The soil volume in which this degradation occurs is referred to as an in situ bioreactor that in many cases can be exploited and optimized to effectively destroy the vapor stream. The ability of the vadose zone to degrade residual vapors, its biodegradation capacity, is dependent on the type and number of indigenous soil microbes, the type and concentration of hydrocarbon, and the physical characteristics of the vadose zone soils (depth, porosity, specific surface area, heterogeneity, and anisotropy). Aerobic laboratory microcosms made of Novato soils and groundwater showed complete MTBE removal without breakdown product (TBA or TBF) accumulation; therefore, if the vadose zone soils can be exploited to destroy the residual vapor stream, no vapor collection and treatment systems will be required. However, SVE wells will be installed with the biosparging system to collect vadose zone vapors in the event that the in situ bioreactor is unable to sufficiently destroy the residual vapor stream.

Design. The biosparging system will be designed with flexible system controls that allow optimization of the system to achieve the maximum attainable rate of removal via the biological mechanisms described above. Deep soil-gas monitoring probes and groundwater monitoring wells will provide feedback regarding in situ conditions and enable informed decision-making for parameter adjustment. The actual locations of sparge wells, SVE wells, soil-gas monitoring probes, and groundwater monitoring wells will be based on site characteristics found during the system installation phase.

Installation. During the biosparging system installation, a sparge curtain or barrier is planned near the Navy property boundary to ensure the containment of MTBE at the Navy property boundary. The sparge wells within the barrier will be placed in a relatively narrow channel of more permeable soil deposits to treat groundwater as it passes through the barrier, thereby allowing only treated groundwater that is being transported within the preferential flowpath to pass across the Navy property boundary. Sparge wells will also be within the areas of higher permeability, upgradient of the sparge barrier, to decrease the highest concentrations of MTBE and accelerate the remediation process. After the highest concentrations of MTBE are removed and the plume continues its collapse on itself at an accelerated rate, MNA mechanisms will cause conditions at the Site to return to MCLs.

Operation. Routine system operation of the biosparging system will focus on removal of MTBE from the groundwater in and around the sparging barrier area to stabilize and contain the MTBE to currently owned Navy property, while concurrent treatment is performed within the MTBE hot spot (current MTBE concentrations > 10,000 μg/L). During system operation, groundwater samples will be collected from performance goal monitoring wells and analyzed for BTEX, MTBE, and MTBE breakdown products (TBA and TBF) to determine the removal efficiency. Based on historical groundwater monitoring results for the Site, TBA and TBF should only be observed at very low concentrations relative to the parent compound MTBE. It is not suspected that biosparging system operation will promote the accumulation of TBA or TBF because the results of the aerobic microcosm studies showed that the breakdown products attenuated similarly to MTBE, and quarterly monitoring has not shown these compounds to accumulate in the aquifer as MTBE is destroyed. However, groundwater monitoring will be performed to verify that the breakdown products are not present at elevated concentrations compared to MTBE, nor that they are accumulating as a result of aerobic biodegradation of MTBE.

Performance Goals. The biosparging/air sparging system can be expected to perform similarly to the IAS system that was operated as the interim remedial action, once some important differences between the two systems are considered, and the expected performance is adjusted for those differences. The biosparging system will be operated at a slightly lower air injection rate than the IAS because its primary objective is the biological destruction of hydrocarbons in a soil region distant and separated from potential aboveground receptors.

To ensure containment of the MTBE plume on Navy property is achieved, MTBE concentrations will be reduced by multiple and overlapping sparging curtains. This will be accomplished by a much more dense well distribution in the region just south of the property boundary than was used in the IAS design for the interim remedial action. A less dense well distribution will be used upgradient of the sparging curtain or barrier to remove elevated concentrations of MTBE (and other hydrocarbons) at an accelerated rate.

An estimate of the expected performance from the biosparging system was prepared by considering the rate of MTBE removal achieved by the interim remedial action IAS, and adjusting it for the differences between that system and the recommended biosparging system (differences are outlined in Section 7 of this CAP). Assuming that a first order removal rate expression approximates actual system behavior, the concentration decreases observed in the IAS treatment area correspond to an overall removal rate (k) of 0.0042/day during the interim remedial action. Note that this overall removal rate includes physical, chemical and biodegradation removal mechanisms as observed in monitoring wells. The overall removal rate of 0.0042/day is therefore the rate that will be adjusted to estimate the performance expected from the biosparging system.

It is estimated that the biosparging system in the recommended configuration will achieve a removal rate (k) approximately two to three times that of the IAS for the reasons discussed in this CAP. The greater removal rate is likely to yield reductions measured as absolute mass per unit time at a slower rate because of the lower initial concentrations of MTBE currently observed at the Site, compared to the much greater MTBE concentrations that were observed when the IAS was started in 1998. Nevertheless, if the system behaves similarly to the first order model, an overall biosparging removal rate of two times the IAS rate (or 2k) would be expected to result in approximately 95% reduction in concentrations over one year, and an overall biosparging removal rate three times the IAS rate (3k) would be expected to reduce concentrations by about 99% in a year. This range of rates would be expected to remove 51 to 53 kg of the 54 kg of MTBE estimated to be dissolved in groundwater on the Navy portion of the Site (May 2001 estimate) and reduce concentrations by almost two orders of magnitude.

The estimated concentration trends that would be expected given the assumption that the initial average concentration of MTBE in the performance goal monitoring wells is 30,000 μg/L would be MTBE concentrations between 300 μg/L and 1,500 μg/L following one year of biosparging system operation. If system groundwater monitoring reveals that MTBE concentrations are decreasing at a rate substantially below this range (or staying at concentrations near the currently observed concentrations), the biosparging system design would allow for adjustments to improve performance, including:

- Installation of additional sparge wells in selected areas
- Increasing the air injection rate to add more oxygen and increase stripping (this contingency action would be accompanied by careful and frequent soil-gas monitoring to ensure that shallow soil gas between the system area and potential receptors does not exceed a safety threshold)
- Cycling air injection on and off to increase the zone of influence achieved by the system.

Monitoring System Performance. The effect of the active biosparging system barrier and other sparge wells intended to reduce plume concentrations, coupled with natural attenuation mechanisms, the effects of which are already observable at the Site, will overcome the tendency of advection to carry MTBE off site, and will eliminate flux at the property boundary. This effect is consistent with a stable and contained MTBE plume and will be confirmed by groundwater monitoring to demonstrate rapidly declining concentrations in wells near the property boundary.

The performance goal of a removal rate of 0.0084/day (2k) to 0.0126/day (3k) will be confirmed by monitoring wells that will be installed in the treatment area just south of the property boundary on Navy property. Data from samples collected from sparging wells will not be considered adequate to confirm achievement of this performance goal. Approximately five system monitoring wells placed in the permeable flow channel south of the railroad tracks will provide critical performance data on the water quality just south of the Navy property boundary. The actual location of the wells will be determined based on site characterization data found during installation. In addition, three existing monitoring wells at the site will be used to provide performance data, as requested by the RWQCB. All performance goal monitoring wells will be sampled monthly during system operation to provide adequate data to evaluate the concentration trend over time and to ensure these trends reflect the expected system performance.

The monitoring wells just south of the Navy property boundary are proposed to provide data regarding the quality of the groundwater that is about to cross the boundary in the permeable channel, whereas some existing monitoring wells are screened in tighter, less-permeable soils which may not represent the quality of groundwater leaving the Site. The current groundwater monitoring program will be continued to view changes in behavior of the MTBE plume as a result of biosparging operation. However, it is not reasonable to expect MTBE concentrations in all monitoring wells located near the Navy property boundary to rapidly decrease due to biosparging operation because some wells are placed in tighter, clayey soils that will release MTBE primarily by diffusion. The biosparging system will not directly treat the MTBE in clayey soils, but a concentration diffusion gradient will be established, causing an overall decrease in concentrations in all site wells.

Monitoring for Achievement of RAOs. In addition to collecting groundwater from system monitoring wells for tracking biosparging system performance, groundwater samples will be collected from some existing monitoring wells located within the treatment area to track the behavior of the MTBE plume upgradient (south) of the sparging curtain. Biosparging system operation will focus on achieving a stable or decreasing MTBE plume on Navy property, which is considered the RAO that will dictate the duration of operations. It is expected that this objective will be achieved following approximately one year of biosparging system operation.

The status of the MTBE plume on Navy property will be evaluated by analyzing the behavior and size of the MTBE plume during biosparging operation. When monitoring data from the performance goal monitoring wells near the property boundary and upgradient in areas with currently elevated MTBE concentrations indicate that the MTBE plume has been contained and stabilized, the biosparging system will be shut down. Groundwater monitoring will then be performed monthly in selected wells for two quarters to confirm that rebound does not occur and threaten compliance with RAOs.

A stable to decreasing plume is defined as one that shows stable to decreasing concentrations in monitoring wells over time. A stable plume will be demonstrated by showing generally decreasing MTBE concentrations in groundwater after biosparging system shutdown. A contained MTBE plume will be confirmed by the observation of MTBE concentrations off site declining at a rate consistent with the natural attenuation rates already observed throughout the plume, indicating that net flux has been eliminated.

Once a stable and confined MTBE plume is confirmed at the Site, benzene concentrations in groundwater are below RBSLs (410 µg/L), and MTBE concentrations on Navy property are substantially reduced, RAOs will be considered achieved, and groundwater monitoring objectives will focus on the progress of MNA toward achieving final cleanup levels.

SVE Contingency. It is recognized that biosparging operations, although intended to destroy hydrocarbon vapors in deeper soil layers, require that soil-gas monitoring be performed to ensure that hydrocarbon vapors are not allowed to migrate near potential receptors. Shallow soil-gas monitoring probes will be monitored to allow adjustments to be made to the biosparging system operating parameters, such as injection rate or cycling frequency, in the event that concentrations are elevated beyond the safety threshold. If adjusting system operating parameters is unable to maintain shallow soil-gas concentrations below the safety threshold, the contingency soil vapor extraction system will be initiated.

Monitored Natural Attenuation

Active remediation of the entire volume of hydrocarbon-impacted groundwater under the Site is not required by the risk levels at the Site and would involve an excessive resource commitment that would not result in the greatest benefit to the people of the state. MNA has been selected as a supplement to the biosparging system for remediation of remaining concentrations of gasoline constituents to achieve final cleanup levels throughout the gasoline constituent plume.

Implementation of MNA as a remediation technology at the Site will entail a comprehensive groundwater monitoring program to provide data to evaluate intrinsic biodegradation, and to monitor the extent of the plume as a function of time. Analyzing the behavior and size of the MTBE plume over time and calculating the total mass of MTBE on and off the currently Navy-owned property will track progress of MNA and assess the status of the plume. Sampling and analysis will be performed to evaluate the effectiveness of MNA over the entire site, including former HAAF property north of the currently Navy-owned portion.

Existing groundwater monitoring data was evaluated to determine the approximate decrease of MTBE concentrations at the Site over time. If current trends continue as expected, MNA will require approximately 15 years to reach MCLs on former HAAF property and 7 years to reach MCLs on the Navy-owned portion of the Site (after achieving biosparging system RAOs).

Institutional Controls

Institutional controls will be a component of the selected corrective action. The objectives of the ICs are twofold: to ensure that commercial use of the land at the gas station site (immediate area surrounding Building 970) is maintained and that residential use is prohibited in that area; and to ensure that future actions over the entire site do not affect the gasoline constituent groundwater plumes.

The primary legal mechanism used to implement land use controls will be restrictions included in the quitclaim deeds for the subject property.

The following restrictions and controls will apply to the entire Site:

- Construction and/or operations on the property shall not interfere with the ongoing monitoring or assessment of work being conducted by or for federal, state, or local regulatory agencies.

- Removal and disposal of contaminated soil or groundwater by the transferee, its successor or assigns, shall be conducted in accordance with all applicable federal, state, and local regulations governing removal, transport, and disposal of hazardous substances and hazardous waste.

- Disturbance of existing groundwater wells is prohibited unless specifically approved by the Navy and the RWQCB. No groundwater production wells may be installed for residential, municipal, agricultural, or industrial use, without written approval of the RWQCB. Monitoring and other test wells are not subject to this provision, including borings for the purpose of testing wells, wells for monitoring the quality of groundwater, and borings to define geology.

In addition to the above restrictions and controls, the following will be applied to the Sale Area:

- Construction and occupation of residential structures or day-care centers is prohibited.

The United States will retain the right to enter and inspect the property to ensure the viability of the selected institutional controls or to perform any additional response actions. In the deeds affecting transfer of the property, the State of California also will be given such right to enter and inspect the property.

In addition to institutional controls, the DON is willing to enter into an agreement with the State of California, through the DTSC and RWQCB, allowing the State pursuant to the California Civil Code Section 1471 to enforce the restrictions on the use of property for the purpose of protecting human health, safety, and the environment. Such a covenant would be based on the models attached to a March 2000 MOA executed by the DON and the DTSC. This covenant would list environmental restrictions and would serve as the primary legal mechanism to enforce restrictions. Once the covenant is finalized, it will be executed contemporaneously with the negotiation and execution of the conveyance or assignment of the property.

In addition, the DON shall include the same environmental restrictions in the deed between the United States and the transferees pursuant to the California Civil Code Section 1471. These restrictions shall be consistent with restrictions set forth in this CAP and any covenant entered into between the DON and DTSC for the Site.

Table ES-1. Summary Comparison of Remedial Alternatives

Evaluation Factor	**Alternative 1:** Excavation and Dewatering	**Alternative 2:** Interception/Aeration Trench	**Alternative 3:** Collection Trench and Wells with Groundwater Pump and Treat and SVE	**Alternative 4:** Biosparging/Air Sparging
Implementability	This alternative is implementable using standard materials and methods. Excavation would greatly hinder current site operations. Extensive work would be needed to avoid damage and/or service interruption with buried utilities.	This alternative is implementable using standard materials and methods. Construction of the trench would require temporary closure of C Street. The trench must be routed to avoid the railroad easement and underground utilities.	This alternative is implementable using standard materials and methods. Construction of the French drain would require temporary closure of C Street. The trench must be routed to avoid the railroad easement and underground utilities. Implementation may be delayed because a NPDES permit must be procured to discharge treated process water to surface water.	This alternative is implementable using standard materials and methods. Well installation may require brief closure of C Street. Well placement is flexible such that all underground obstructions should be easily avoided.

Table ES-1. Summary Comparison of Remedial Alternatives (continued)

Evaluation Factor	**Alternative 1:** Excavation and Dewatering	**Alternative 2:** Interception/Aeration Trench	**Alternative 3:** Collection Trench and Wells with Groundwater Pump and Treat and SVE	**Alternative 4:** Biosparging/Air Sparging
Effectiveness	Provides an effective and lasting method for removing gasoline constituents from groundwater on the currently Navy-owned property. The excavation volume would be designed such that the upstream concentrations are sufficiently reduced to ensure that MNA would stop migration of any remaining MTBE from migrating off of currently Navy-owned property.	Provides an effective and lasting treatment method for removing gasoline constituents in groundwater as it passively migrates through the trench. The rate of cleanup is limited by the flux of MTBE so air sparging in the trench must continue until the entire extent of the plume with elevated MTBE concentrations passes through the barrier. This alternative is expected to require about 10 years to remediate the Site but could require much longer if the MTBE plume moves at a slower than expected rate.	Groundwater pumping and treatment is an established method for controlling plume migration and extracting groundwater for treatment above ground. Use of a French drain reduces the sensitivity of extraction performance to permeability variations.	Biosparging/air sparging provides a proven treatment technology that has been widely applied and has an established operating history for remediating VOCs in groundwater. Aerobic laboratory microcosm studies with Novato soils and groundwater have shown complete MTBE removal without TBA or TBF accumulation (Battelle, 2001d). Also, interim remedial activities using a similar approach (IAS/SVE) conducted within the former source area at Former UST Site 957/970 showed dramatic decreases of gasoline constituent concentrations in groundwater followed by no rebound.
Benefits	Requires about 25 weeks to implement a remedial action that stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property, and reduces and remediates MTBE and benzene in Site groundwater.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property immediately after interception/aeration trench operation begins. Reduces and remediates MTBE and benzene in Site groundwater as the water migrates through the trench.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property immediately after groundwater pumping operation begins. Reduces and remediates MTBE and benzene in Site groundwater by groundwater extraction and treatment.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property shortly after air sparging operation begins. Reduces and remediates MTBE and benzene in Site groundwater by air sparging.

Table ES-1. Summary Comparison of Remedial Alternatives (continued)

Evaluation Factor	**Alternative 1:** Excavation and Dewatering	**Alternative 2:** Interception/Aeration Trench	**Alternative 3:** Collection Trench and Wells with Groundwater Pump and Treat and SVE	**Alternative 4:** Biosparging/Air Sparging
Impact on public health and welfare and the environment	Short-term risks exist to workers due to the heavy construction activities required for site excavation and backfilling. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility	Short-term risks exist to workers due to the heavy construction activities required to excavate and backfill the interception/aeration trench. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility.	Short-term risks exist to workers due to the heavy construction activities required to excavate and backfill the French drain. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility.	Short-term risks associated with this alternative are within those normally associated with light construction activities (e.g., well drilling and installing small-diameter pipe).
Cost	$15,735,000	$3,129,550	$2,912,400	$1,855,290
Time to Plume Stabilization (yrs)[(a)]	0.50	1.5	0.25	1.5
Time to Remediate to Basin Plan Requirements (yrs)[(a)]	0.50	10	3	7

(a) Estimated time to plume stabilization and remediation to Basin Plan requirements for Navy Property only. Because MNA is a common element of each alternative to achieve Basin Plan requirements on former HAAF property, the estimated time of 15 years to reach MCLs on former HAAF property is consistent between alternatives.

Section 1.0: INTRODUCTION

This Corrective Action Plan (CAP) describes the current conditions of property at Former Underground Storage Tank (UST) Site 957/970 and recommends a corrective action strategy to ensure protection of human health and the environment in compliance with Regional Water Quality Control Board, San Francisco Bay Area (RWQCB) Order No. 00-64, Task 6 (see Attachment 1). The previously existing USTs served a former Naval Exchange (NEX) service station and former Naval Public Works Center (PWC) gas station at U.S. Department of Defense Housing Facility (DoDHF), Novato, California. This work is being performed for the U.S. Navy under Navy Facilities Engineering Service Center (NFESC) Contract Number N47408-95-D-0730, Delivery Order No. 0037, and is funded by Engineering Field Division (EFD) Southwest in San Diego, California.

This CAP is organized into the following sections:

- **Section 1.0:** Includes this **introduction**, the objectives of the CAP in the context of the project, a brief site description, site history and background;
- **Section 2.0:** Describes the **previous investigations** performed;
- **Section 3.0:** Describes the **interim remedial action** taken to remove gasoline from areas having elevated concentrations in soil or groundwater;
- **Section 4.0:** Assesses the impacts that exist as they pertain to the **conceptual site model** and the current **distribution of gasoline constituents** in environmental media at the Site;
- **Section 5.0:** Evaluates the **site conditions** and presents the **remedial action objectives** for the Site;
- **Section 6.0:** Identifies and analyzes the **remedial alternatives** that were evaluated to satisfy the remedial action objectives and identifies the **selected corrective action**;
- **Section 7.0:** Describes the **recommended remedy**; and
- **Section 8.0:** Lists **references** cited in the document.

1.1 Objectives

The objectives of this CAP are to provide a thorough review of site history, provide a site characterization summary that incorporates all investigations performed to date, and recommend cost-effective corrective actions necessary to protect human health and the environment from gasoline constituents released to the environment.

1.2 Site Description

The subject of this report is Former UST Site 957/970 (the Site) on DoDHF Novato, California. The Site is located approximately 20 miles north of San Francisco in Marin County, California (Figure 1-1). The Site comprises an area of approximately 13 acres of land (an approximate rectangle with dimensions 1,100 ft by 500 ft) bounded on the south by Main Entrance Road, and on the north by a set of Golden Gate Company railroad tracks (Figure 1-2). The eastern border of the site runs north-south from the intersection of Main Entrance Road and C Street, and the western border of the site runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street.

The Site is the location of a former NEX gas station and a former Naval PWC gas station at DoDHF Novato, California (see Regional Location Map in Figure 1-1 and Site Location Map in Figure 1-

2). Both the NEX gas station and the PWC gas station operated USTs that stored gasoline. The NEX gas station tanks were associated with Building 970, and the PWC gas station tank was identified with former Building 957. Because groundwater at the site was thought to be impacted by fuel releases from both the NEX gas station and the PWC gas station, the respective site designations were merged and the label "Former UST Site 957/970" was adopted.

The following text describes Site features from south to north. The southern portion of the Site consists of the service station areas, and is almost completely covered with asphalt pavement. An 8-ft-tall chain-link security fence surrounds the service station areas, with one double-door gate providing access to the NEX service station (Building 970) area, and another double-door gate providing access to the former Naval PWC support area. Both gates are accessible from C Street. North of the fenced service station areas is an asphalt-paved parking lot that supports Building 971. Building 971 lies at the northern end of the parking lot. State Access Road is located north of Building 971. The Golden Gate Company railroad tracks intersect State Access Road and serve as the Navy's northern property boundary at the Site. Continuing north of Navy property onto former Hamilton Army Airfield (HAAF) property, an area referred to as "Hamilton Meadows Subdivision" exists, and is currently being developed for residential use and recreational areas. The area northwest of Hamilton Meadows Subdivision is open land that is not currently in use, and is planned for recreational purposes or open space. The area northeast of Hamilton Meadows Subdivision is Landfill 26. A small creek, Pacheco Creek, runs in culverts or pipe along the western edge of the Site along the service station areas, and discharges into a concrete-lined culvert just north of Navy property. The creek flows northward on former HAAF property, until it passes the Hamilton Meadows Subdivision, where it flows west for about 1,000 ft before turning north again, flowing more than 3,000 ft before emptying into Ignacio Reservoir (Pacheco Pond). A row of former storage bunkers running east-west approximately 1,000 ft south of Ammo Hill, a local bedrock outcropping, also lie on former HAAF property.

The area in which the Site is located has a Mediterranean climate consisting of mild, wet winters and warm, dry summers. Average temperatures during the spring and summer are between 50 and 100°F (10 to 38°C), while temperatures in the fall and winter range between 35 and 70°F (2 to 31°C) (PRC, 1994). During the rainy season from November through March, rainfall averages between 4 and 7 inches (10 to 18 cm) per month. During summer months, rainfall averages less than 0.1 inch (0.25 cm) per month (IT Corporation, 1995). The region gets about 20 inches of precipitation per year, largely during the wet season.

The Site is within the Northern Coastal Ranges physiographic province, in the Franciscan Complex (PRC, 1994). The Franciscan Complex consists predominantly of sandstone and shale, with some chert, limestone, conglomerate, and various metamorphic rocks such as serpentine and greenstone (PRC, 1994). The site geology is heterogeneous, with sands and clay encountered in different proportions and at varying depths across the site. Bedrock is typically encountered at 15 to 20 ft below ground surface (bgs) and underlies a shallow, thin aquifer encountered at about 9 ft bgs. Surface water is primarily limited to Pacheco Creek, which is located north of the Site (Figure 1-2).

1.3 Site History and Background

Hamilton Air Force Base (AFB) was in use by the Air Force prior to being transferred to the Army, the Navy, and the Coast Guard. Most of the AFB was used by the Army Air Corps and was designated Hamilton Army Airfield. The Navy took over many of the housing units on the AFB and established DoDHF Novato to help manage a housing shortage for Navy personnel in the San Francisco Bay area. The Coast Guard also managed some housing units on the AFB. The Navy-occupied portion of the AFB included various operations to support the housing facility, including the NEX gas station and PWC gas station (Figure 1-3) that were in use from the mid-1970s to the early 1990s. At that time the gas

stations were closed and the three (3) USTs that had supported the NEX gas station (UST 970-1, UST 970-2, and UST 970-3) and the single UST (UST 957) that had supported the PWC gas station were removed. A Tank 970-Waste Oil storage tank associated with Building 970 and the NEX gas station was also excavated and removed in the mid-1990s. Water and soils collected from excavations during tank removal activities indicated that gasoline had been released to the environment from USTs in both areas (957 and 970). In the early 1990s, HAAF and DoDHF Novato (administrated by the Navy) were scheduled for closure under the Base Realignment and Closure (BRAC) program.

DoDHF Novato is scheduled for transfer of ownership under the BRAC program. As described in the *Hamilton Army Airfield Reuse Plan: Final Reuse Plan* (Hamilton Local Reuse Authority, 1996), a portion of the site, referred to as the "Sale Area", will be sold to the City of Novato, California, for commercial/industrial use, and other portions will be transferred to the Novato Unified School District (NUSD) as an educational public benefit conveyance (PBC) (NUSD, 1996). The NUSD intends to use portions of the PBC Area as a bus driver training facility for public school system drivers, as parking space for school buses, and for on-site vocational training. The land use designations for selected areas are shown in Figure 1-3. The planned future uses of DoDHF Novato property indicate that currently paved areas of the Site are likely to remain paved to serve their future functions. Most support buildings on the service station areas are planned for demolition, with the exception of at least one, Building 971, which is planned for immediate occupation by the NUSD.

The U.S. Navy is the lead agency administrating the remediation and closure of the Site, and it is Department of Defense (DoD) policy to achieve site closure with the agreement of local regulatory authorities. Because the source of gasoline constituents was a UST hydrocarbon release, the RWQCB is the local regulatory authority with which this project has been coordinated. The California Department of Toxic Substances Control (DTSC) is involved as the lead state agency for closing former military installation and has oversight concerning risk assessment activities at the Site.

1.3.1 Chronology of Events. The following bulleted list provides a summary chronology of events related to site characterization and remediation at Former UST Site 957/970. Detailed descriptions of site investigations to date are given in Section 2.0.

- March 1992: UST 957 was removed. Gasoline was observed in soils during excavation activities.

- November/December 1994 and January 1995: Screening level soil and groundwater sampling was conducted in the area surrounding former UST 957 using a Geoprobe™. The objective of the investigations was to delineate the extent of hydrocarbons released from USTs in the service station area. Samples from the initial investigations were analyzed for total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX) only.

- December 1994: Permanent groundwater monitoring wells were installed in the area surrounding former UST 957 and sampled in January 1995.

- January 1995: UST 970-3 was removed by the Navy's PWC. Gasoline was observed in water and soils during the excavation activities, and a hole was observed in the tank.

- January 1995: Tank 970-Waste Oil was removed by Navy Public Works Center (NPWC) personnel. The tank appeared to be in good condition upon removal and confirmation soil sampling indicated that hydrocarbon impact was below applicable guidelines.

- October/November 1995; January 1996; and October 1996: Soil and groundwater sampling were conducted in the area of former UST 970-3 using a Geoprobe™.

- May 1996: Groundwater sampling and cone penetrometer testing (CPT) was performed by PRC Environmental Management, Inc., using the Navy's Site Characterization and Analysis Penetrometer System (SCAPS). The investigation focused on the NEX gas station area around Building 970.

- July 1996: USTs 970-1 and 970-2 were removed.

- October 1996: Installed six additional permanent monitoring wells (five in the vicinity of former 970 USTs and one in the vicinity of former UST 957).

- June/July 1997: Additional groundwater sampling was conducted because methyl-*tert*-butyl ether (MTBE), a constituent of reformulated gasoline, became a concern. The investigation was conducted using a Geoprobe™ for screening level site characterization of MTBE concentrations in groundwater.

- July 1997 to January 1998: Reports summarizing the preliminary site characterization and recommendations for remedial alternatives submitted to the Navy were reviewed by Battelle. Preliminary comparison of gasoline constituent concentrations in groundwater against concentrations conservatively accepted to be protective of human health under most circumstances revealed that 1) some localized areas had elevated concentrations that substantially exceeded conservative protective concentrations, and 2) the most problematic potential exposure pathway appeared to be volatilization of volatile organic compounds (VOCs) from groundwater to indoor air. Battelle developed an approach to site remediation and closure and submitted a work plan to the Navy (January 1998). A groundwater monitoring plan (GMP) also was submitted.

- February 1998: A Tier 1 Risk-Based Corrective Action (RBCA) Assessment was performed and submitted to the Navy. This assessment confirmed that some gasoline constituents, including benzene and MTBE, existed at greater than Tier 1 "lookup table" values that are protective of human health under conservative assumptions. These values do not take into consideration site-specific conditions.

- March 1998: Battelle conducted a limited investigation using a Geoprobe™ system to identify the leading edge of the MTBE groundwater plume prior to the installation of permanent monitoring wells. According to the GMP, monitoring wells were to be placed around the perimeter of the gasoline constituents dissolved in groundwater, including MTBE. The investigation was designed to determine the downgradient extent of MTBE based on the delineation performed previously, and revealed that the MTBE plume required substantial further investigation to define its perimeter. The leading edge of the plume was not delineated.

- March 1998: An addendum to the work plan was submitted to the Navy describing a stepwise investigation to characterize the mass transport and potential exposure pathway of volatilization of VOCs from groundwater to indoor and outdoor air. The work plan addendum included three proposed investigative approaches: 1) direct sampling and analysis of indoor and outdoor air, 2) soil-gas concentration profile characterization, and

3) flux box testing. In response to comments from the RWQCB, flux box testing was abandoned and not performed.

- April/May 1998: An interim remedial action was initiated at the gas station areas in localized areas having elevated hydrocarbon concentrations in soil and groundwater. Air sparging with soil vapor extraction (SVE) was used to reduce mass that could have been serving as a source of hydrocarbons to groundwater. The system included 10 air sparging wells and 6 SVE wells arranged to treat 4 "hot spots."

- April/May 1998: An extensive groundwater monitoring well network was installed at the site. The network included:

  - 18 groundwater monitoring wells for routine sampling (designated MW)
  - 8 groundwater monitoring wells for evaluating natural attenuation rates (designated NA)
  - 4 multilevel soil gas and groundwater monitoring points for evaluating system operation (designated MP).

- May 1998: A second limited investigation was performed using a CPT to delineate the boundaries of the MTBE groundwater plume. This investigation was also based on the previous delineation, but was expanded to over 200 ft beyond the boundaries identified by previous contractors. This investigation also failed to identify the boundaries of the existing MTBE in groundwater at the Site.

- June 1998: Soil gas from beneath Building 973 was collected and analyzed to initially characterize the concentration profile of VOCs like BTEX and MTBE in the soil void spaces from the water table to the building foundation.

- August 1998: Another investigation using a CPT was performed that delineated the MTBE plume. The MTBE plume was found to extend 1,400 ft downgradient (north) beyond the boundaries previously identified, and was observed to have a width of approximately 600 ft. (In the vicinity of the previously identified leading edge of the MTBE groundwater plume, an artifact of the heterogeneity of aquifer sediments produces MTBE concentrations in groundwater that approach non-detectable levels, but vary seasonally. Beyond this area, MTBE concentrations rise again. The current understanding is that there is an area of low permeability near State Access Road that produces a deceptive concentration anomaly.)

- October 1998: Groundwater monitoring results from permanent wells not available at the time of pilot system design and installation indicated that greater concentrations of gasoline constituents existed outside the areas treated by the interim (pilot) action system. The system was therefore expanded to almost twice its originally designed capacity to ensure that effective hot spot remediation was achieved. During expansion activities, an additional 8 sparge wells and 7 SVE wells were installed at the Site.

- November 1998: Because of the absence of historical groundwater monitoring data for the Site, an effort was begun to predict the future behavior of MTBE in groundwater at the Site. Aquifer parameters were entered into a numerical model to estimate the likely behavior of the MTBE plume. All site characterization information was assimilated and

incorporated into a site conceptual model. This conceptual model was used as a "living" representation of typical site conditions, exposure pathways, and future land uses, and was updated and revised as new information became available.

- December 1998: Additional permanent monitoring wells were installed around the perimeter and within the MTBE groundwater plume. These new wells, as well as selected wells installed by the United States Army Corps of Engineers (USACE) were monitored monthly for four (4) months to ensure that the MTBE plume had been adequately delineated, and quarterly thereafter.

- January 1999: An Interim Project Report was submitted to the Navy for the purpose of summarizing remedial progress and site activities to date.

- March 1999: A Tier 2 RBCA Assessment was prepared by the Navy. This assessment incorporated responses to comments from the RWQCB on the Tier 1 RBCA Assessment, as well as some limited site-specific parameters, such as soil porosity, bulk density, and depth to the water table. The Tier 2 RBCA Assessment also found that existing benzene and MTBE concentrations exceeded those protective of human health. However, the most restrictive exposure pathway (volatilization of VOCs from groundwater to indoor air) was believed to incorporate incorrect and incomplete assumptions. A Tier 3 RBCA Assessment was planned that would include extensive site-specific data related to that exposure pathway as provided by implementation of the work plan addendum described above (March 1998).

- April 1999: Groundwater monitoring and purged water quality information collected over time was used to perform a preliminary evaluation of the potential for the Site to be remediated by natural attenuation mechanisms. This preliminary evaluation indicated that TPH and BTEX were stable in groundwater. MTBE was not included in this evaluation due to insufficient time series data.

- May 1999: A separate Interim Project Report was submitted to the Navy for purposes of informing the Army of the results of investigations performed by the Navy on Army property. This report was designated the Army Interim Project Report and was necessitated by the impending transfer of portions of the property owned by the Army to the City of Novato.

- July 1999: A draft Tier 3 RBCA Assessment was prepared by the Navy. This report included a detailed evaluation of the volatilization from groundwater to indoor air pathway and incorporated results from direct air sampling and soil-gas sampling performed at the Site. This detailed evaluation revealed that existing concentrations of BTEX and MTBE were very near or below protective concentrations. Comments from the RWQCB on the Tier 3 RBCA Assessment included two substantive requests for further assessment: (1) confirmation soil-gas sampling under worst case conditions at the end of the dry season when dry soils would be most conducive to vapor transport, and (2) more detailed assessment concerning the potential exposure of the ingestion of homegrown fruits and vegetables.

- July 1999: Some groundwater monitoring wells were destroyed by road construction and utility installation activities as the City of Novato rerouted State Access Road.

- October 1999: The Navy replaced one (1) groundwater monitoring well, and installed two (2) new soil-gas monitoring arrays north of State Access Road and out of the way of future construction activities.

- October 1999: A revised and Final Tier 3 RBCA Assessment was prepared by the Navy that included results of confirmation soil-gas sampling and the expanded assessment of the ingestion of homegrown fruits and vegetables potential exposure pathway as requested by the RWQCB.

- October 1999: Mass removal rates achieved by the interim remedial action system had decreased to below cost-effective levels. Because the Tier 3 RBCA Assessment indicated that protective concentrations were achieved almost everywhere on the Site, the interim remedial action was halted, and the system was shut down. Groundwater monitoring results show that concentrations in groundwater under the service station areas have been reduced by about an order of magnitude, and extracted vapor monitoring indicates that over 23,000 lb of gasoline was removed from the Site by that removal mechanism alone.

- October 1999: Developers began grading property designated for residential use north of State Access Road. One temporary groundwater monitoring well installed by the Navy was destroyed by that activity.

- November 1999: To avoid further well destruction by grading activities on HAAF, four (4) groundwater monitoring wells were abandoned by Battelle according to the requirements of the Marin County Department of Health Services.

- December 1999: A Draft Ecological Risk Scoping Assessment was performed by the Navy and submitted to the RWQCB. The assessment included areas of the Site and former HAAF property (i.e., Pacheco Creek).

- April 2000: Hydraulic lift and oil/water separator removal activities in Building 970 began. The activities followed procedures outlined in the Final Work Plan for Hydraulic Lift and Oil/Water Separator Removal, which was submitted to and approved by the RWQCB in March 2000 (Battelle, 2000e). The finding of unexpected subsurface lines and features (i.e., an additional oil/water separator) extended and expanded field excavation activities, and several locations required overexcavation and confirmation sampling. Excavation and backfilling activities were completed in May, and soil disposal was completed in June.

- June 2000: Surface water monitoring at four (4) locations within Pacheco Creek began. Following receipt of the analytical results, four (4) additional locations associated with culvert outfalls were sampled to determine whether the culverts were likely sources of MTBE in Pacheco Creek.

- July 2000: The RWQCB issued Order No. 00-064 which identified requirements for the Site. The Order required additional soil and groundwater investigations, development of a CAP for plume containment and cleanup, and continuation of groundwater monitoring and reporting. In addition, the Order required interim controls on the excavation of soils or discharge of groundwater at the Site.

- July 2000: A "Draft Summary Report for Hydraulic Lift and Oil/Water Separator Removal from Building 970" (Battelle and RRM, 2000) activities was submitted to the RWQCB for review. The Navy forwarded preliminary responses to comments provided by the RWQCB in November 2000 and is awaiting final approval of the responses before finalizing the draft document.

- August 2000: A *Final Work Plan for Remedial Investigation of Former UST Site 957/970* (Battelle, 2000f) was prepared by the Navy and submitted to the RWQCB in compliance with Order No. 00-064 Task 1.

- September 2000: A Groundwater Monitoring Plan and Monitoring Well Protection were prepared by the Navy and submitted to the RWQCB in compliance with Order No. 00-064 Task 8 and Task 5, respectively. The monitoring plan described procedures for groundwater sampling of existing wells at the Site and surface water sampling of Pacheco Creek.

- September 2000: A "Draft Interim Site Control Plan for the Department of Defense Housing Facility, Novato, California" (Battelle, 2000c) was prepared by the Navy and submitted to the RWQCB in compliance with Order No. 00-064 Task 7. The Navy forwarded preliminary responses to comments provided by the RWQCB in December 2000 and received verbal approval of the responses in October 2001. The draft document was revised and distributed to interested parties in October 2001 (Battelle, 2001e).

- September 2000: Remedial investigation activities were performed in compliance with Order No. 00-064 Task 2 at the Site following procedures outlined in the Work Plan for Remedial Investigation (Battelle, 2000f).

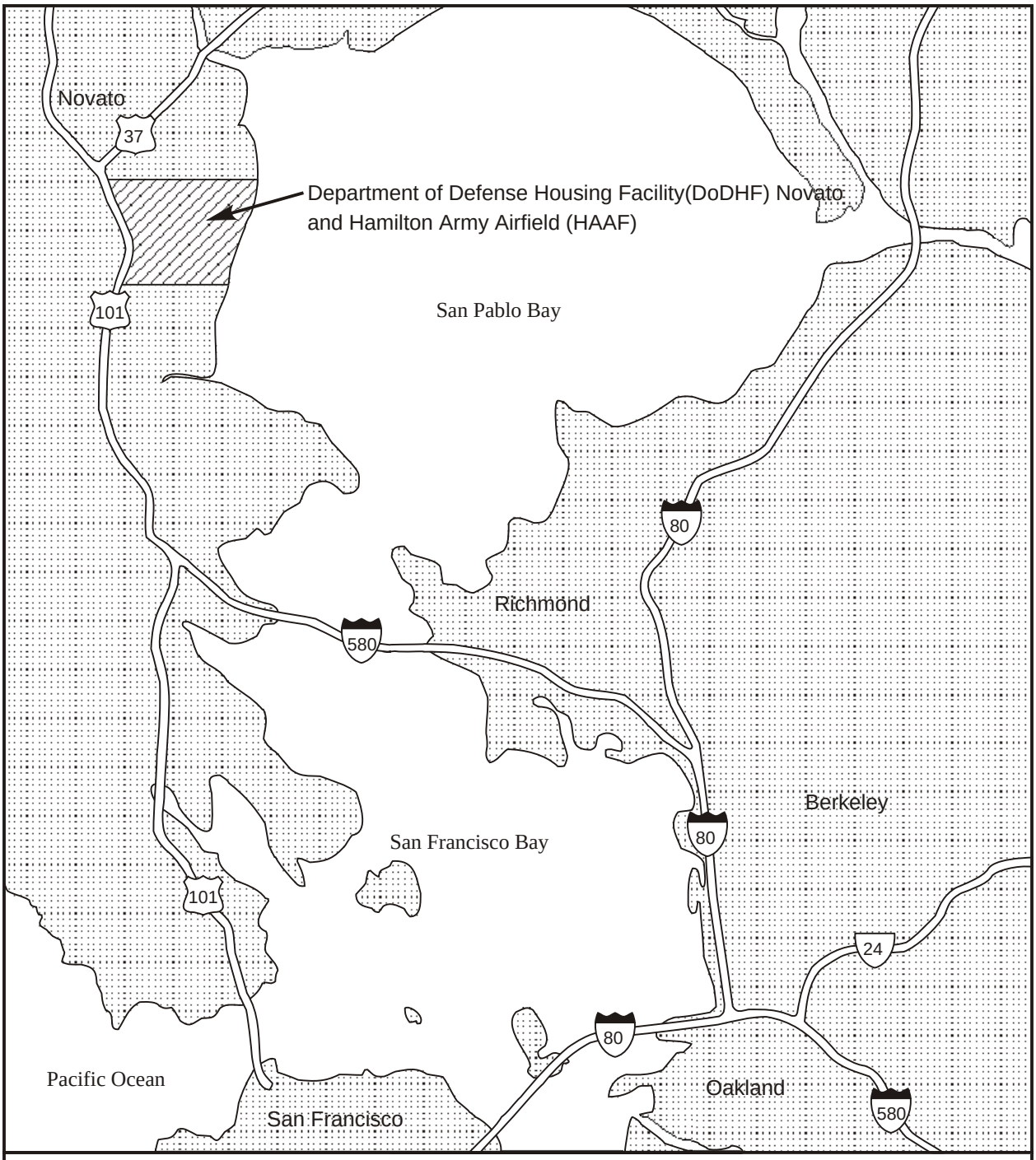
- October 2000 (quarterly thereafter): A quarterly Site Status Report presenting the results of groundwater and surface water monitoring activities performed in August was prepared by the Navy and submitted to the RWQCB in compliance with Order No. 00-064 Task 9. The Navy will continue to submit quarterly status reports in compliance with Order No. 00-064 Task 9.

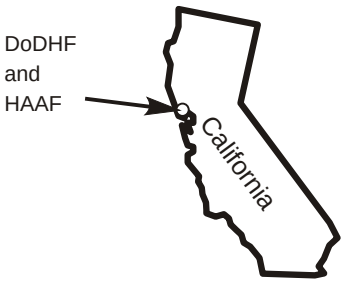
- January 2001: Results of the remedial investigation activities were presented in the Final Remedial Investigation Report prepared by the Navy and submitted to the RWQCB in compliance with Order No. 00-064 Task 2. The remedial investigation activities addressed nine (9) subtasks outlined under Task 1 of Order No. 00-064 by accomplishing four (4) main tasks: (1) reduce the uncertainty related to whether gasoline constituent concentrations in groundwater are decreasing downgradient of the former UST 970 tank complex; (2) install new monitoring wells and replace previously abandoned wells in order to augment existing monitoring well network and thus reduce the uncertainty associated with overall and intraplume migration; (3) determine whether a continuing source of gasoline constituents to groundwater existed in the shallow and smear zone soils in and around the former UST locations following the interim remedial action; and (4) determine whether a pathway conducts groundwater flow preferentially to the property north of the Site.

- March 2001: A Draft Revised Risk Assessment was conducted by the Navy in response to comments provided by the DTSC on the Tier 3 RBCA Assessment. The Draft Revised Risk Assessment was performed in accordance with the United States Environmental

Protection Agency's (U.S. EPA's) *Risk Assessment Guidance for Superfund* (1989) and California DTSC Human and Ecological Risk Division's (HERD) *Supplemental Guidance for Superfund Risk Assessment* (Cal-EPA, 1992).

1.3.2 Summary. Site characterization activities have determined gasoline constituents exist in soils around the former UST locations, and in groundwater downgradient from former UST locations. Gasoline constituents observed in soils and groundwater include total petroleum hydrocarbons quantified as gasoline (TPH-G), BTEX, and MTBE. TPH-G and BTEX have only been observed approximately 800 ft downgradient (north) of the NEX gas station. The only gasoline constituent extending beyond 900 ft north from the former UST 970 tank complex is MTBE. Site characterization evidence indicates that MTBE in groundwater extends approximately 1,800 ft north of State Access Road (or about 3,000 ft north of the NEX gas station).



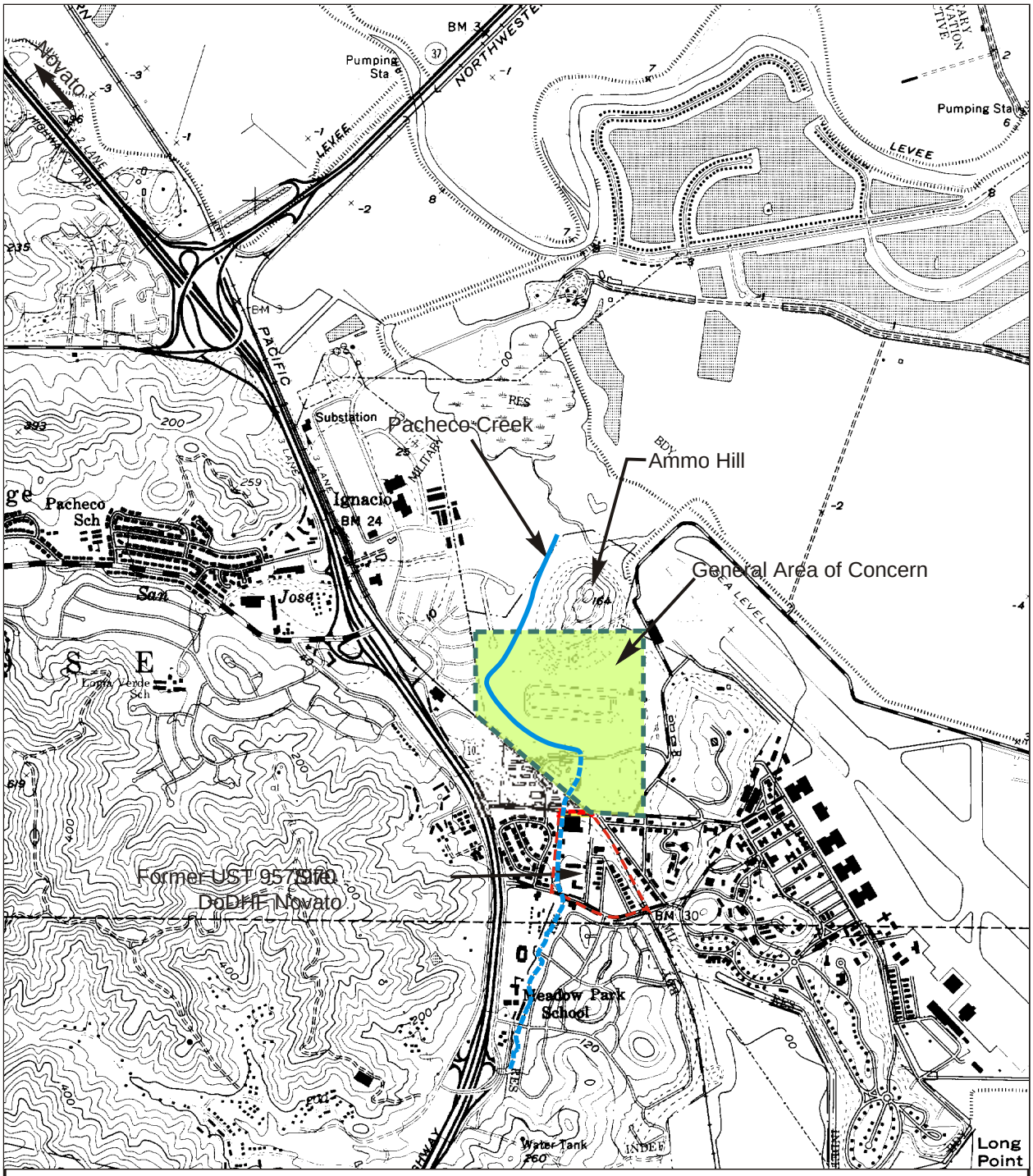


Scale in Miles

0 4 8

BAY LOC01.CDR

DESIGNED BY JG	Battelle … Putting Technology To Work		
DRAWN BY LC	Regional Location Map		
CHECKED BY MK	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	DATE 10/01	



N

Scale in Feet

0 1000 2000 3000

1-3 LOCATION.CDR

DESIGNED BY JG	Battelle … Putting Technology To Work		
DRAWN BY VS	Site Location Map		
CHECKED BY MK	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	DATE 01/02	

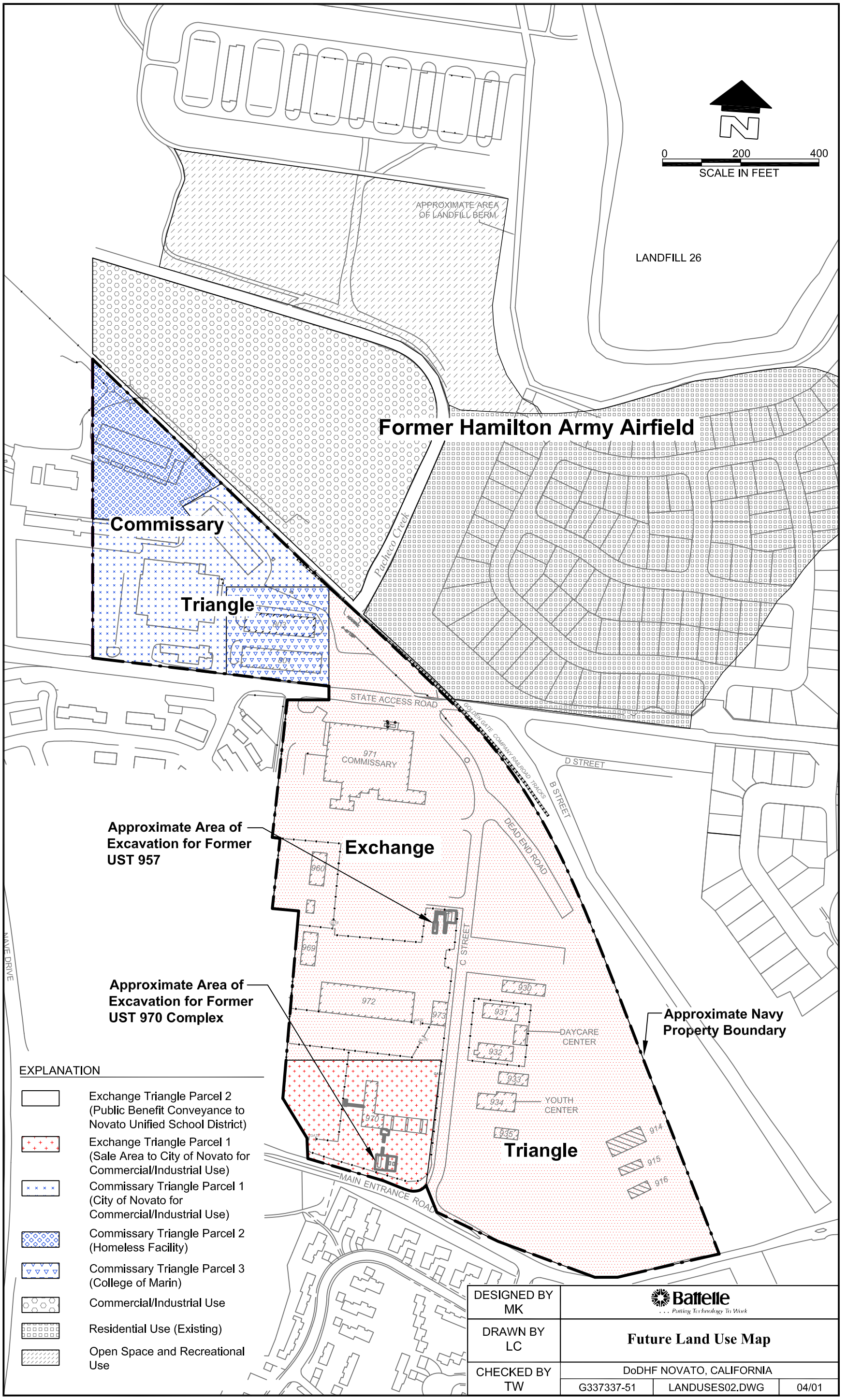


Figure 1-3. Future Land Use Map

Section 2.0: PREVIOUS INVESTIGATIONS

This section summarizes the investigations performed at the Site to date. All site-specific data from environmental monitoring is current through February 2001. Previous investigations at the Site were conducted to evaluate the Site against, and satisfy, the six RWQCB criteria for a low risk site, and to comply with RWQCB Order No. 00-64. Additional information was also obtained for this section from the quarterly groundwater and surface monitoring events performed at the Site.

2.1 Source Identification and Removal

Site investigations and tank removal activities that were documented in historical reports were reviewed and are discussed in the following subsections. Sources are defined as structures (i.e., tanks, pipes) that leak hydrocarbons, or as the presence of free product (free-phase petroleum or fuel light, nonaqueous-phase liquid [LNAPL]) resulting from the leaking structure. All tanks and associated piping at the Site have been removed. Two (2) observances of free product have been recorded at the Site: (1) in the vicinity of UST 957 during a Geoprobe™ investigation conducted in late 1994 by ERM-West (ERM-West, 1995a); and (2) measured in monitoring well 970-MW5 in August 1996 (ERM-West, 1998). However, the presence of free product has not been observed in any of the Site wells, soils, or purged groundwater since Battelle began activities at the Site in December 1997.

2.1.1 Source Removal. Impact to soil and groundwater was the result of gasoline releases from the former USTs and associated piping. Removal of the USTs and associated piping occurred in the early to mid-1990s. Soil underlying and adjacent to the tanks and pipes was excavated following removal of the USTs. The amount of soil removed during excavation activities was based on visual observation of hydrocarbons and photoionization detector (PID) readings. Some hydrocarbon-impacted soils were left in place under the assumption that future remedial activities would be performed at the Site. For this reason, the IAS/SVE system installed at the Site focused on areas having elevated hydrocarbon concentrations. Refer to Section 3.0 for further discussion on the design and implementation of the interim remedial system. Source removal activities as described in the *Final UST Investigation Report for Former Underground Storage Tank Site 957/970* (ERM-WEST, 1998) have been summarized below.

2.1.1.1 UST 957. The tank and underground piping for UST 957 were removed in March 1992. The former location of UST 957 and associated piping is shown in Figure 2-1. After tank removal, underlying and adjacent soil was excavated, resulting in an excavation of 28 ft by 30 ft by 12 ft. Groundwater was encountered at 11 ft bgs. Underground piping from the UST to the pump island (109 ft) and vent lines from the tank (10 ft) were removed. The piping trenches were overexcavated to depths of 2 to 4 ft bgs. Two confirmatory soil samples were collected from the north and south sidewalls of the UST excavation. Analysis of the soil samples showed TPH-purgeables as an unknown hydrocarbon at concentrations of 150 and 220 mg/kg, and maximum concentrations of BTEX compounds were detected at 360 µg/kg benzene, 560 µg/kg toluene, 1,000 µg/kg ethylbenzene, and 3,800 µg/kg xylenes, respectively. Soil sampling locations and TPH-purgeable results are shown in Figure 2-1. A groundwater sample was collected from within the UST excavation. Analysis of the groundwater sample showed TPH-purgeables as gasoline at concentrations of 60 mg/L (see Figure 2-1) and BTEX constituents at maximum concentrations of 4,400 µg/L. Soil samples were collected from the piping trenches at a frequency of one sample per 20 linear feet. Three samples from the western piping trench showed TPH-purgeables as gasoline or an unknown hydrocarbon at a maximum concentration of 1,200 mg/kg. Two eastern trench soil samples contained low (maximum of 32 mg/kg) concentrations of TPH-purgeables as an unknown hydrocarbon. A single soil sample from the northern trench did not contain detectable TPH or BTEX concentrations. All analytical results of soil and groundwater samples collected during UST 957 removal activities are provided in Table 2-1. The removal and investigation of UST 957 is described further in the

Underground Storage Tank Removal and Preliminary Investigation (PRC Environmental Management, Inc., 1992b).

2.1.1.2 UST 970-3. UST 970-3 was removed on January 5, 1995. The location of the tank and associated piping is shown in Figure 2-2. During tank removal, it was noted that UST 970-3 had a hole at the fill end of the tank and that the tank was completely filled with water. Visible hydrocarbons were observed in the sidewalls of the excavation and water within the excavation. Following removal of UST 970-3 and associated piping, two soil samples and one water sample were collected from the excavation and analyzed for TPH-G and BTEX. Maximum concentrations of hydrocarbons or gasoline constituents detected in the soil samples were TPH-G at 18 mg/kg, benzene at 150 μg/kg, toluene at 130 μg/kg, ethylbenzene at 160 μg/kg, and xylenes at 1,700 μg/kg. Gasoline constituents detected in the groundwater sample included TPH-G at 45 mg/L, benzene at 1,900 μg/L, toluene at 4,800 μg/L, ethylbenzene at 490 μg/L, and xylenes at 6,200 μg/L. On February 6, 1995, 4,000 gallons of water was removed from the excavation, and groundwater was allowed to recharge overnight. On February 7, 1995, another groundwater sample was collected from the excavation and analyzed for TPH-G and BTEX. The analytical results for the second groundwater sample indicated that TPH-G was present at 21 mg/L, benzene at 640 μg/L, toluene at 1,300 μg/L, and xylenes at 2,600 μg/L. Tables 2-2 and 2-3 present the analytical data gathered during UST 970-3 removal activities and Figure 2-2 shows the location of soil sampling locations.

On February 22, 1995, approximately 12,150 gallons of rainwater were removed from the excavation. Three feet of soil were removed from the north, west, and east sidewalls of the excavation and visibly contaminated soils were removed from the piping trench between the tank and pump islands. On February 23, 1995, confirmatory soil samples were collected from the north, south, and west sidewalls of the excavation. A groundwater sample was not collected because there was no water accumulated in the excavation. Gasoline constituents detected in the confirmatory soil samples indicated the presence of TPH-G and BTEX compounds. TPH-G was detected at a maximum concentration of 13 mg/kg, while BTEX compounds were detected at maximum concentrations of 1,200 μg/kg benzene, 70 μg/kg toluene, 550 μg/kg ethylbenzene, and 2,600 μg/kg xylenes.

On March 27, 1995, additional confirmatory soil samples were collected from the tank excavation and piping trench and analyzed for TPH-G and BTEX. Gasoline constituents reported in the excavation samples included TPH-G (ranging from nondetect to 520 mg/kg), benzene (ranging from nondetect to 200 μg/kg), toluene (ranging from nondetect to 730 μg/kg), ethylbenzene (ranging from nondetect to 520 μg/kg), and xylenes (ranging from non-detect to 11,000 mg/kg). No gasoline or BTEX compounds were detected in the soil samples collected from the pipe trench. The excavation was backfilled and covered with asphalt with the approval of the Marin County Department of Health (ERM, 1998).

2.1.1.3 Tank 970-Waste Oil. On January 9, 1995, NPWC personnel removed Tank 970-Waste Oil (ERM, 1998). The 1000-gallon steel tank's dimensions were approximately 4 ft by 12 ft and appeared to be in good condition upon removal. For additional information concerning the tank removal activities and results refer to the *Final UST Investigation Report for Former Underground Storage Tank Site 957/970* (ERM-West, Inc., 1998). Sampling locations are shown in Figure 2-3.

Preceding the removal activities, on November 15, 1994, a sample of the tank contents were collected and analyzed for petroleum hydrocarbons and metals in order to classify the waste. Based on the analytical results, the liquid was characterized as non-Resource Conservation and Recovery Act (RCRA) Hazardous Waste. On January 3, 1995, one cored soil sample (WO-1) was collected from a depth of 5 ft bgs within the excavation pit area and analyzed for petroleum hydrocarbons. The sample

was collected to better define the nature and extent of hydrocarbons and determine whether overexcavation of soils around the tank might be necessary during its removal. Concentrations of 7.8 mg/kg TPH-G, 6,500 mg/kg total petroleum hydrocarbons quantified as diesel (TPH-D), 1,700 mg/kg total petroleum hydrocarbons quantified as motor oil (TPH-MO), and <250 mg/kg total petroleum hydrocarbons extractable as jet fuel (TPH-JF) were detected. In addition, concentrations of 17 μg/kg toluene, 47 μg/kg ethylbenzene, and 290 μg/kg xylenes were detected. These data indicated that overexcavation of soils may be warranted during the tank removal.

On January 9, 1995, following the identification of underground utilities, an excavator was used to breakup and remove asphalt located above Tank 970-Waste Oil. A vacuum truck was used to remove approximately 500 gallons of a water/hydrocarbon mixture from the tank. The mixture was transported and disposed of at Erickson Environmental in Richmond, California. The tank was removed with an excavator and loaded onto a flatbed for off-site disposal. The waste oil tank trench showed no visual signs of hydrocarbons, and PID readings of the sidewalls were at background levels. However, two confirmatory soil samples (A and B) were collected from the excavation at the vadose/saturated zone interface and analyzed for TPH and BTEX. The groundwater level was above the depth of the excavation due to heavy seasonal rains (approximately 4 ft bgs), and hence a groundwater sample (C) was collected from the tank excavation and analyzed for TPH-D.

Before analytical results of the confirmatory samples collected during the tank removal were received, the sidewalls of the excavation (with the exception of the western wall due to an existing chain link fence) were cut back by 2 ft. The soils contained within these 2-ft intervals were considered contaminated based on analytical results of the soil sample collected on January 3, 1995 (WO-1). On February 6, 1995, three confirmatory samples were collected from the widened excavation – two from the sidewalls ("North" and "South") and one from the bottom of the excavation ("Bottom"). The "Bottom" sample was the only one with petroleum hydrocarbon constituents above analytical detection limits with detected concentrations of toluene at 81 μg/kg, ethylbenzene at 54 μg/kg, xylenes at 180 μg/kg, and TPH-D at 2.0 mg/kg. Analytical results of soil and groundwater samples collected during Tank 970-Waste Oil removal activities are provided in Table 2-4.

2.1.1.4 UST 970-1 and UST 970-2. UST 970-1 and UST 970-2, located 70 ft south of the NEX Service Station pumping islands and adjacent to and east of UST 970-3, were removed on July 3, 1996. The location of the USTs are featured in Figure 2-3. Five soil samples were collected from the north, south, and east sidewalls of the excavation upon removal of the USTs. Analytical results from the investigation are presented in Table 2-5. Because the west sidewall of the excavation was composed of clean backfill and pea gravel after removal of UST 970 -3, no soil samples were collected from that sidewall. Three soil samples were collected beneath the piping (12 to 16 inches bgs) at each of the pump islands. All soil samples were analyzed for TPH-G (1,200 to 6,800 mg/kg), benzene (8,800 to 61,000 μg/kg), toluene (45,000 to 340,000 μg/kg), ethylbenzene (13,000 to 67,000 μg/kg), xylenes (120,000 to 720,000 μg/kg), and MTBE (33,000 to 310,000 μg/kg). One groundwater sample was collected from the tank pit and analyzed for TPH-G, BTEX, and MTBE. Analytical results from the groundwater sample are presented in Table 2-5. Analysis of soil samples collected beneath the pump island piping found TPH-G (ranging from nondetect to 2,800 mg/kg), benzene (ranging from nondetect to 170 μg/kg), toluene (ranging from nondetect to 36,000 μg/kg), ethylbenzene (ranging from nondetect to 33,000 μg/kg), xylenes (ranging from non-detect to 310,000 μg/kg) and MTBE (ranging from non-detect to 22,000 μg/kg). Soil sampling results are presented in Table 2-6. The excavation was backfilled and covered with asphalt with the approval of the Marin County Department of Health Services. Further detail on the removal of UST 970-1 and UST 970-2 can be found in the UST removal summary report (NPWC, 1996b).

2.1.1.5 Building 970 Hydraulic Lift Investigation and Removal Activities. Two different investigations of soils have been conducted in the area of Building 970 hydraulic lifts. An investigation was performed in October 1995 by ERM-West and Battelle performed an additional investigation in March 1998. Battelle also investigated groundwater in March 1998. Sampling results from these investigations indicated that a limited volume of soils immediately adjacent to hydraulic lifts located within Building 970 were impacted with hydraulic fluid. Following the soil and groundwater investigations, from April 17, 2000 to June 22, 2000, the Navy removed and disposed of several subsurface structures associated with Building 970. The soil and groundwater investigations performed near Building 970 hydraulic lifts and removal activities conducted by the Navy (Battelle and RRM, 2000) are discussed below.

2.1.1.5.1 Building 970 Hydraulic Lift Investigations. In 1998, a soil and groundwater sampling plan (Battelle, 1998e) was developed and executed to evaluate and confirm the extent of a hydraulic fluid release from the northernmost of two hydraulic lifts in Building 970 as reported by a previous contractor (PRC, 1997). The soils in the vicinity of the hydraulic lifts were previously investigated by ERM-West during the Basewide Environmental Baseline Survey (EBS) for DoDHF Novato (PRC, 1997). The investigation was completed in October 1995. Soil samples were collected from depths of 4.0-5.0 ft bgs and from 9.0-10.0 ft bgs. The soil sample collected at 4.0-5.0 ft bgs contained a 15,000 mg/kg concentration of TPH-MO, whereas the soil sample collected from 9.0-10.0 ft contained only a 12-mg/kg concentration of TPH-MO. Groundwater in the vicinity of the hydraulic lift was not investigated at that time (PRC 1997).

During Battelle's March 1998 investigation, soil samples were collected from two depths in pushes located approximately 1 ft and 5 ft downgradient (north) of the northernmost hydraulic lift. Groundwater samples were collected from these pushes and also from pushes approximately 25 and 50 ft downgradient of the hydraulic lift. Push locations are presented in Figure 2-4. Both the soil and the groundwater samples were analyzed for semivolatile organic compounds (SVOCs), TPH-extractable; BTEX; and MTBE. One soil sample was analyzed for polychlorinated biphenyls (PCBs).

Prior to beginning the investigation, all points (Ps) were cleared using ground-penetrating radar (GPR). Borings P-1 and P-2 were advanced using a Geoprobe™ to the desired depth for soil sample collection. A split-spoon sampler containing 6-inch brass sleeves was advanced ahead of the borehole to obtain soil samples. Soil samples were collected from 4.5 to 5.5 ft bgs and from 6.5 to 7.5 ft bgs in both P-1 and P-2. The two points were subsequently advanced to 12 ft bgs for groundwater sample collection. P-3 and P-4 were advanced to a depth of 12 ft bgs for groundwater sample collection only. The soil sampling intervals were selected based on the results of the ERM-West investigation. The shallow sample was used to confirm the elevated hydrocarbon concentration found in the initial investigation, and the deeper sample was used to confirm that the hydrocarbons did not extend deeper. Soil samples at these same depth intervals were collected at a location 5 ft downgradient of the lift to determine the lateral extent of soils containing hydrocarbons.

The highest hydrocarbon concentration in soil was detected at the 4.5- to 5.5-ft-depth interval in the push located closest to the hydraulic lift (P-1). TPH-MO was detected in this sample at a concentration of 18,000 mg/kg. Naphthalene, phenanthrene, and pyrene were also detected in this sample. All analytes were below detection limits in the 6.5- to 7.5-ft-depth interval at P-1. TPH-MO was detected at low concentrations in soil at both depths in P-2. A naphthalene concentration of 4,200 µg/kg also was detected at the 4.5- to 5.5-ft interval of P-2. Groundwater concentrations of TPH-MO ranged from below the detection limit in P-2 to 5.6 mg/L in P-3. Groundwater concentrations of TPH-D were approximately 1 mg/L or less at all sample locations. The analytical results from soil and groundwater sampling and their respective locations relative to the hydraulic lift are presented in Figure 2-4. The

analytical data reports for samples collected during the March 1998 investigation are provided in Appendix A.

The sampling results from Battelle's March 1998 investigation indicated that some limited soil volume immediately adjacent to the lift at 4.5 to 5.5 ft bgs had been impacted with hydraulic fluid at concentrations similar to those concentrations reported during ERM-West's investigation two years earlier

2.1.1.5.2 Building 970 Hydraulic Lift and Oil/Water Separator Removal Activities. Excavation and removal of subsurface features in and around Building 970 followed the *Final Work Plan for Hydraulic Lift and Oil/Water Separator Removal From Building 970* (Battelle and RRM, 2000), which was prepared by the Navy and approved by the RWQCB. As removal activities proceeded, additional subsurface features were identified that were not described in the Work Plan. These features were removed and sampled in accordance with procedures described in the Work Plan. Subsurface features removed from the Site include the following:

- Three hydraulic lifts and associated control lines
- Control line for a suspected former hydraulic lift and confirmation sampling at the location of the suspected former lift
- Two oil/water separator (OWS) systems (identified as OWS1 and OWS2) and associated influent and effluent piping
- Four floor drains associated with the influent line of OWS1
- Four buried drums (Drums 1 through 4) acting as collection tanks associated with the influent line of OWS2
- Effluent line of OWS2 running along the footer on the west side of Building 970
- Sanitary sewer lateral associated with the OWS1 and OWS2 systems
- Waste oil line associated with a former waste oil tank.

During removal activities, petroleum hydrocarbon-impacted soil was encountered near both OWS units, around Drums 1 and 2, and beneath and around the foundations in the northern and northwestern portions of Building 970. Verification soil sampling was performed at locations immediately beneath and around the removed subsurface facilities. Overexcavation activities were performed to the extent practicable to remove affected soils encountered during removal activities. Complete removal of affected soil was constrained by the limited work area inside the building and the potential to undermine building foundations. Verification samples were collected to confirm the absence of impacted soils or to define the degree and extent of impacted soils left in place.

Soil samples were collected from sidewalls and trench bottoms to confirm the remaining concentrations of TPH and metals. Analytical results for soil, product, and water samples collected during the hydraulic lift removal activities are provided in Tables 2-7 through 2-15. Please refer to Appendix A for a complete listing of the analytical laboratory data and chain-of-custody documentation for samples collected during the hydraulic lift removal. Overexcavation activities were performed to the extent practicable to remove affected soils from those areas where the petroleum hydrocarbon soil

cleanup levels and/or Region 9 Residential PRGs were exceeded. Excavation activities were not permitted to extend underneath building footers or internal walls to protect the structural integrity of the building. For more detailed information regarding field and analytical procedures and removal activities refer to the Draft Summary Report for Hydraulic Lift and Oil/Water Removal from Building 970 (Battelle and RRM, 2000).

2.2 Site Characterization

Soil and groundwater characterization sampling was conducted at Former UST Site 957/970 on several occasions prior to the fall of 1997. The initial design of the interim remedial action air sparging and soil vapor extraction system installed in Spring 1998 was based on site characterization data available at that time. Further site characterization was performed in 1998 to define the limits of the MTBE plume and again in September 2000 to comply with RWQCB Order 00-064 and to assess the effectiveness of the IAS/SVE system. Continuous soil cores were collected, examined, and logged at every borehole advanced for every subsurface installation across the entire Site. These data provided information representing soil stratigraphy and variability across the Site. This section provides a summary of site characterization activities performed at the Site to date.

2.2.1 Preliminary Site Characterization. Soil and groundwater sampling was performed by ERM-West, Inc., between November 1994 and July 1997 using a Geoprobe™ covering the approximate lateral and downgradient extent of the groundwater BTEX plumes. Investigations using SCAPS were performed by PRC Environmental Management, Inc., from May 15 to 22, 1996, mostly in the region around the NEX Service Station and extending to north of Building 970 (PRC, 1996). Direct push technologies such as Geoprobe™, SCAPS, and cone penetrometer systems are cost-effective for preliminary characterization, but permanent groundwater monitoring wells are generally accepted as yielding more reliable data representative of conditions in groundwater at their specific locations. A timeline of site characterization activities conducted at the Former UST Site 957/970 is presented in Section 1.3.1.

The ERM-West, Inc., Geoprobe™ investigation included the collection of 64 soil samples from 39 discrete locations in and around the areas of the former USTs (ERM-West, 1997). Soil sampling locations for samples collected from a depth of 5 ft bgs and a depth of 8 to 10 ft bgs are shown in Figures 2-5 and 2-6, respectively. Soil samples were analyzed for TPH-G, TPH-D, and BTEX. Analytical results for all soil samples are presented in Figures 2-5 and 2-6. Estimated areas of elevated hydrocarbon concentrations in soil are shown graphically in Figure 2-7.

Based on the results of preliminary soil sampling activities, ERM-West (1998) concluded that although the volume of hydrocarbon-impacted soil in the area of former UST 970 complex and Former UST 957 appears to be relatively small, the soil potentially constitutes an ongoing source of hydrocarbons to the groundwater an should be remediated. The interim remediation system installed at the Site in April 1998 was designed based on this characterization data and focused on these areas of soil where a possible ongoing source of hydrocarbons to groundwater existed.

The Geoprobe™ was also used to collect 58 groundwater samples over the entire Site. Sampling locations are shown in Figure 2-8. All groundwater samples were analyzed for TPH-G, TPH-D, and BTEX. Analytical results for all groundwater screening activities are shown in Figure 2-8. Groundwater monitoring wells 957-MW1 through 957-MW4 were installed in December 1994 subsequent to the removal of UST 957, and groundwater monitoring wells 970-MW1 through 970-MW5 were installed in October 1996 subsequent to the removal of the UST 970 tanks. Six of the soil samples collected during monitoring well installation were analyzed for MTBE, TPH-G, TPH-D, BTEX, and total lead. Six additional soil samples collected from boreholes drilled for monitoring well installations were

analyzed for TPH-G, TPH-D, BTEX, and total lead only. Groundwater samples collected from monitoring wells 957-MW1 through 957-MW4 and from 970-MW1 through 970-MW5 were analyzed for TPH-G, TPH-D, BTEX, MTBE, and total lead, with the exception of one sampling event prior to 1996 in which MTBE was not analyzed.

The PRC Environmental Management, Inc. (1996) SCAPS investigation extended the area sampled to the southern (UST 970) portion of the Site, and included 23 pushes ranging from 4.6 to 23 ft bgs. These pushes were conducted to screen for the presence of petroleum hydrocarbons. Nine groundwater samples were collected from approximately 9 ft bgs and analyzed for TPH-G, BTEX, and MTBE. Four soil samples were collected from 9 to 10 ft bgs and analyzed for total recoverable petroleum hydrocarbons (TRPH), TPH-G, BTEX, and MTBE. Groundwater and soil analytical results are presented in Tables 2-16 and 2-17, respectively. Sampling locations are featured in Figure 2-8.

Groundwater concentration contours were developed based on Geoprobe™ and SCAPS screening investigations and on samples collected from the nine permanent monitoring wells. The estimated extent of MTBE and TPH in groundwater at the end of 1997 is shown graphically in Figure 2-9. The interim remediation system installed at the Site in April 1998 was designed based on this characterization data. Following installation of permanent wells, it was observed that areas of elevated hydrocarbon concentrations were shifted somewhat from what is seen in Figure 2-9.

In addition to hydrocarbon concentrations in soil and groundwater, the investigations described above revealed that the Site is underlain with weathered bedrock at about 15 ft bgs, and that the bedrock surface indicates the presence of an old streambed running generally south to north that has been filled in with heterogeneous alluvial deposits and some backfill at the surface. Channelized bedrock, etched by an old stream, is consistent with the limited degree of lateral hydrocarbon dispersion found in groundwater of the Site. ERM-West Inc. (1998) recommended that data be collected during future site investigations to evaluate the vertical extent of hydrocarbons in groundwater and whether the weathered bedrock underlying the Site was impacted by hydrocarbons. The Navy has investigated hydrocarbon impact to weathered bedrock since these conclusions were made (see Section 2.2.3).

2.2.2 MTBE Plume Delineation. Three investigations were performed by the Navy to delineate the extent of the MTBE plume north of the Site. These included a Geoprobe™ investigation conducted in March 1998, a CPT investigation conducted in April/May 1998, and another CPT investigation conducted in August 1998. Each progressive investigation was required based on results of the previous investigation. Initially, based on results of investigations prior to September 1997, the MTBE plume had been incompletely delineated and was thought to extend only approximately 1,400 ft north of the former NEX gas station. However, subsequent to plume delineation activities described here, the MTBE plume was found to extend approximately 2,700 ft north of the former NEX gas station area. The MTBE groundwater plume has since been surrounded by permanent monitoring wells to assess plume behavior.

The Geoprobe™ investigation conducted in March 1998 consisted of 13 pushes. Push locations are shown in Figure 2-10. Following advancement of the boring to its final depth, 1-inch PVC well casing terminating with a 5-ft screened interval was lowered into the boring. Prior to collecting a groundwater sample, the point was purged until the water was relatively clear or until the point no longer produced water. If the point had been pumped dry, groundwater was allowed to recover into the well for sample collection. After the groundwater was collected, all PVC casings were removed from the borings, and the boreholes were backfilled with bentonite grout. All groundwater samples were analyzed for MTBE and BTEX by U.S. EPA Method 8260b. Results of the investigation are presented in Table 2-18, and copies of laboratory analytical reports are presented in Appendix B.

A CPT investigation was conducted on April 30 and May 1, 1998, to provide subsurface geologic characterization on former HAAF property and to further characterize the MTBE plume. During the investigation a total of 15 borings were advanced. As the cone penetrometer was pushed into the ground, soil parameters such as cone bearing, sleeve friction, friction ratio, and pore water pressure measurements were collected. A data acquisition system located on-board the CPT rig processed the data in real time. This data aided in determining groundwater sampling depths and soil layering characteristics. Twelve (12) groundwater samples were collected from the CPT push locations (Figure 2-10) and were analyzed for BTEX and MTBE using U.S. EPA Method 8260. In addition, four piezometers (PZ-1 through PZ-4) were installed at CPT push locations as identified in Figure 2-10. Sampling locations were selected to provide coverage in the area west of Pacheco Creek, where groundwater chemical concentration data were not previously available. The investigation was also used to confirm that gasoline constituents in groundwater do not extend past the western boundary of Former UST Site 957/970. Results of the investigation are presented in Table 2-19. Laboratory analytical reports are presented in Appendix B**,** and CPT plots are presented in Appendix C.

A second CPT investigation was conducted from August 3 to 6, 1998. A total of 26 CPT borings were advanced during the investigation, with two points located on DoDHF Novato Navy property and the remaining points located on former HAAF property. Locations were selected to delineate the outermost perimeter of the plume as well as to further characterize areas where data gaps existed. An on-site lab was used to make field decisions for the determination of the next push location. CPT pushes were advanced at locations until a non-detect MTBE concentration was achieved in all directions away from known MTBE-impacted groundwater. Locations where borings were advanced are shown in Figure 2-10. During the CPT investigation, groundwater samples were collected from two temporary wells installed by IT Corporation (B833-STW-006 and B833-STW-007). The on-site lab was used to analyze these samples for BTEX and MTBE using U.S. EPA Method 8260B. Analytical results of groundwater samples collected during the CPT investigation are presented in Table 2-20. Laboratory analytical reports are presented in Appendix B, and CPT plots are presented in Appendix C.

In addition to the Geoprobe™ and CPT investigations conducted by the Navy in 1998, permanent monitoring wells already existing on former HAAF property were sampled to supplement data collected during MTBE investigative activities. Groundwater sampling was conducted in accordance with the procedures outlined in the then-current *Groundwater Monitoring Plan* (Battelle, 1998c). Wells were sampled throughout the time period from June to August 1998 and the results are presented in Table 2-21.

Additional permanent monitoring wells were installed at locations based on MTBE concentrations in groundwater observed during Geoprobe™ and CPT investigative activities. Geoprobe™ and CPT methods were performed primarily to delineate the extent of MTBE in groundwater and determine the optimal location for permanent monitoring wells.

2.2.3 Remedial Investigation. In September 2000, the Navy performed a remedial investigation at the Former UST Site 957/970, to comply with RWQCB Order No. 00-64, Task 1. The purpose of the remedial investigation was to gather additional data to enhance previously collected site characterization data, and to fill data gaps identified by the RWQCB. The following discussion summarizes the activities performed during the remedial investigation and results of those activities. Further detail can be found by reviewing the *Final Remedial Investigation Report for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California* (Battelle, 2001b).

Fieldwork activities for the remedial investigation were conducted from September 11 to October 20, 2000. The additional site characterization data was gathered by completing four (4) tasks. The following subsections discuss the objectives of the tasks and fieldwork performed to fulfill each task.

2.2.3.1 Task 1. The objective of Task 1 was to reduce uncertainty related to whether gasoline constituent concentrations in groundwater were decreasing downgradient of the former UST 970 complex, which is located within the Sale Area as described in Section 1.3. Three monitoring wells (MW-5A, MW-6A, and MW-7A) were installed along a transect positioned perpendicular to the direction of groundwater flow and immediately downgradient (within 10 ft) of the former UST 970 complex (an area southeast of Building 970) using a hollow-stem auger (HSA). One additional monitoring well (MW-8A) was installed within the excavation area of the former UST 970-3, also using an HSA. An additional objective of Task 1 was to determine the potential impact (if any) to groundwater in fractured bedrock. Two wells (MW-9A and MW-3D) were installed in areas where groundwater was most heavily impacted by hydrocarbons (i.e, near the Former UST 970 complex and Former UST 957), and were screened below the surface of the fractured bedrock. These bedrock wells were installed using a combination of HSA, hard rock coring, and reaming. Figures 2-11 and 2-12 show the locations of wells installed during the remedial investigation. Analytical results of groundwater samples collected from these additional monitoring and bedrock wells will be discussed in Section 4.2.2.

2.2.3.2 Task 2. The objective of Task 2 was to install new monitoring wells and replace previously abandoned wells to augment the existing monitoring well network and thus reduce the uncertainty associated with overall and intraplume migration. (Construction associated with redevelopment in the area north of State Access Road forced the abandonment of seven monitoring wells, which have been replaced.) As shown in Figure 2-13, the abandoned wells, MW-M7, piezometer (PZ)-2, MW-M4, MW-M5, MW-M6, TW-M2, and TW-M1, were replaced by newly installed monitoring wells MW-M16, MW-M17, MW-M20, MW-M21, MW-M22, MW-M23, and MW-M24, respectively, in September 2000. The replacement wells were positioned as close to their original locations as possible. Due to accessibility issues, preference was given to placement in roadway areas if possible. Network augmentation wells consisted of MW-10A, MW-6B, MW-2E, MW-M14, MW-M18, MW-M19, MW-M25, MW-M26, and MW-M27. Analytical results of groundwater samples collected from these replacement and network augmentation monitoring wells will be discussed in Section 4.2.2.

2.2.3.3 Task 3. The primary objective of Task 3 was to determine whether a continuing source of gasoline constituents to groundwater existed in the shallow and smear zone soils in and around the former UST locations following the interim remedial action described in Section 3.0. A Geoprobe™ was used to collect soil samples from 20 locations in the vicinity of the former UST 970 complex (within the Sale Area) and 16 locations in the vicinity of the former UST 957 (within the PBC Area) to confirm that a residual source adding gasoline mass to groundwater does not exist in shallow and smear zone soils at these locations. Soil samples also were collected at four locations near the former UST 970 complex during Task 1 well installation activities. In the Sale Area, a total of 46 soil samples were collected using U.S. EPA Method 5035 and analyzed using U.S. EPA Method 8260B. Similarly, 32 soil samples were collected in the PBC Area using U.S. EPA Method 5035 and analyzed for VOCs using U.S. EPA Method 8260B. Additionally, samples were analyzed for TPH using U.S. EPA Method 8015. Soil samples from the Sale Area were analyzed for TPH-G only, whereas soil samples collected from the PBC Area were analyzed for TPH-G and TPH-D. The laboratory reported results for selected soil samples from the Area as TPH-MO and as jet propellant 5 (i.e., JP-5, which is also known as kerosene). The presence or absence of free product was evaluated during the advancement of soil borings that were located in areas of the Site where past observances of free product were noted. Additional physical parameter data for soils at the Site were collected to support future remedial decisions and evaluate site risks.

Soil sampling results from September 2000 for gasoline constituents in the Sale Area are summarized in Table 2-22. The locations in the Sale Area from which soil samples were obtained are presented in Figures 2-14 (for samples obtained from <8 ft bgs) and 2-15 (for samples obtained from >8 ft bgs). Generally, contaminant concentrations in the Sale Area vary over several orders of magnitude, and variation is present both vertically and horizontally. Hydrocarbons were generally greater in

concentration within the former UST cavity and adjacent areas. During drilling activities, no separate-phase hydrocarbons were observed in the Sale Area boring locations. Laboratory analytical data are presented in Appendix D.

Soil sampling results for the PBC Area are presented in Tables 2-23 and 2-24. The locations in the PBC Area from which soil samples were obtained are presented in Figures 2-14 (for samples obtained from <8 ft bgs) and 2-15 (for samples obtained from >8 ft bgs). Similar to the Sale Area, hydrocarbon concentrations were greater in locations adjacent to the former UST cavity. No separate-phase hydrocarbons were observed in the PBC Area boring locations. Laboratory analytical data are presented in Appendix D.

2.2.3.4 Task 4. The objective of Task 4 was to determine whether a relatively narrow pathway conducts groundwater flow preferentially to an area north of the Site. For this task, the vertical and horizontal distribution of permeable deposits just south of State Access Road was assessed. The physical and chemical properties of a three-dimensional volume of soil in this area were characterized using CPT methods. During Task 4 activities, the lithology south of State Access Road was investigated by performing CPT pushes at 42 locations along four transects that were oriented perpendicular to the groundwater flow direction. A total of 20 groundwater samples (18 samples and two duplicates) were obtained using a Hydropunch™ and analyzed for BTEX and MTBE using U.S. EPA Method 8260B. The CPT push locations and groundwater sampling locations are depicted in Figure 2-16.

Lithologic information was collected during each of the CPT pushes, and logs of depth vs. lithology were plotted for each push (see Appendix E). These logs were used to construct a series of four cross sections, one along each of the east-west oriented transects. Three additional cross sections were constructed perpendicular to the transects. Figure 2-17 shows the traces of each of the seven cross sections. Results of the CPT investigation will be presented with discussion of the site conceptual model in Section 4.1.

2.2.4 Continuous Coring and Soil Lithology. Continuous coring was conducted during the installation of all wells at the Site to obtain information on soil lithology. An on-site geologist, under the supervision of a California-certified geologist, logged soil cores. Boring logs for subsurface installations completed at the Site are presented in Appendix F. Site lithology information was obtained during CPT investigations conducted in April/May 1998, August 1998, and September 2000. CPT boring logs for April/May 1998, August 1998, and September 2000 can be found in Appendices C and E, respectively. The CPT investigations consisted of 15 locations in April/May 1998, 26 locations in August 1998, and 42 locations in September 2000. In addition, lithological information was collected during soil sampling activities conducted during Task 3 of the remedial investigation (Battelle, 2001b). Boring logs for remedial investigation soil borings also are provided in Appendix F. In order to correlate the site lithology data from continuous cores examined by a geologist with the lithology data from CPT investigations, a comparison was made between boring logs from permanent wells installed adjacent to CPT pushes. The CPT consistently identified the materials to be finer than what was observed by a geologist from cores and laboratory grain-size analyses. Since the CPT appeared to give a finer-grained interpretation than the cores and laboratory analyses, it is likely that the materials are more coarsely grained than was indicated by the CPT logs. This difference was taken into account when developing the conceptual model presented in Section 4.1.

As permanent monitoring wells, air sparging wells (see Section 3.0), and soil vapor extraction wells (see Section 3.0) were installed at the Site, soil samples were collected for analysis of both chemical and physical parameters. The objective of these soil samples was to confirm the presence of hydrocarbons in areas to be treated or monitored with the interim remedial action system wells or groundwater monitoring wells, respectively. A 1.5-ft, split-barrel, split-spoon sampler containing three 6-

inch-long by 2-inch-diameter brass sleeves was advanced ahead of the HSA to collect the soil core samples. An on-site geologist under the supervision of a California-certified geologist determined the most appropriate depth interval for sample collection. The analytical methods, laboratory detection limits, and relevant sampling information are summarized in Appendix A of the Draft Work Plan (Battelle, 1998b). Soil sampling results prior to the remedial investigation (Battelle, 2001b) are tabulated in Appendix G and supporting laboratory analytical reports are provided in Appendix H.

2.3 Groundwater and Surface Water Monitoring Program

The Navy has performed quarterly groundwater monitoring at Former UST Site 957/970 since May 1998. Also, the Navy has performed quarterly surface water monitoring since June 2000. The following subsections discuss the groundwater and surface water monitoring that has been conducted by the Navy at the Site. The February 2001 quarterly monitoring event represents the twelfth quarterly groundwater monitoring event and fourth quarterly surface water monitoring event.

2.3.1 Groundwater. Quarterly groundwater monitoring has been conducted in accordance with the revised *Groundwater Monitoring Plan* (Battelle, 2000a) and *Draft Health and Safety Plan* (Battelle, 1998a) at the Site since May 1998. The scope of the groundwater monitoring program conducted in a comprehensive set of wells each quarter includes the measurement of water levels, sufficient purging of each well, and the collection of groundwater samples. Groundwater level data and purge logs are provided in Appendices I and J, respectively. Groundwater samples collected at the Site are analyzed for TPH-G using U.S. EPA Method SW-8015; and for BTEX and MTBE by U.S. EPA Method 8260B. However, groundwater samples collected from areas of the Site where MTBE was the only gasoline constituent in groundwater were not analyzed for TPH. When TPH is quantified as gasoline using methods specified in the *California Leaking Underground Fuel Tank (LUFT) Manual* (California State Water Resource Control Board [SWRCB], 1989), MTBE has a lower response factor than typical gasoline constituents (approximately one-fifth). Therefore, the TPH concentration quantified by the *California LUFT Manual* methods is lower than the MTBE concentration quantified by U.S. EPA Method 8260B for the same sample. For this reason, when MTBE is the only gasoline constituent present, a direct quantification of MTBE by U.S. EPA Method 8260B is more reflective of concentrations in the groundwater than is a quantification of TPH-G by methods specified by the *California LUFT Manual*. Analytical methods and relevant sampling information are summarized in Table 2-25. Laboratory practical quantitation limits (PQLs) for analytes based on clean matrices are provided in Table 2-26. Quality assurance/quality control (QA/QC) measurements were taken in the field to ensure that meaningful and representative data sets were generated. Table 2-27 summarizes the frequency of QA/QC sample collection.

In addition to quarterly monitoring of gasoline constituents in groundwater, indicators of monitored natural attenuation (MNA) including nitrate, sulfate, dissolved iron, manganese, dissolved methane, and alkalinity were periodically measured to determine whether biodegradation of gasoline constituents was occurring at the Site. Also, methylated benzenes including 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, 1,2,4,5-tetramethylbenzene (TeMB), and 1,2,3,4-TeMB were monitored as gasoline constituent tracers because they are recalcitrant and are thought to not easily degrade. Oxygenates other than MTBE (i.e., *tertiary*-butyl alcohol [TBA], di-isopropyl ether [DIPE], ethyl tertiary-butyl ether [ETBE], and *tertiary*-amyl methyl ether [TAME]) and a degredation byproduct of MTBE (i.e., tertiary-butyl formate [TBF]) also were monitored. Results of MNA indicator parameters will be discussed in Section 5.2.3.1.2.

The monitoring well network used since quarterly groundwater monitoring began has been modified as a result of more complete delineation of MTBE dissolved in groundwater and construction activities occurring north of the Site on the former HAAF property. Some monitoring wells that served as

obstacles to construction activities on the former HAAF property were abandoned. During remedial investigation activities conducted in September 2000 (Section 2.2.3), replacement wells were installed near areas where former wells were abandoned, monitoring wells were installed into the fractured bedrock near the former USTs, and additional monitoring wells were installed both to augment the existing well network (i.e., subdivision development area monitoring, creek monitoring, plume perimeter monitoring) and to assess the vertical stratification of MTBE in groundwater. Figure 2-18 shows all monitoring wells that have been or currently are included in the monitoring well program. Monitoring well construction details of all wells that have been included in the groundwater monitoring program are provided in Appendix K. Table 2-28 identifies monitoring wells that are currently included (as of February 2001) in the monitoring program and the objective of sampling each well. Sixty-eight (68) monitoring wells were sampled during the latest quarterly event in February 2001.

As of February 2001, the maximum concentration of MTBE ever observed at the Site in a permanent well was 280,000 μg/L during the May 1998 quarterly groundwater monitoring event. This concentration was observed in sparge well AS-1A, located in the Sale Area near the former UST 970 tank complex. The maximum benzene concentration observed during quarterly monitoring was found in sparge well AS-6A (also located in the Sale Area near the former UST 970 tank complex) at 18,000 μg/L during October 1998. Maximum concentrations of other gasoline constituents that have been detected at the Site include: 29,000 μg/L toluene in May 1998, 3,500 μg/L ethylbenzene in May 1998, and 18,000 μg/L total xylenes in May 1998. Current concentrations are much lower and will be discussed in Section 4.2.2. A complete listing of historical analytical results from quarterly monitoring events is tabulated in Appendix L and all laboratory analytical reports are provided in Appendix M.

2.3.2 Surface Water. Surface water monitoring has been conducted at the Site since June 2000 in accordance with the revised *Groundwater Monitoring Plan* (Battelle, 2000a). All surface water samples were analyzed for BTEX and MTBE by U.S. EPA Method 8260B. Table 2-29 summarizes the decision criteria and objectives for all sampling locations. The nine locations where surface water samples were collected during February 2001 are shown on Figures 2-19 and 2-20. Figure 2-19 includes the four locations that were originally proposed in the *Groundwater Monitoring Plan* (Battelle, 2000a) and an additional location that was sampled for the first time in February 2001. The original locations include one sample collected upstream of the Site, one sample within the area of dissolved MTBE in underlying groundwater (near the culvert outfalls), and two downstream samples. The additional sampling location shown on Figure 2-19 (PC-SW-5) is within the area of dissolved MTBE in underlying groundwater and positioned near monitoring well IT-2MW1. PC-SW-5 was added to the monitoring program to better evaluate whether MTBE concentrations dissolved in the surface water were similar to MTBE concentrations dissolved in groundwater.

Figure 2-20 shows four additional sampling locations that are between the culvert outlet and the North Hamilton Parkway Bridge. These locations were selected and sampled to determine whether a source of MTBE exists in water originating from the individual culverts that enter the creek in this area. As shown in Figure 2-20, surface water sampling locations PC-SW-C1, PC-SW-C2, and PC-SW-CE are associated with specific culvert outlets. PC-SW-CW, formerly located immediately downstream of the railroad bridge and intended to be representative of the outfall from the two westernmost culverts, was altered slightly (in February 2001) due to clearing of vegetation within the creek. Formerly the two westernmost culverts were isolated from the eastern culverts by vegetation in the middle of Pacheco Creek. After dredging took place, the culverts were exposed allowing sampling to take place at the culvert outlet. Dredging revealed that water flow occurred only in the westernmost rather than in the two westernmost culverts. For this reason, a sample was collected from the westernmost culvert only. Although the location changed slightly, it is still representative of outfall from the same culvert (see Figure 2-20).

Surface water samples were collected directly into VOA vials and acidified with hydrochloric acid (HCl) for preservation. Immediately following sample collection, VOA vials were maintained at 4°C until receipt by the analytical laboratory. Copies of the laboratory analytical reports and sampling log sheets (in addition to all pertinent surface water sampling information) are provided in Appendices M and J, respectively.

Four quarters of surface water results have reported a maximum MTBE concentration of 2,400 µg/L during July 2000 at sampling location PC-SW-CE (see Figure 2-20), which is well below the water quality objective for protection of freshwater aquatic life (66,000 µg/L) adopted by the RWQCB (RWQCB, 1998). This sample is not collected from surface water flowing in Pacheco Creek, but is collected from the inside of a storm sewer outlet, which enters the creek laterally from the east and slightly downstream of the railroad bridge, and may be a source of MTBE in Pacheco Creek. The maximum concentration of MTBE that has been detected in a sample collected from Pacheco Creek surface water was 190 µg/L in June 2000 at PC-SW-2 (Figure 2-19). Figure 2-19 indicates that MTBE has not been detected in surface water upgradient of the Site (PC-SW-1) during any quarterly monitoring events, and generally MTBE concentrations decrease as surface water flows downstream in the creek. Figures 2-19 and 2-20 provide a comprehensive list of MTBE concentrations detected in Pacheco Creek at all sampling locations during each quarterly monitoring event. A cumulative summary of the surface water sampling results for gasoline constituents of concern is provided in Table 2-30.

In order to determine whether MTBE-impacted groundwater is interacting with surface water in Pacheco Creek, Figure 2-21 illustrates streambed elevations, groundwater elevations, and MTBE concentrations measured in Pacheco Creek and nearby monitoring wells during the latest quarterly monitoring event (February 2001). The streambed elevation of Pacheco Creek steadily declined from 36.77 ft above mean sea level (amsl) at the first sampling location (PC-SW-1) to 3.72 ft amsl at the farthest downstream sampling location (PC-SW-4), approximately 1,500 ft downstream from the leading edge of MTBE-impacted groundwater. As shown in Figure 2-21, the streambed elevation is 17.50 and 14.38 ft amsl at sampling location PC-SW-2 and PC-SW-3, respectively. The groundwater elevations in monitoring wells which are located near Pacheco Creek (shown in Figure 2-21), ranged from 14.94 ft amsl (IT-PZ-5) to 21.23 ft amsl (IT-2MW-1). These results indicate that the elevation of the aquifer is higher than the streambed elevation in some areas; however, because the creek is concrete lined in the area of the dissolved MTBE plume, limited interaction between the two is expected.

2.4 Human Health Risk Assessments

A Tier 3 RBCA Assessment (Battelle, 1999b) was prepared and submitted to the RWQCB that developed risk-based screening levels (RBSLs) protective of potential receptors that may come into contact with hydrocarbon-impacted media at the Site. The approach used in the Tier 3 RBCA assessment was to compare concentrations of gasoline constituents on site against health-based screening concentrations derived to determine the suitability of the Site for its intended future use. However, the DTSC prefers an alternate approach to risk assessment that is outlined in the U.S. EPA's *Risk Assessment Guidance for Superfund* (1989) and the DTSC HERD *Supplemental Guidance for Superfund Risk Assessment* (Cal-EPA, 1992). In the DTSC-preferred approach, a multimedia, multichemical risk assessment is performed in the *forward* direction to estimate cancer risk and chemical hazard (non-cancer risk), rather than in the *reverse* direction as was done in the RBCA assessment by deriving target concentrations. Therefore, a *Final Revised Risk Assessment* (Battelle, 2001c) was conducted by the Navy to address specific comments provided by the DTSC on the Tier 3 RBCA Assessment. Results of the *Final Revised Risk Assessment* are favored over those in the Tier 3 RBCA for exposures pathways that were evaluated in both assessments. The following subsections briefly summarize the risk evaluations.

2.4.1 Tier 3 RBCA Assessment. A Tier 3 RBCA Assessment was prepared and submitted to the RWQCB to determine if the Site poses a risk to human health. The report, dated November 24, 1999, is titled *Tier 3 Risk-Based Corrective Action (RBCA) Assessment for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California, and Adjoining Property on Hamilton Army Airfield* (Battelle, 1999c). The Tier 3 addressed the adjoining former HAAF property with respect to the area impacted by MTBE released from Former UST Site 957/970.

The objective of the Tier 3 RBCA assessment was to develop RBSLs that are protective of potential receptors that may come into contact with impacted media at the Site. RBSLs are gasoline constituent concentrations in soil or groundwater that will produce a specified target risk or hazard level if a receptor comes into contact with the media according to a defined exposure scenario. Comparing existing gasoline constituent concentrations (actual levels) to the RBSLs (protective levels) can allow decisions to be made regarding the need for (further) site remediation. Furthermore, because RBSLs represent concentrations that correspond to a known risk (e.g., 1×10^{-6}) or hazard (e.g., 1.0) level, the RBSLs can be used to derive an estimate of potential risk or hazard posed by a chemical for a particular exposure scenario.

The RBSLs were calculated for all reasonably likely exposure scenarios that could result in exposure of an individual under the intended future land-use conditions at Former UST Site 957/970 (i.e., the Sale Area and PBC Area) and adjoining property on the Hamilton Army Airfield (HAAF) property (i.e., the areas outside the Sale Area and PBC Area overlying the MTBE groundwater plume). Potential future receptors included in this risk evaluation were an adult and child resident, a full-time occupational worker, and a construction/excavation worker. Exposure pathways evaluated include:

- Incidental ingestion and dermal contact with soil
- Dermal contact with groundwater
- Inhalation of outdoor air from chemicals in soil
- Inhalation of outdoor air from chemicals in groundwater
- Inhalation of indoor air from chemicals in soil and groundwater
- Incidental ingestion and dermal contact with surface water (pacheco creek)
- Inhalation of outdoor air from chemicals in surface water.

The results of the Tier 3 RBCA Assessment (Battelle, 1999c) supports that the current conditions on areas outside the Sale Area and the PBC Area overlying the MTBE plume (i.e., the former HAAF property) are not likely to be associated with adverse health effects for residential receptors that could potentially come into contact with gasoline constituents by ingesting homegrown fruits/vegetables or coming into contact with surface water in Pacheco Creek during recreational activities.

The Tier 3 RBCA Assessment (Battelle, 1999c), submitted on November 24, 1999, is considered final because the document responded to all comments provided by the RWQCB on the draft version of the document, and the RWQCB provided no further comments on the revised document. After the Tier 3 RBCA Assessment was considered final, the DTSC opted to exercise their regulatory oversight for the human health risk assessment at the Site and request the use of their preferred risk assessment method. The DTSC approach to risk assessment varies from that performed in the RBCA assessment; therefore, a *Final Revised Risk Assessment* (Battelle, 2001c) was conducted by the Navy to address specific comments provided by the DTSC on the Tier 3 RBCA Assessment. The following section describes the methodology and results of the Final Revised Risk Assessment.

2.4.2 Revised Risk Assessment. A *Final Revised Risk Assessment* (Battelle, 2001c) was prepared in response to DTSC comments on the Tier 3 RBCA Assessment. The *Final Revised Risk Assessment*

(Battelle, 2001c) has been reviewed and agreed upon by the DTSC (see concurrence letter included in Attachment 2). As part of the *Final Revised Risk Assessment*, additional health risk assessment analyses were conducted by the Navy which could be used by transferees to comply with the statutory requirements in Section 17213 of the California Education Code. This revised risk report provides a multimedia, multichemical risk assessment that estimates cancer risk and chemical hazard (noncancer risk) incurred by future site occupants from exposure to residual hydrocarbons in soil and groundwater at the Site. As stated previously, the results of this revised risk assessment are favored over risk results presented in the Tier 3 RBCA Assessment for comparable exposure scenarios. Therefore, the following subsections have been provided to summarize, in greater detail, the potential exposure scenarios, methodology, results, and conclusions of the *Final Revised Risk Assessment*.

2.4.2.1 Potential Exposure Scenarios. In the *Final Revised Risk Assessment*, the Sale Area was evaluated for a commercial/industrial scenario and the PBC Area was evaluated for a residential use scenario, based on the planned future uses of Navy property as discussed in Section 1.3 (see Figure 1-3). All likely exposures to gasoline constituents in soil and groundwater at Former UST Site 957/970 were evaluated based on the planned future uses of the Site. A full-time occupational worker was identified as the future potential receptor for the Sale Area. For the PBC Area, two potential receptors were evaluated: a child representing ages 0-6 years, and an age-adjusted composite receptor based on a child, ages 0-6 years, and an adult, ages 7-31 years. For both the Sale Area and the PBC Area, an additional scenario was evaluated that examined potential risks to an excavation worker that could be involved in soil trenching activities, such as installation of underground utilities.

Receptors may be exposed to gasoline-impacted soil or groundwater either directly through activities that result in contact with impacted environmental media (for example, digging in soil) or indirectly as a result of migration of gasoline constituents to locations where contact with receptors can occur (for example, inhalation of vapors). Exposure pathways that were evaluated in the risk assessment and that replace those in the Tier 3 RBCA Assessment include:

- Direct exposure to soil (including incidental ingestion and dermal contact)
- Inhalation of vapors from soil in outdoor air
- Inhalation of vapors from groundwater in outdoor air
- Inhalation of vapors from soil and groundwater in indoor air.

Dermal contact with groundwater, incidental ingestion and dermal contact with surface water (Pacheco Creek), and inhalation of outdoor air from chemicals in surface water are exposure pathways that were evaluated in the Tier 3 RBCA Assessment. These same pathways were not reevaluated because they are not pathways that exist on the site as defined in the revised risk assessment; therefore, risks from these pathways should be obtained from the Tier 3 RBCA Assessment.

2.4.2.2 Methodology. Predicted concentrations of gasoline constituents in indoor air that might exist inside a home or building that overlies impacted soil or groundwater were calculated by using a spreadsheet model provided by the DTSC. The spreadsheet model, which was developed for the U.S. EPA by Environmental Quality Management, Inc. (EQM) (1997), is based on the Johnson and Ettinger (1991) vapor intrusion model. Risks resulting from direct contact with soil were evaluated using methods based on guidance documents from U.S. EPA and exposure parameters consistent with those used by U.S. EPA Region 9 and Cal-EPA.

Throughout the *Final Revised Risk Assessment*, the Sale Area and the PBC Area were evaluated based on samples collected in and around the localized areas within them where maximum concentrations of gasoline constituents exist. There have been no detections of any gasoline constituent

except MTBE in groundwater outside the Sale Area and the PBC Area. There also have been no detections of any gasoline constituent in soil outside the Sale Area and the PBC Area.

2.4.2.3 Results. Tables 2-31 and 2-32 present the total risk posed by all gasoline constituents to each receptor (residential, occupational, and excavation worker), for all media (soil and groundwater), and through all exposure pathways (indoor inhalation, outdoor inhalation, direct contact with soil) from the *Final Revised Risk Assessment* (Battelle, 2001c).

Sale Area. The total cancer risk for the occupational receptor in the Sale Area is 2.57×10^{-6} and 8.26×10^{-6} based on the federal and Cal-EPA unit risk factors for benzene, respectively; and the total noncancer risk (hazard index) is below 1.0 for the occupational receptor (see Table 2-31).

PBC Area. Total cancer risk is below 1×10^{-6} and total noncancer risk is below 1.0 for the residential receptor in the PBC Area (see Table 2-31).

Excavation Worker. Estimates of total cancer risk for the excavation worker are 4.78×10^{-7} and 1.73×10^{-6} for the Sale Area based on the federal and Cal-EPA unit risk factors for benzene, respectively. For the PBC Area, total cancer risk is less than 1×10^{-6}. Total noncancer risk for the Sale Area is 1,130 and total noncancer risk for the PBC Area is 52 (see Table 2-32). The results of the excavation worker scenario are useful for determining appropriate protective measures that such workers should take when working on site; however, these results are not intended to drive cleanup decisions.

2.4.2.4 Conclusions. Results of the risk assessment indicate that the cancer risk estimates to the occupational receptor in the Sale Area fall within the risk range (1×10^{-6} to 1×10^{-4}) that warrants a site-specific risk management decision regarding the suitability of the property for its intended future use; however, the total cancer risk estimates in the Sale Area are most likely overestimated (Battelle, 2001c). Per U.S. EPA guidance (U.S. EPA, 1991), remedial action generally is not warranted at a site if the total cancer risk is below 1×10^{-4} (one in ten thousand) and the total noncancer risk (hazard index) does not exceed 1.0 unless a risk manager decides that there are extenuating circumstances. Therefore, based on the results of the risk assessment (Battelle, 2001c), DTSC's concurrence with the risk assessment, and in accordance with EPA guidance (EPA 1991), the Sale Area is suitable for its intended commercial/industrial use.

The results of the risk assessment indicate that the educational PBC Area and areas outside the Sale Area and the PBC Area overlying groundwater with dissolved MTBE resulting from the UST releases (i.e., Hamilton Meadows Subdivision) are suitable for unrestricted land use because the total cancer risk falls below 1×10^{-6} and the noncancer risk is below 1.0.

The results of the risk assessment pertaining to an excavation worker at Former UST Site 957/970 indicate that precautionary measures should be taken when working at the Site. Recommendations for reducing VOC emission rates during excavation activities are provided by U.S. EPA (1992).

2.5 Ecological Risk Assessment

A draft scoping level ecological risk assessment was prepared to determine if the Site poses a risk to the environment. The draft report, submitted on December 8, 1999, is titled the *Draft Ecological Risk Scoping Assessment for Former UST Site 957/970, Department of Defense Housing Facility and Adjoining Portions of Hamilton Army Airfield, Novato, California* (Battelle, 1999a).

This report was updated to incorporate the results of surface water sampling in a pre-draft final version of the ecological risk assessment dated June 19, 2001. The following paragraphs discuss the results of the ecological risk assessment.

The purpose of the scoping ecological risk assessment was to determine the potential for exposure of ecological receptors to gasoline resulting from releases at Former UST Site 957/970. The report focuses on determining the potential ecological receptors and the potentially complete exposure pathways, according to the methodologies described by the Cal-EPA (1996) for scoping assessments, and is consistent with U.S. EPA guidance for problem formulation (U.S. EPA, 1998a). According to Cal-EPA (1996), additional assessment is not required if the scoping assessment determines that either no complete exposure pathways exist or that the impacted areas are not significantly utilized by biota.

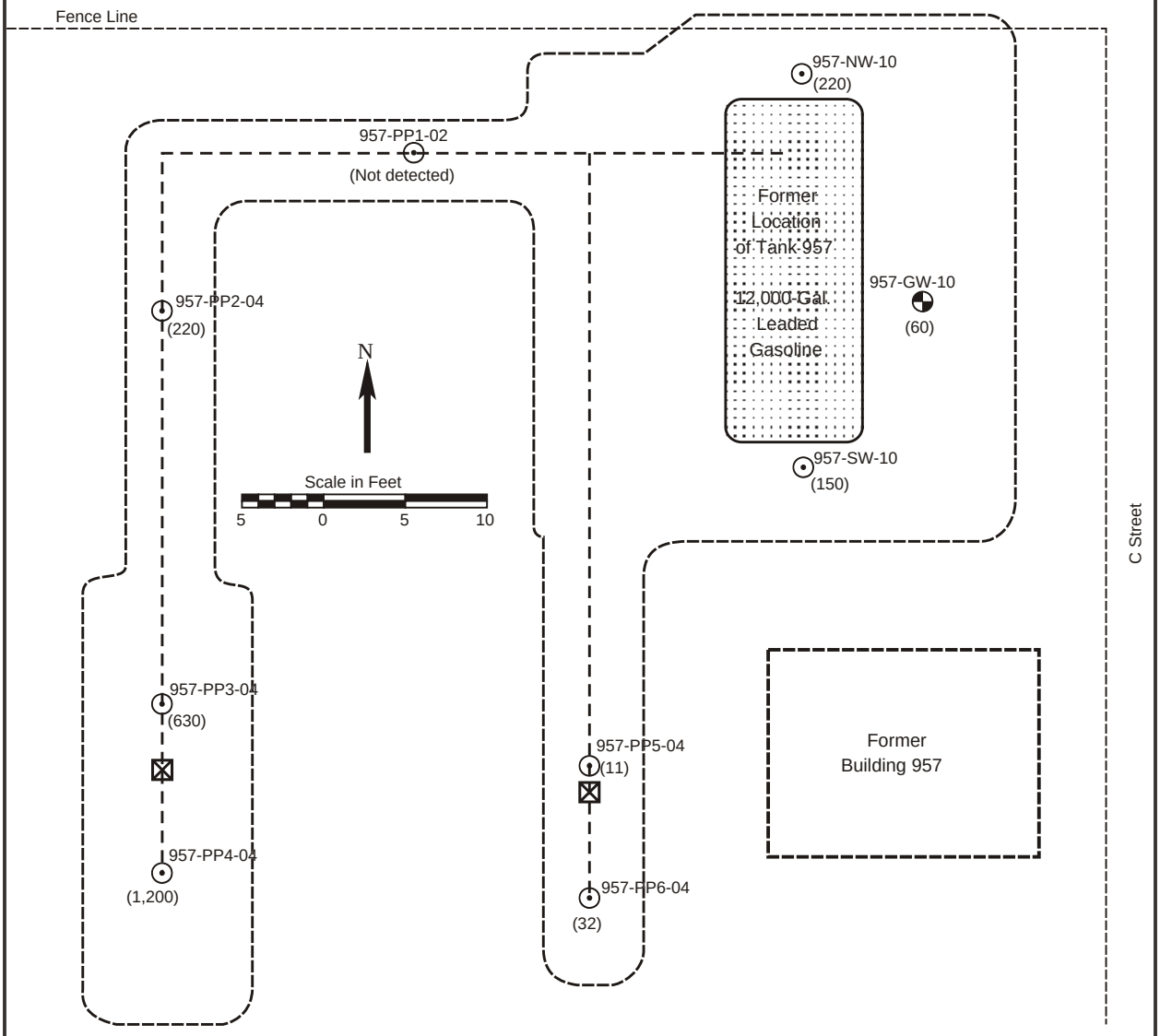
A review of the available information indicates that the primary habitats associated with the area impacted by the MTBE plume are grasslands dominated by introduced European plant species and limited riparian and aquatic habitat associated with Pacheco Creek. Ecological receptors supported by these habitats potentially include a variety of birds and mammals, a few reptiles, and limited species of small forage fish and aquatic invertebrates, although development activities in the vicinity are likely to decrease use of the area by grassland and riparian species. The potentially complete exposure pathways that were identified include soil/sediment exposures, air exposures, and surface water exposures. The ecological conceptual site model in Table 2-33 identifies each environmental medium of concern, the receptor groups associated with that medium, and potential exposure routes.

Because of the chemical and physical properties of MTBE, it is unlikely that this chemical will migrate from groundwater to surface soils, sediment, or air at potential levels of ecological concern. Therefore, exposure pathways associated with those environmental media are considered incomplete.

MTBE was analyzed in surface water from Pacheco Creek in 2000 and 2001. MTBE concentrations ranged from nondetect (<0.5 μg/L) to a maximum of 2,400 μg/L. The highest concentration was detected in a sample collected from inside a storm sewer outfall (sampling location PC-SW-CE) in June 2000. In the most recent sampling at this location (February 2001), the MTBE concentration was only 330 μg/L. Concentrations in the creek itself have consistently been much lower than the concentrations at the stormwater drain discharge and, by the time the water reaches the downstream sampling location PC-SW-4, MTBE concentrations have been near or below the detection limit (with the exception of 24 μg/L being detected in February 2001).

Because MTBE was detected in the creek, the surface water pathway is considered complete; however, risk to ecological receptors from MTBE in surface water is negligible. Because the riparian and grassland species may use other water sources in addition to Pacheco Creek, and because concentrations in the creek decrease rapidly downstream from the stormwater drain, exposure of these receptors is not expected to result in toxicity. Aquatic receptors living in the creek have the greatest potential exposure; however, the concentrations detected do not represent a significant risk. The maximum concentration detected in the storm sewer outfall (2,400 μg/L) is well below the Recommended Interim Water Quality Objective (or Aquatic Life Criteria) of 66,000 μg/L MTBE for chronic exposure of freshwater organisms (RWQCB, 1998). The hazard quotient, calculated by dividing the exposure concentration by the Water Quality Objective is 0.04. Any hazard quotient below 1.0 is considered acceptable.

Therefore, based on the results of the updated scoping assessment from June 2001, it was confirmed that the groundwater MTBE plume poses minimal risk to ecological receptors, and as defined by Cal-EPA (1996), further evaluation of ecological risk is not required at this time.

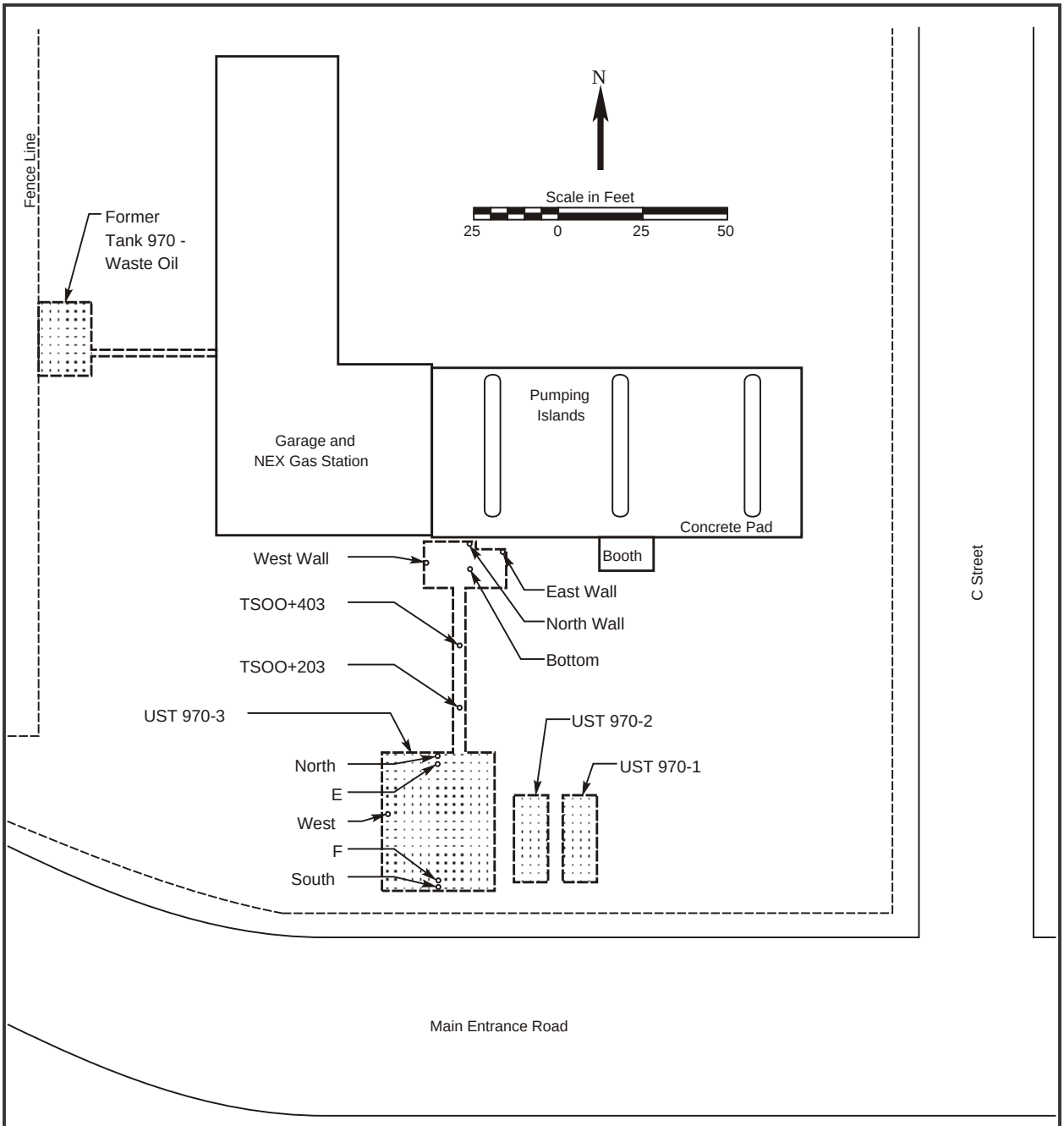


Explanation

- Previous excavation
- Former piping location
- Former fuel dispenser location
- (32) Soil sample location with TPH-P concentration (mg/kg)
- (60) Groundwater sample location with TPH-P concentration (mg/L)

Source: PRC Environmental Management, Inc., Sept. 1992

DESIGN BY JG	Battelle … Putting Technology To Work		
DRAWN BY LC	Tank Site 957 Sample Locations and Results		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	FILE 957SITE01.CDR	DATE 4/01



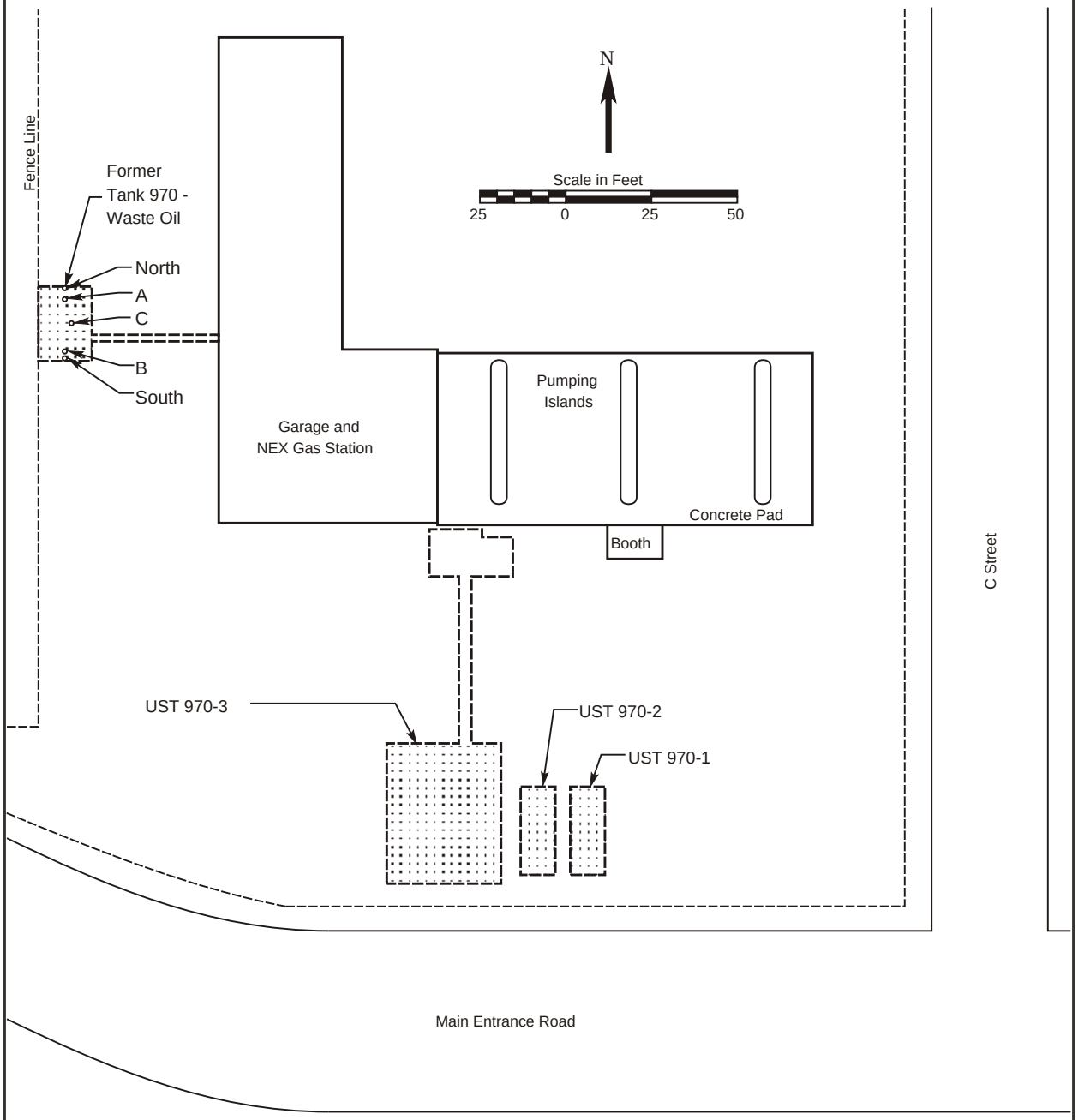
Explanation

Excavation area

Soil sample location

Sources: ERM-West, Inc., May 1995; Navy Public Works Center, July 1996

DESIGN BY JG	Battelle ... Putting Technology To Work		
DRAWN BY LC	Site 970 Tank, Piping, and Sampling Locations		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	FILE 970SITE01.CDR	DATE 4/01



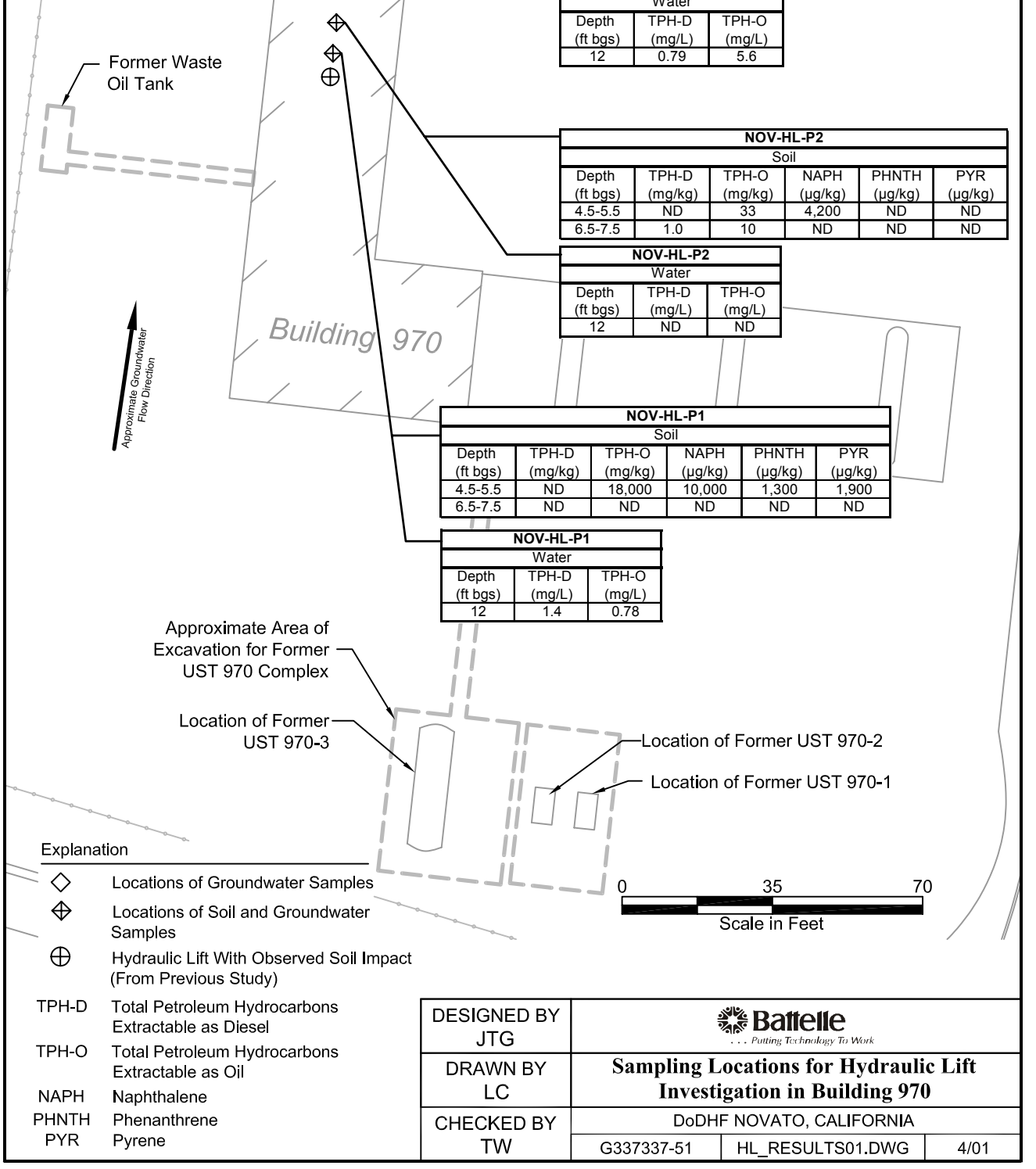
Explanation

Excavation area

Soil sample location

Sources: ERM-West, Inc., May 1995; Navy Public Works Center, July 1996

DESIGN BY JG	Battelle ... Putting Technology To Work		
DRAWN BY LC	Site 970 - Waste Oil Tank Sampling Locations		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	FILE WASTEOILTANK.CDR	DATE 4/01



Water

Depth (ft bgs)	TPH-D (mg/L)	TPH-O (mg/L)
12	0.79	5.6

NOV-HL-P2

Soil

Depth (ft bgs)	TPH-D (mg/kg)	TPH-O (mg/kg)	NAPH (µg/kg)	PHNTH (µg/kg)	PYR (µg/kg)
4.5-5.5	ND	33	4,200	ND	ND
6.5-7.5	1.0	10	ND	ND	ND

NOV-HL-P2

Water

Depth (ft bgs)	TPH-D (mg/L)	TPH-O (mg/L)
12	ND	ND

NOV-HL-P1

Soil

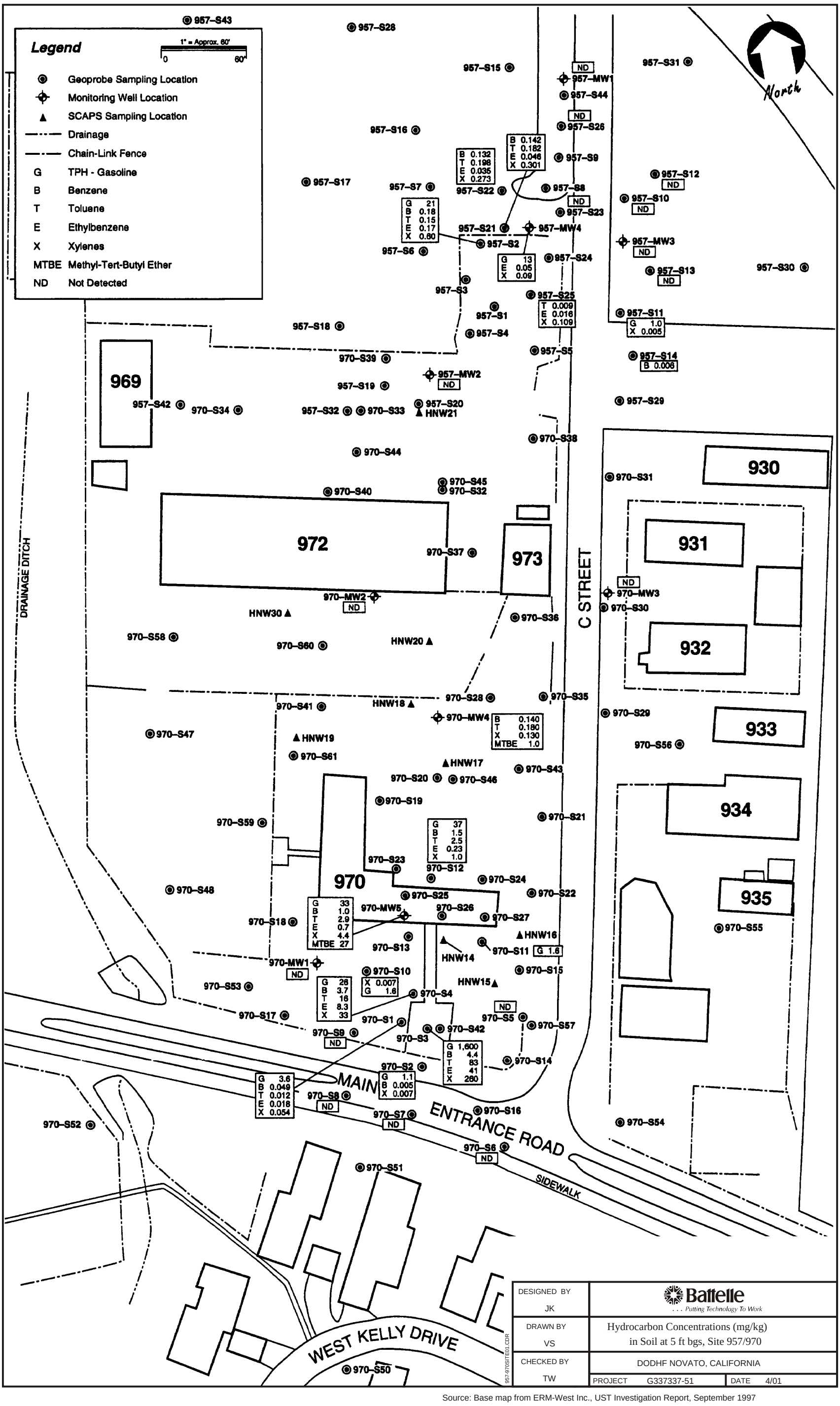
Depth (ft bgs)	TPH-D (mg/kg)	TPH-O (mg/kg)	NAPH (µg/kg)	PHNTH (µg/kg)	PYR (µg/kg)
4.5-5.5	ND	18,000	10,000	1,300	1,900
6.5-7.5	ND	ND	ND	ND	ND

NOV-HL-P1

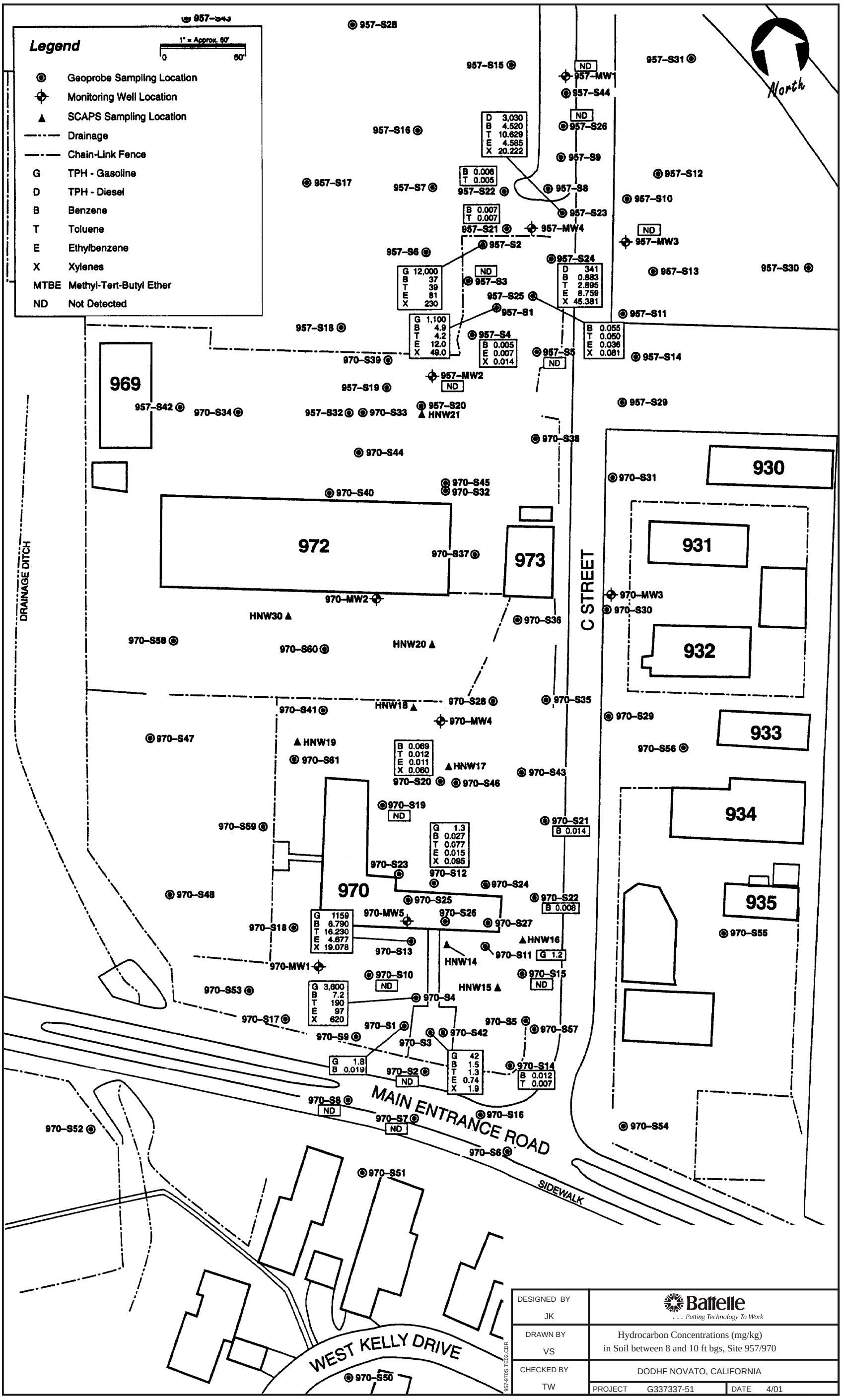
Water

Depth (ft bgs)	TPH-D (mg/L)	TPH-O (mg/L)
12	1.4	0.78

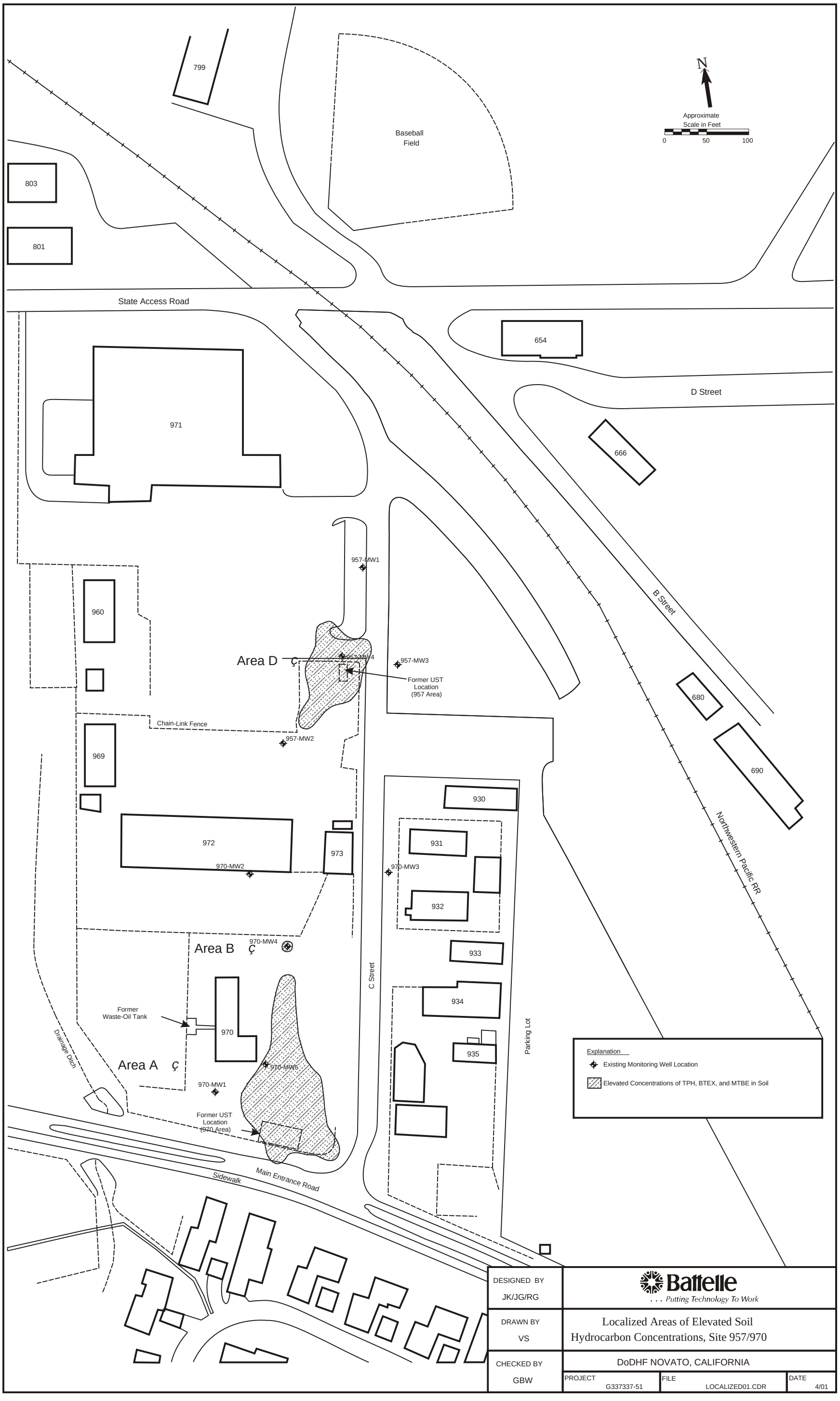
Figure 2-4. Sampling Locations for Hydraulic Lift Investigation in Building 970



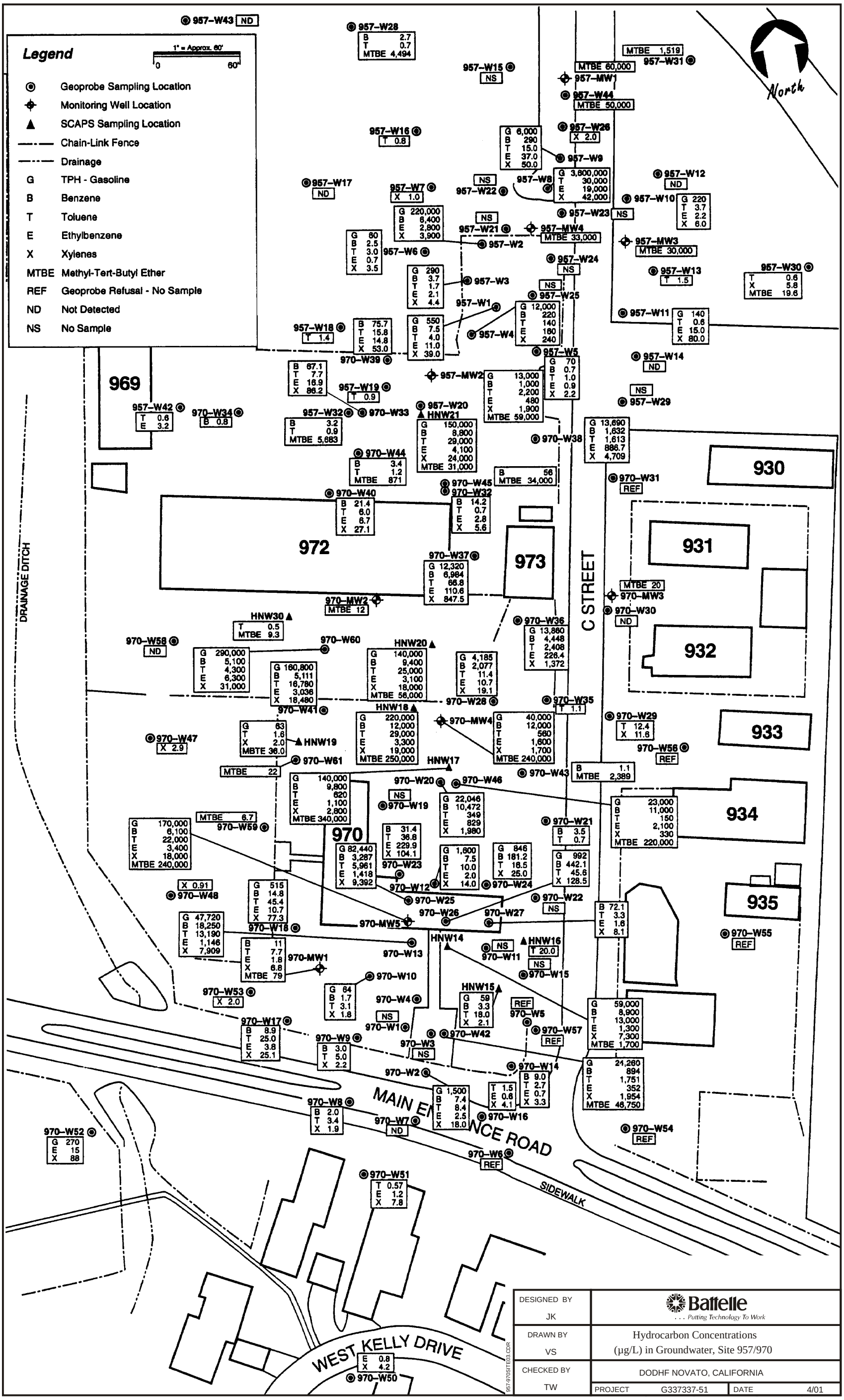
Source: Base map from ERM-West Inc., UST Investigation Report, September 1997



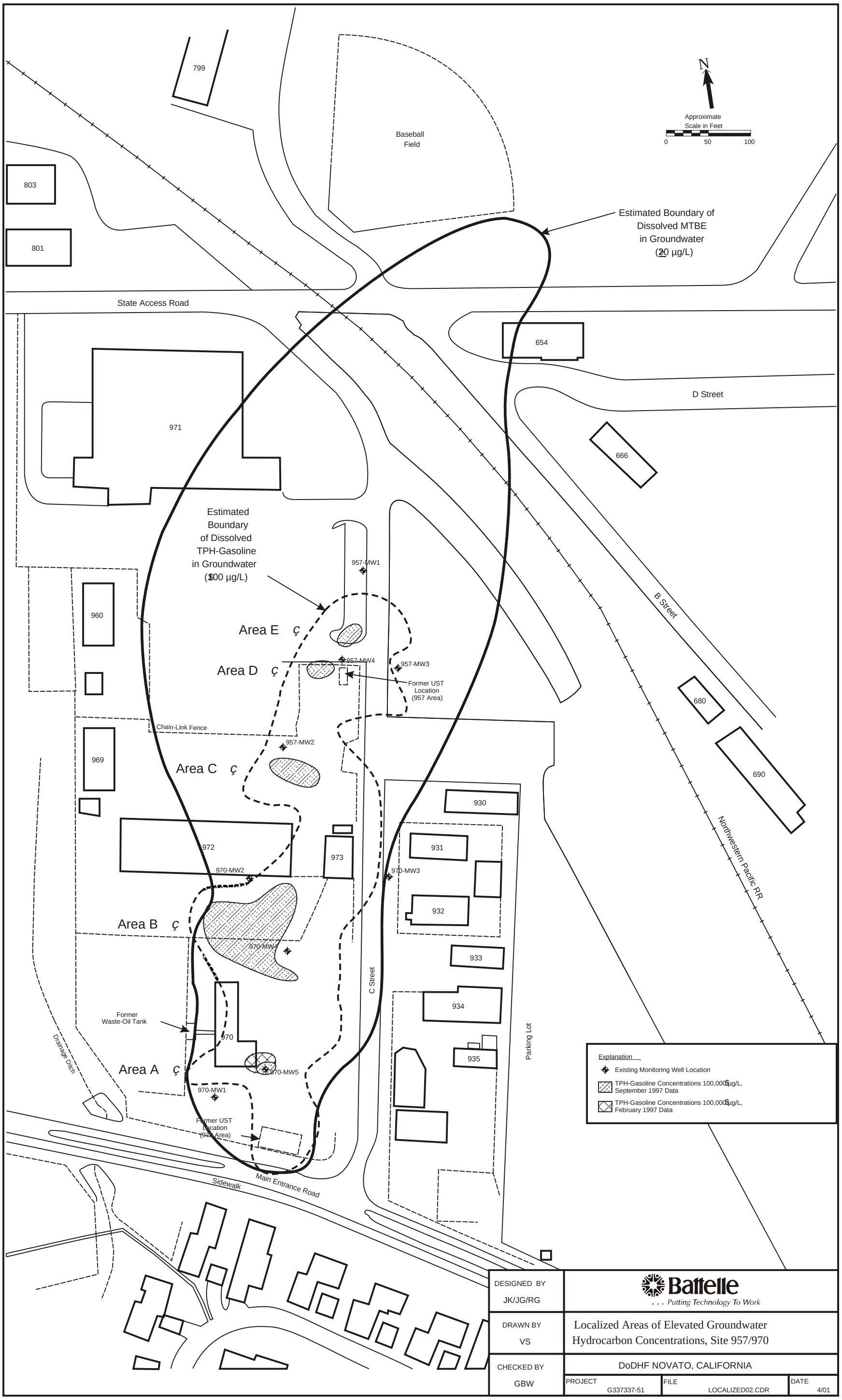
Source: Base map from ERM-West Inc., UST Investigation Report, September 1997



Source: Base map from ERM-West Inc., UST Investigation Report, September 1997



Source: Base map from ERM-West Inc., UST Investigation Report, September 1997



Source: Base map from ERM-West Inc., UST Investigation Report, September 1997

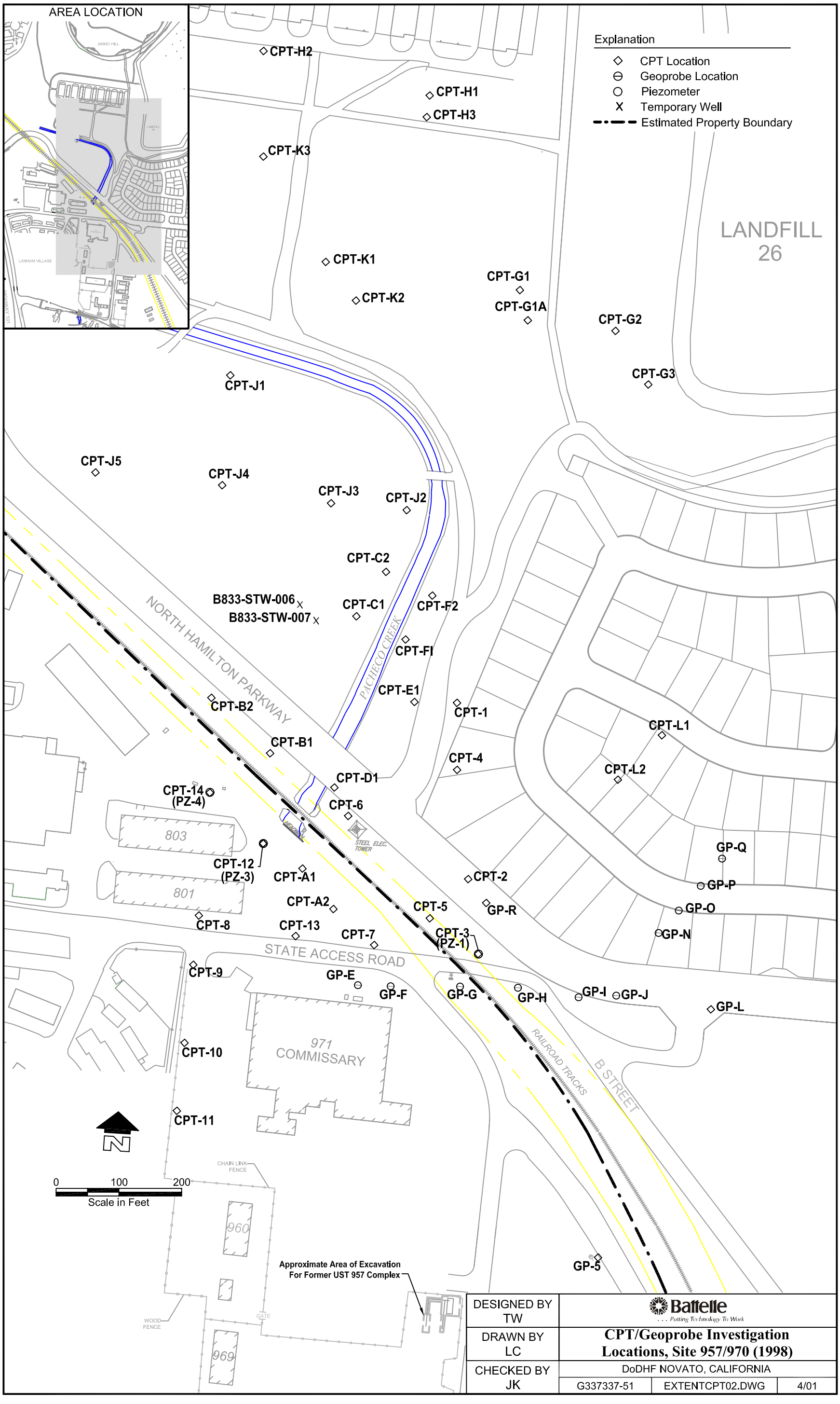
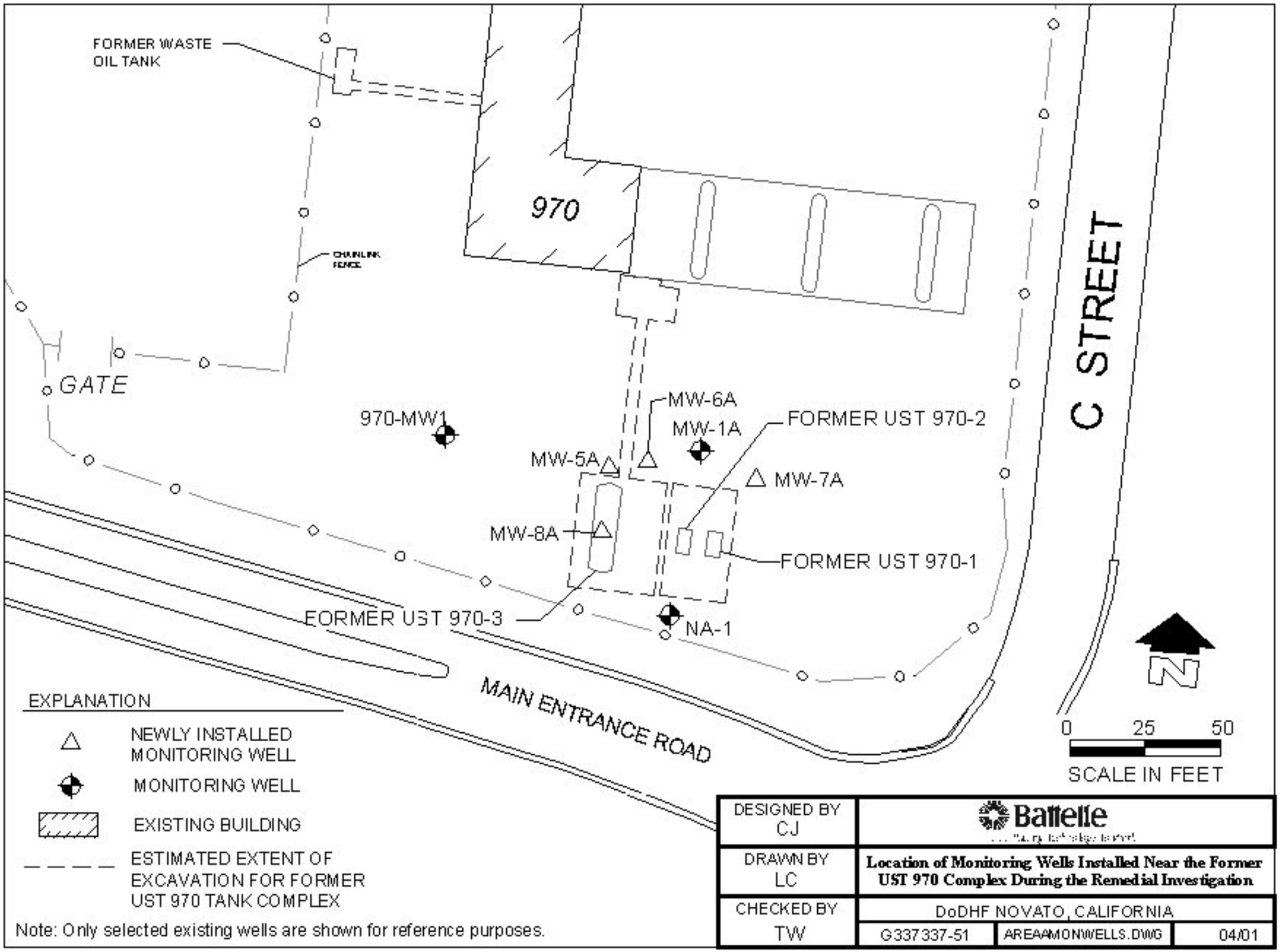


Figure 2-10. CPT/Geoprobe Investigation Locations, Site 957/970 (1998)


FORMER WASTE OIL TANK
970
CHAINLINK FENCE
GATE
970-MW1
MW-6A
MW-1A
FORMER UST 970-2
MW-5A
MW-7A
MW-8A
FORMER UST 970-1
FORMER UST 970-3
NA-1
C STREET
MAIN ENTRANCE ROAD
N
0 25 50
SCALE IN FEET
EXPLANATION
NEWLY INSTALLED MONITORING WELL
MONITORING WELL
EXISTING BUILDING
ESTIMATED EXTENT OF EXCAVATION FOR FORMER UST 970 TANK COMPLEX
Note: Only selected existing wells are shown for reference purposes.
DESIGNED BY CJ
DRAWN BY LC
CHECKED BY TW
Battelle
Location of Monitoring Wells Installed Near the Former UST 970 Complex During the Remedial Investigation
DoDHF NOVATO, CALIFORNIA
G337337-51
AREAAMONWELLS.DWG
04/01

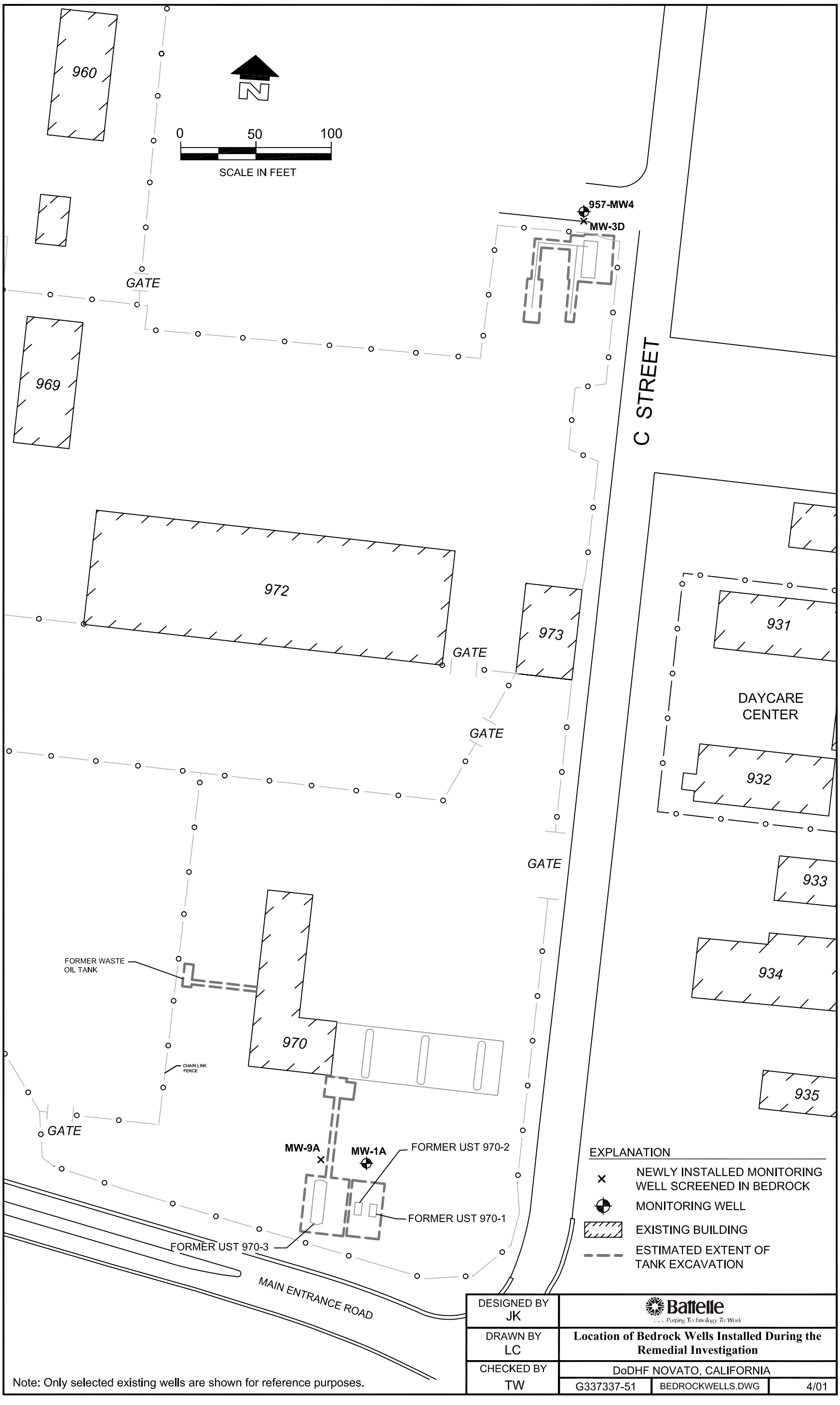


Figure 2-12. Location of Bedrock Wells Installed During the Remedial Investigation

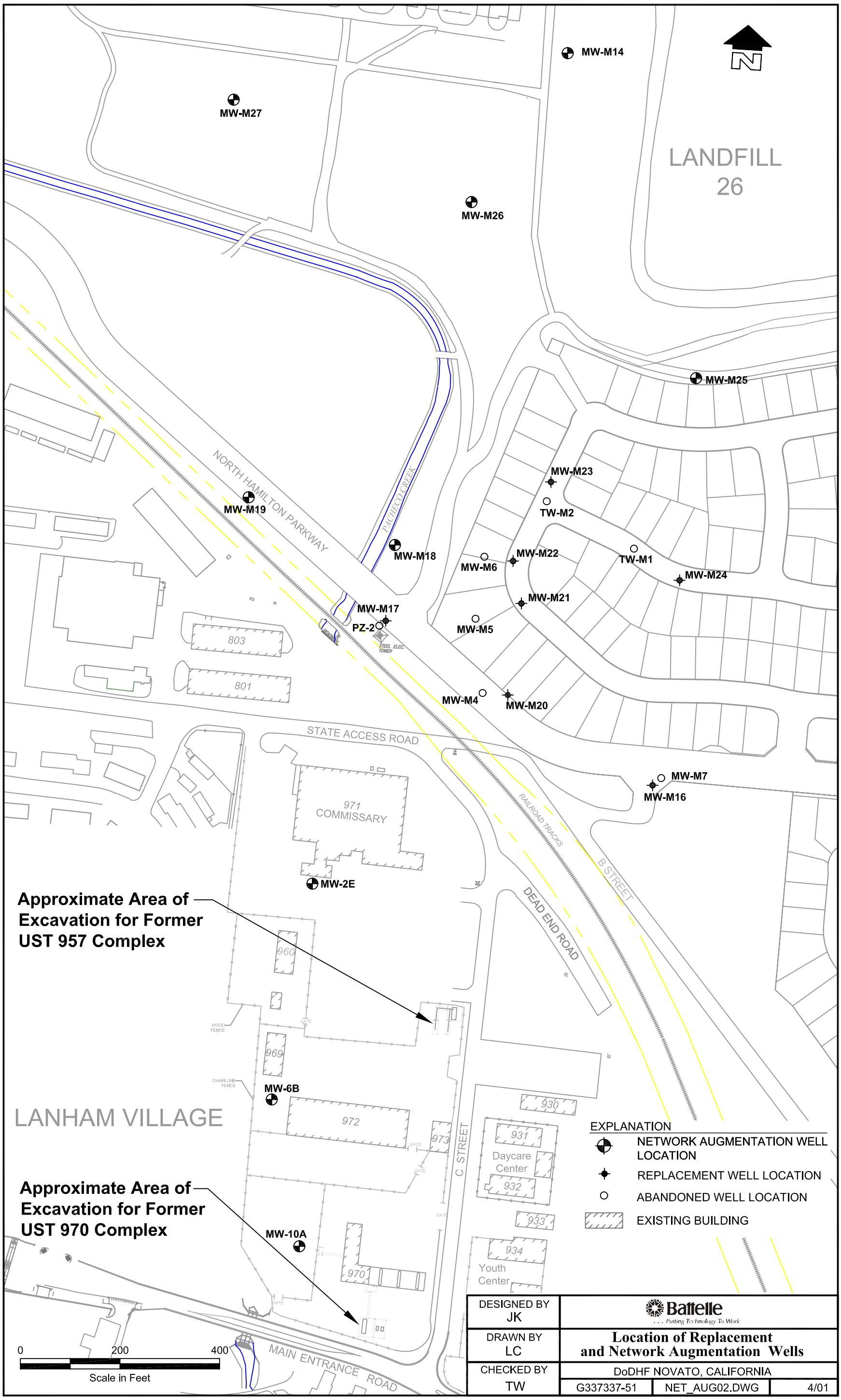
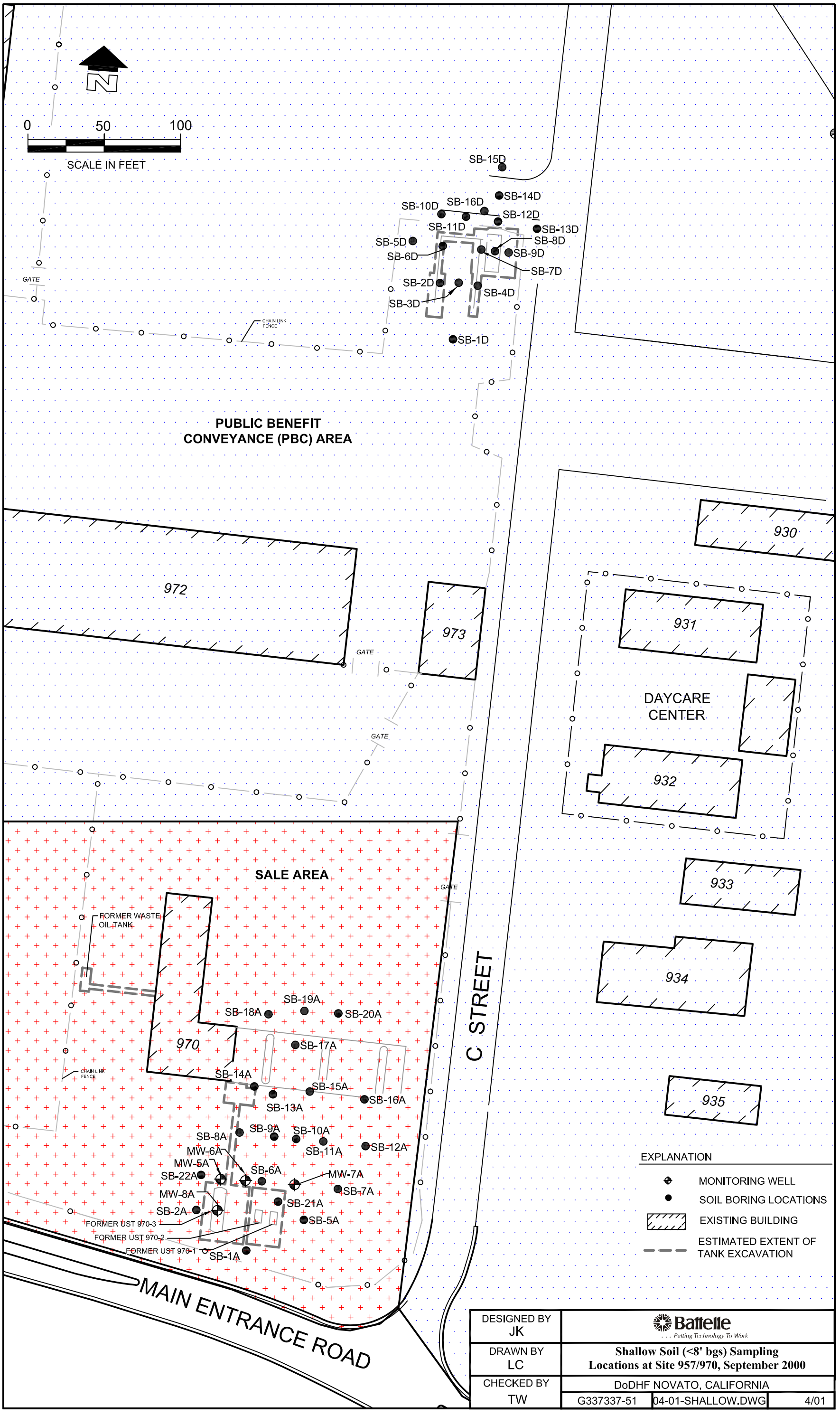


Figure 2-13. Location of Replacement and Network Augmentation Wells



DESIGNED BY JK	Battelle ... Putting Technology To Work	
DRAWN BY LC	**Shallow Soil (<8' bgs) Sampling Locations at Site 957/970, September 2000**	
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA	
	G337337-51	04-01-SHALLOW.DWG 4/01

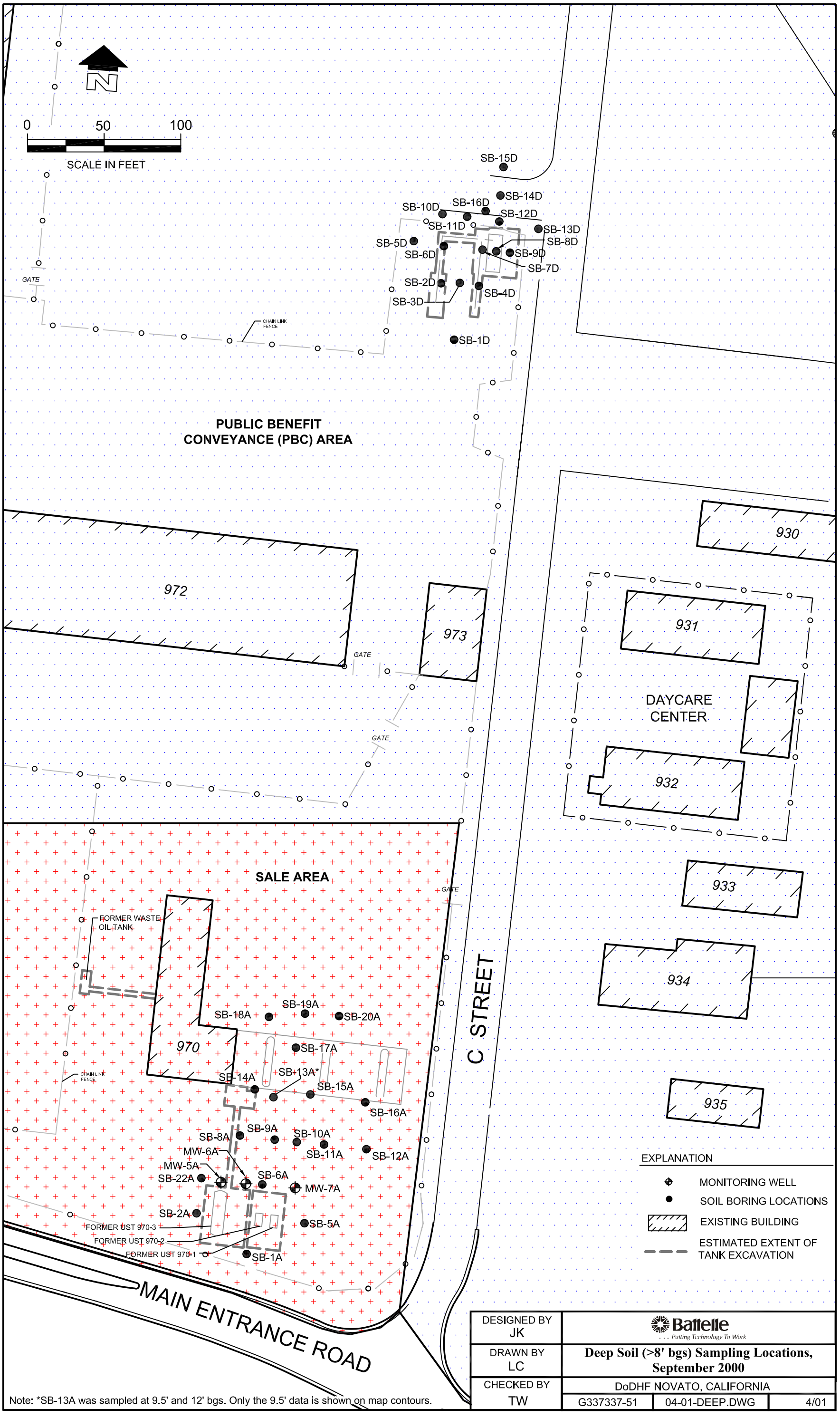


Figure 2-15. Deep Soil (>8'bgs) Sampling Locations, September 2000

BASE EXCHANGE BUILDING

B STREET

RAILROAD TRACKS

DEAD END ROAD

C STREET

T1 1 2 3 4 5 6 7 8

T2 1 2 3 4 5 6 7 8 9

T3 1 2 3 4 5 6 7 8 9

T4 1 2 3 4 5 6 7 8 9 10

I-1 I-2 I-3 I-4 I-5 I-6

N

0 25 50

SCALE IN FEET

EXPLANATION

◇ CPT BORING LOCATION

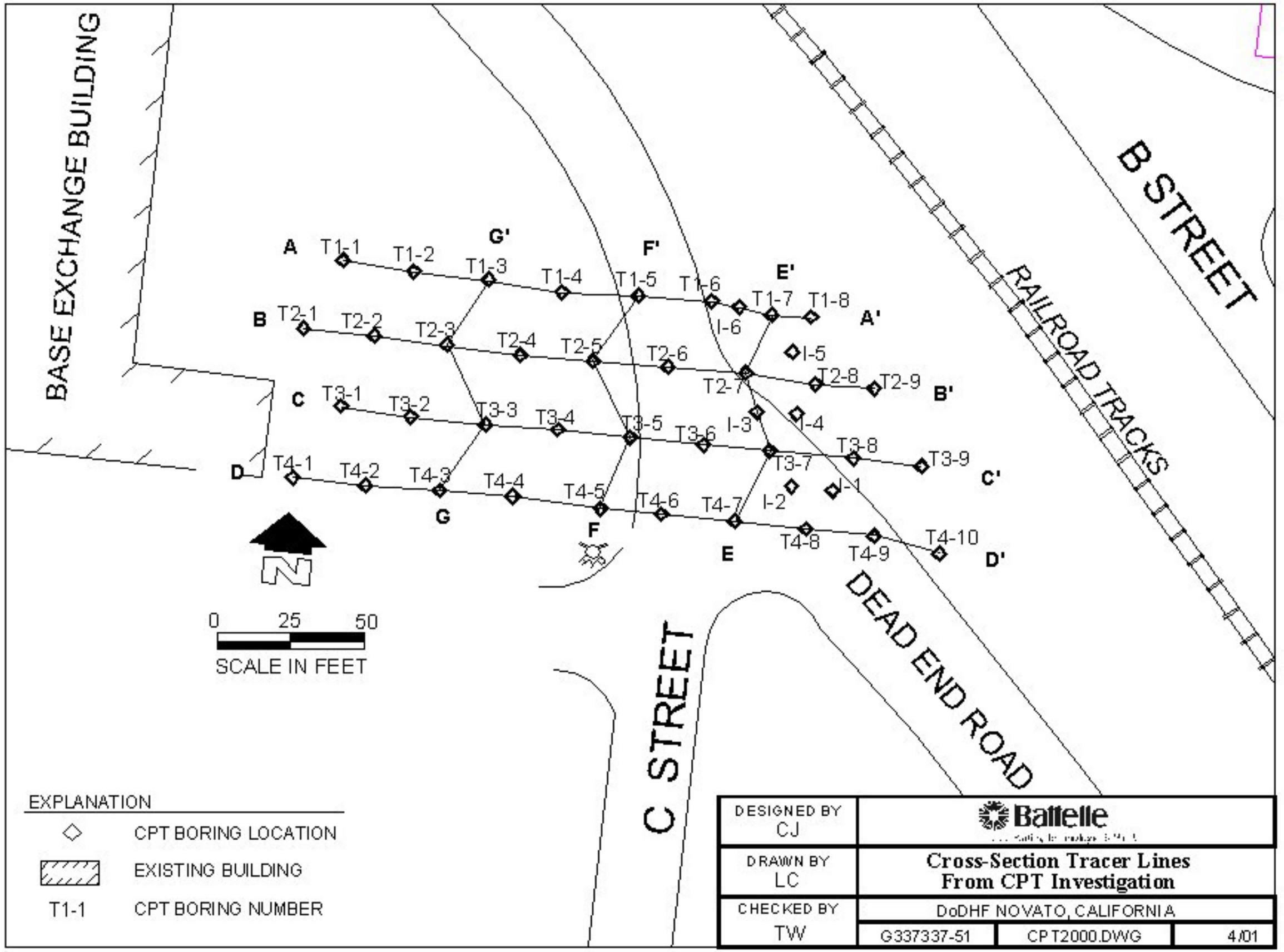
◆ CPT GROUNDWATER SAMPLING LOCATION

EXISTING BUILDING

T1 TRANSECT NUMBER

1 CPT LOCATION NUMBER

DESIGNED BY CJ	Battelle		
DRAWN BY LC	CPT Investigation Locations at Site 957/970, September, 2000		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	CPT2000.DWG	4/01


BASE EXCHANGE BUILDING
B STREET
RAILROAD TRACKS
C STREET
DEAD END ROAD
A
B
C
D
A'
B'
C'
D'
E
E'
F
F'
G
G'
T1-1
T1-2
T1-3
T1-4
T1-5
T1-6
T1-7
T1-8
T2-1
T2-2
T2-3
T2-4
T2-5
T2-6
T2-7
T2-8
T2-9
T3-1
T3-2
T3-3
T3-4
T3-5
T3-6
T3-7
T3-8
T3-9
T4-1
T4-2
T4-3
T4-4
T4-5
T4-6
T4-7
T4-8
T4-9
T4-10
I-1
I-2
I-3
I-4
I-5
I-6
N
0
25
50
SCALE IN FEET
EXPLANATION
CPT BORING LOCATION
EXISTING BUILDING
T1-1 CPT BORING NUMBER
DESIGNED BY
CJ
DRAWN BY
LC
CHECKED BY
TW
Battelle
Cross-Section Tracer Lines
From CPT Investigation
DoDHF NOVATO, CALIFORNIA
G337337-51
CPT2000.DWG
4/01

AMMO HILL

LANDFILL 26

LANHAM VILLAGE

IT-MW-81
IT-PZ-16
IT-PZ-17
IT-PZ-15
IT-MW-92-41
IT-GMP-18
MW-M12
MW-M13
IT-GMP-17
MW-M14
IT-1MW-5
IT-PZ-7
IT-GMP-16
MW-M27
IT-PZ-9
MW-M26
IT-PZ-5
IT-EW91-2
IT-GMP-15
IT-EW91-1
IT-2MW-2
IT-MW-92-38
IT-1MW-4A
IT-PZ-4
IT-MW-92-39
ITPZ-2
MW-M11
MW-M25
IT-1MW-2
IT-2MW-1
MW-M23
TW-M2
MW-M19
MW-M15
MW-M18
MW-M6
MW-M22
TW-M1
MW-M24
MW-M21
MW-M5
PZ-4
MW-M17
PZ-2
STEEL ELEC. TOWER
PZ-3
IT-PZ-1
MW-M4
MW-M20
PZ-1
MW-M1
MW-M10
MW-M9
MW-M8
MW-M7
MW-M16
MW-M3
MW-2E
MW-2D
957-MW1
MW-1E
SVE-1E
AS-2E
SVE-4D
AS-1E
MP-1D
957-MW4
AS-4D
MW-3D
AS-1D
AS-2D
SVE-1D
957-MW3
MW-1D
SVE-3D
NA-7
SVE-2D
AS-3D
NA-6
957-MW2
NA-5
NA-4
MW-6B
NA-3
NA-2
970-MW2
AS-6B
VW-2B
SVE-4B
MW-2B
MW-5B
MP-1B
SVE-2B
AS-2B
AS-3B
SVE-1B
VW-1B
AS-1B
970-MW4
MW-4B
MW-1B
AS-5B
SVE-3B
AS-4B
MW-10A
MW-4A
MW-3A
MP-2A
AS-3A
MW-2A
AS-1A
AS-2A
MP-1A
970-MW5
AS-4A
SVE-1A
AS-5A
970-MW1
MW-9A
MW-1A
MW-5A
SVE-2A
MW-7A
MW-6A
AS-6A
MW-8A
NA-1
NA-0
Location of Former UST 970-1
Location of Former UST 970-2
Location of Former UST 970-3

Approximate Area of Excavation for Former UST 957 Complex

Approximate Area of Excavation for Former UST 970 Complex

Area A
Area B
Area C
Area D
Area E

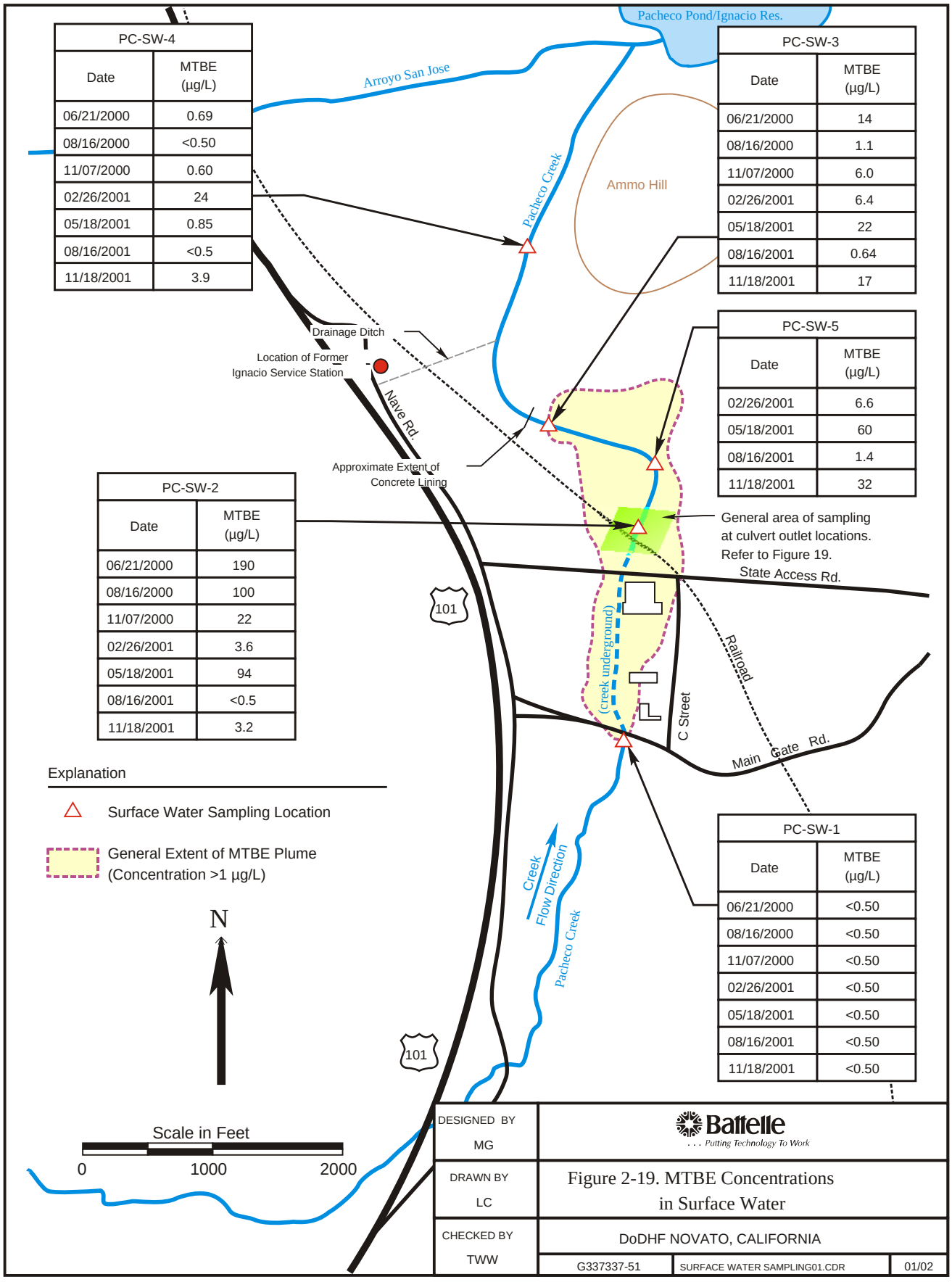
803
801
971 COMMISSARY
960
969
972
973
970
930
931
933
934
935
914
915
1000
Daycare Center
Youth Center

STATE ACCESS ROAD
MAIN ENTRANCE ROAD
B STREET
C STREET
DEAD END ROAD
RAILROAD TRACKS
PACHECO CREEK
NORTH HAMILTON PARKWAY
HIGHWAY 101
NAVE DRIVE
WOOD FENCE
CHAIN LINK FENCE
GATE
Former Waste Oil Tank

0 100 200
Scale in Feet

Explanation
- Monitoring Well
- Bedrock Monitoring Well
- Abandoned Well
- Sparge Well
- Vent Well
- SVE Well
- Soil Gas/Groundwater Monitoring Point
- Piezometer

DESIGNED BY TW	Battelle … Putting Technology To Work		
DRAWN BY LC	**Figure 2-18. Well Location Map**		
CHECKED BY JK	DoDHF NOVATO, CALIFORNIA		
	G337337-51	WELLLOC.DWG	4/01



PC-SW-4	
Date	MTBE (µg/L)
06/21/2000	0.69
08/16/2000	<0.50
11/07/2000	0.60
02/26/2001	24
05/18/2001	0.85
08/16/2001	<0.5
11/18/2001	3.9

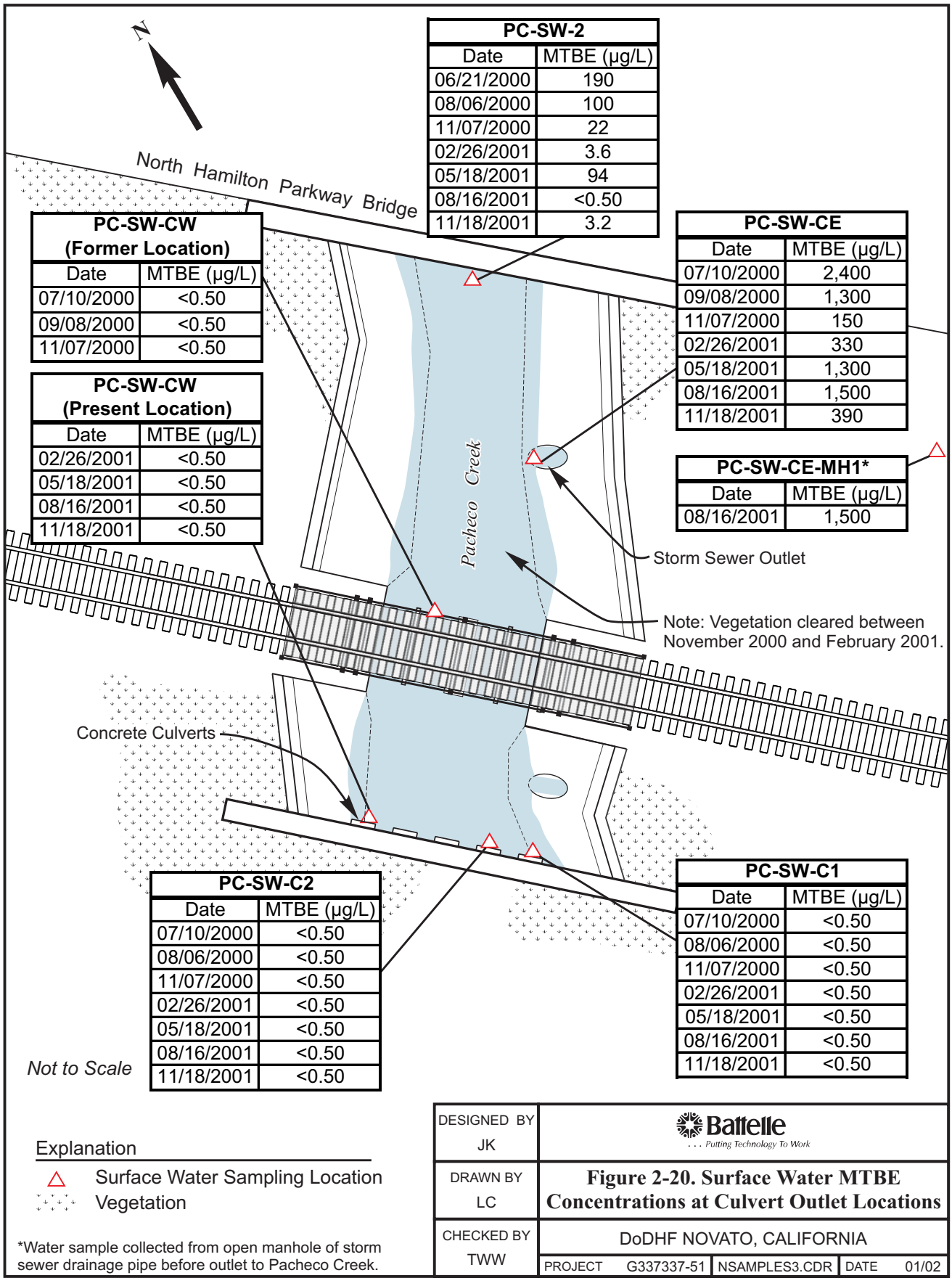
PC-SW-3	
Date	MTBE (µg/L)
06/21/2000	14
08/16/2000	1.1
11/07/2000	6.0
02/26/2001	6.4
05/18/2001	22
08/16/2001	0.64
11/18/2001	17

PC-SW-5	
Date	MTBE (µg/L)
02/26/2001	6.6
05/18/2001	60
08/16/2001	1.4
11/18/2001	32

PC-SW-2	
Date	MTBE (µg/L)
06/21/2000	190
08/16/2000	100
11/07/2000	22
02/26/2001	3.6
05/18/2001	94
08/16/2001	<0.5
11/18/2001	3.2

PC-SW-1	
Date	MTBE (µg/L)
06/21/2000	<0.50
08/16/2000	<0.50
11/07/2000	<0.50
02/26/2001	<0.50
05/18/2001	<0.50
08/16/2001	<0.50
11/18/2001	<0.50

DESIGNED BY MG	Battelle … Putting Technology To Work	
DRAWN BY LC	Figure 2-19. MTBE Concentrations in Surface Water	
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA	
	G337337-51	SURFACE WATER SAMPLING01.CDR 01/02



PC-SW-2	
Date	MTBE (µg/L)
06/21/2000	190
08/06/2000	100
11/07/2000	22
02/26/2001	3.6
05/18/2001	94
08/16/2001	<0.50
11/18/2001	3.2

PC-SW-CW (Former Location)	
Date	MTBE (µg/L)
07/10/2000	<0.50
09/08/2000	<0.50
11/07/2000	<0.50

PC-SW-CW (Present Location)	
Date	MTBE (µg/L)
02/26/2001	<0.50
05/18/2001	<0.50
08/16/2001	<0.50
11/18/2001	<0.50

PC-SW-CE	
Date	MTBE (µg/L)
07/10/2000	2,400
09/08/2000	1,300
11/07/2000	150
02/26/2001	330
05/18/2001	1,300
08/16/2001	1,500
11/18/2001	390

PC-SW-CE-MH1*	
Date	MTBE (µg/L)
08/16/2001	1,500

PC-SW-C2	
Date	MTBE (µg/L)
07/10/2000	<0.50
08/06/2000	<0.50
11/07/2000	<0.50
02/26/2001	<0.50
05/18/2001	<0.50
08/16/2001	<0.50
11/18/2001	<0.50

PC-SW-C1	
Date	MTBE (µg/L)
07/10/2000	<0.50
08/06/2000	<0.50
11/07/2000	<0.50
02/26/2001	<0.50
05/18/2001	<0.50
08/16/2001	<0.50
11/18/2001	<0.50

Explanation

△ Surface Water Sampling Location

Vegetation

*Water sample collected from open manhole of storm sewer drainage pipe before outlet to Pacheco Creek.

DESIGNED BY JK	Battelle … Putting Technology To Work
DRAWN BY LC	**Figure 2-20. Surface Water MTBE Concentrations at Culvert Outlet Locations**
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
PROJECT G337337-51	NSAMPLES3.CDR DATE 01/02

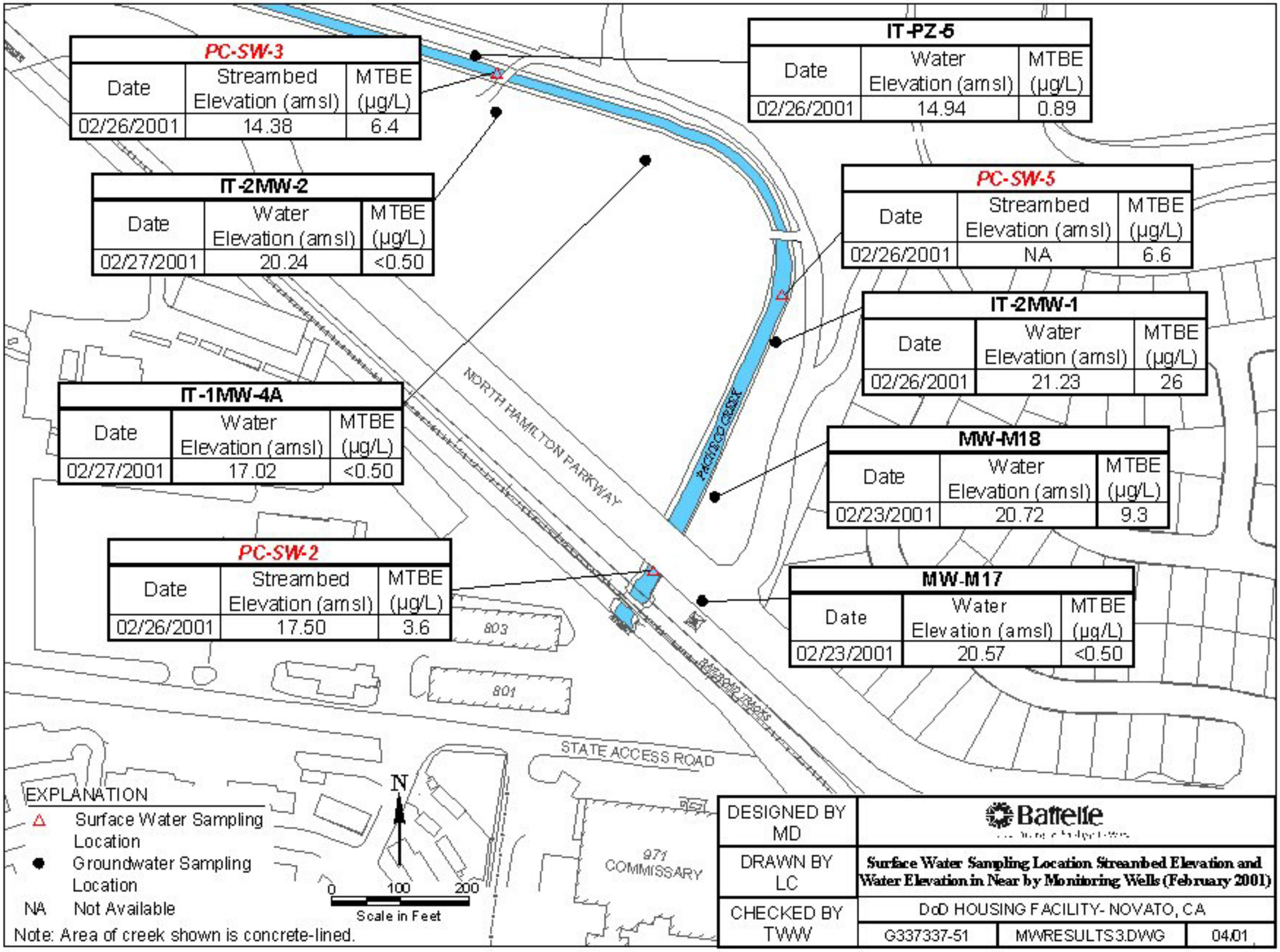

PC-SW-3
Date | Streambed Elevation (amsl) | MTBE (µg/L)
02/26/2001 | 14.38 | 6.4
IT-2MW-2
Date | Water Elevation (amsl) | MTBE (µg/L)
02/27/2001 | 20.24 | <0.50
IT-1MW-4A
Date | Water Elevation (amsl) | MTBE (µg/L)
02/27/2001 | 17.02 | <0.50
PC-SW-2
Date | Streambed Elevation (amsl) | MTBE (µg/L)
02/26/2001 | 17.50 | 3.6
IT-PZ-5
Date | Water Elevation (amsl) | MTBE (µg/L)
02/26/2001 | 14.94 | 0.89
PC-SW-5
Date | Streambed Elevation (amsl) | MTBE (µg/L)
02/26/2001 | NA | 6.6
IT-2MW-1
Date | Water Elevation (amsl) | MTBE (µg/L)
02/26/2001 | 21.23 | 26
MW-M18
Date | Water Elevation (amsl) | MTBE (µg/L)
02/23/2001 | 20.72 | 9.3
MW-M17
Date | Water Elevation (amsl) | MTBE (µg/L)
02/23/2001 | 20.57 | <0.50
NORTH HAMILTON PARKWAY
PACHECO CREEK
803
801
STATE ACCESS ROAD
971
COMMISSARY
EXPLANATION
Surface Water Sampling Location
Groundwater Sampling Location
NA Not Available
N
0 100 200
Scale in Feet
Note: Area of creek shown is concrete-lined.
DESIGNED BY MD
DRAWN BY LC
CHECKED BY TWW
Battelle
Surface Water Sampling Location Streambed Elevation and Water Elevation in Near by Monitoring Wells (February 2001)
DoD HOUSING FACILITY- NOVATO, CA
G337337-51
MWRESULTS3.DWG
04/01

Table 2-1. Analytical Results From UST 957 Removal Activities in 1992

Compound	Sample Type	UST Contents (mg/L)	Excavation Groundwater (mg/L)	Excavation Sidewall (mg/kg)		Piping Trench Bottom (mg/kg)					
	Sample ID	957-TC	957-GW-10	957-NW-10	957-SW-10	957-PP1-02	957-PP2-04	957-PP3-04	957-PP4-04	957-PP5-04	957-PP6-04
Benzene		36.0	2.5	0.36	0.14	ND	0.49 J	1.5 J	ND	ND	ND
Toluene		260.0	1.8	0.56	0.29	ND	0.56 J	12.0 J	18.0 J	ND	0.022 J
Ethylbenzene		140.0	1.2	1.0	0.73	ND	1.0 J	5.2 J	34.0 J	0.045 J	0.077 J
Total Xylenes		830.0	4.4	3.8	2.8	ND	6.0	28.0	60.0	0.39	0.53
TPH-gas											
as Gasoline		8,300.0	60.0	ND	ND	ND	ND	630	1,200	ND	ND
as Unknown Hydrocarbon		ND	ND	150	220	ND	220	ND	ND	11.0	32.0
Organic Lead		2.1 J	NA	ND	ND	ND	ND	ND	ND	ND	ND

J = Value is estimated.
NA = Not analyzed.
ND = Not detected.
Source: PRC Environmental Management, Inc., 1992a.

Table 2-2. Analytical Results from Groundwater and Tank Content Samples Collected During UST 970-3 Removal Activities in 1995

Compounds	Units	Tank Contents	Groundwater	
		11/15/1994	01/09/1995	02/07/1995
Benzene	µg/L	26,000	1,900	640
Toluene	µg/L	46,000	4,800	1,300
Ethylbenzene	µg/L	3,200	490	<50
Xylenes	µg/L	22,000	6,200	2,600
TPH-G	mg/L	240	45	21
TPH as Motor oil	mg/L	<200,000	1.1	ND(10)
TPH as Diesel	mg/L	300,000	0.64	20
TPH as Jet Fuel	mg/L	260,000	NA	18

Source: Navy Public Works Center, 1996a

Table 2-3. Analytical Results from Soil Samples Collected During UST 970-3 Removal Activities in 1995

Compounds	Units	TANK EXCAVATION				
		E	F	North	South	West
		01/09/95	01/09/95	02/23/95	02/23/95	02/23/95
Benzene	µg/L	24	150	21	1,200	170
Toluene	µg/L	74	130	<5.0	70	14
Ethylbenzene	µg/L	49	160	<5.0	550	41
Xylenes	µg/L	270	1,700	<5.0	2,600	180
TPH-G	mg/L	5.2/1.1[(1)]	18	<1.0	13	3

Compounds	Units	PIPING AND NORTH EXCAVATION					
		TS 00 + 20 3'	TS 00 + 403	Bottom 5' TP	North Wall	West Wall	East Wall
		03/27/95	03/27/95	03/27/95	03/27/95	03/27/95	03/27/95
Benzene	µg/L	<5.0	<5.0	<50	21	<5.0	<500
Toluene	µg/L	<5.0	<5.0	<50	<5.0	<5.0	730
Ethylbenzene	µg/L	<5.0	<5.0	740	<5.0	16	5,200
Xylenes	µg/L	<5.0	<5.0	2,600	<5.0	52	11,000
TPH-G	mg/L	<1.0	<1.0	39	<1.0	<1.0	520

Notes:
(1) Two samples analyzed.
Source: Navy Public Works Center, 1996a

Table 2-4. Analytical Results from Soil, Groundwater, and Tank Content Samples Collected During Tank 970-Waste Oil Removal Activities in 1995

Compound	Tank Contents (µg/L)	Groundwater (µg/L)	Soil – Excavation and Piping (mg/kg)					
	Oil Tank 11/15/94	C 01/09/05	WO-1 01/03/95	A 01/09/95	B 01/09/95	North 02/06/95	South 02/06/95	Bottom 02/06/95
Benzene	<0.25		<0.005	<0.005	<0.005	<0.005	<.005	<0.005
Toluene	<0.25		0.017	0.032	0.046	<0.005	<.005	0.081
Ethylbenzene	<0.25		0.047	0.017	0.030	<0.005	<.005	0.054
Xylenes	<0.25		0.29	0.14	0.19	<0.005	<.005	0.18
Lead	<.010							
Chlorinated Hydrocarbons[(a)]	EPA 8240 ND							
TPH purgeables as Gasoline	<50		7.8	2.4	3.2	<1.0	<1.0	<1.0
TPH extractables								
as Motor Oil	28,000	1,100	6,500			<10	<10	<10
as Diesel	29,000	640	1,700	<1.0	2.5	<1.0	<1.0	2.0
as Jet Fuel	<800		<250	9.3	13	<1.0	<1.0	<1.0

(a) ND indicates non-detect for all compounds tested.
Source: Navy Public Works Center, 1996a

Table 2-5. Analytical Results from Soil and Groundwater Samples Collected During UST 970-1 and UST 970-2 Removal Activities

Soil Analytical Results						
Sample ID	**TPH-G (mg/kg)**	**Benzene (µg/kg)**	**Toluene (µg/kg)**	**Ethylbenzene (µg/kg)**	**Xylene (µg/kg)**	**MTBE (µg/kg)**
Northeast	4,600	61,000	340,000	67,000	690,000	310,000
Southeast	3,600	34,000	94,000	63,000	330,000	130,000
Northwest	1,200	8,800	45,000	13,000	120,000	110,000
Southwest	3,400	23,000	110,000	46,000	400,000	36,000
East Sidewall	6,800	32,000	180,000	52,000	720,000	33,000
Groundwater Analytical Results						
Sample ID	**TPH-G (mg/L)**	**Benzene (µg/L)**	**Toluene (µg/L)**	**Ethylbenzene (µg/L)**	**Xylene (µg/L)**	**MTBE (µg/L)**
NEX-GW	<50	1,10	510	<500	3,500	170,000

Source: Navy Public Works Center, 1996b

Table 2-6. Analytical Results from Soil Samples Collected from Pump Island During UST 970-1 and UST 970-2 Removal Activities

Sample ID	**TPH-G (mg/kg)**	**MTBE (µg/kg)**	**Benzene (µg/kg)**	**Toluene (µg/kg)**	**Ethylbenzene (µg/kg)**	**Xylenes (µg/kg)**
1A	<1.0	<25	<5.0	<5.0	<5.0	13
1B	24	410	<50	<50	<50	110
1C	2000	<7,500	<1,500	8,400	16,000	110,000
2A	46	22,000	170	2,200	840	7,200
2B	1.1	3,800	<5.0	6.4	<5.0	17
2C	<1.0	25	<5.0	<5.0	<5.0	<5.0
3A	2800	<25,000	<5,000	36,000	33,000	310,000
3B	18	<50	<10	<10	<10	33
3C	<1.0	<25	<5.0	<5.0	<5.0	<5.0

Source: Navy Public Works Center, 1996b.

Table 2-7. Hydraulic Lift Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs)

Sample Description	Sample Depth (feet)	Date Sampled	TPH-G (ppm)	TPH-O (ppm)	TPH-D (ppm)	TOG (ppm)	Benzene (ppm)	Toluene (ppm)	Ethyl-benzene (ppm)	Xylenes (ppm)	MTBE EPA 8020 (ppm)	SVOCs EPA 8270[c] (ppm)	PCBs EPA 8082 (ppm)	VOCs EPA 8010 (ppm)
Hydraulic Lift Removal														
H-N-10	10	04/19/00	**32**	**780**	NA	NA	<0.0125	<0.0125	**0.016**	**0.19**	<0.125	NA	NA	NA
H-N-N5	5	04/19/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	**0.024**	<0.05	NA	NA	NA
H-N-S5	5	04/19/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
H-N-E5	5	04/19/00	<1	**150**	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
H-N-W5	5	04/19/00	<1	<13	NA	NA	**0.006**	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
H-Mid-10	10	04/19/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
H-S-10	10	04/19/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
H-4-10	10	04/25/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
Hydraulic Lift Control Line Removal														
CL-N-2	2	04/18/00	<1	**470**	NA	NA	<0.005	<0.005	**0.011**	**0.010**	<0.05	NA	NA	NA
CL-S-2	2	04/25/00	<1	<13	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
CL-Mid-2	2	04/25/00	<1	**180[a]**	NA	NA	<0.005	<0.005	<0.005	<0.005	<0.05	NA	NA	NA
Drum-1-3.5	3.5	04/25/00	<1	**2,700[a]**	**1,500[a]**	**1,100**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[b]
Drum-1-5	5	05/02/00	NA	**66**	**55 [a]**	**170**	NA	NA	NA	NA	NA	NA	NA	NA

TPH-G = gasoline range total petroleum hydrocarbons.
TPH-D = diesel range total petroleum hydrocarbons.
TPH-O = hydraulic oil range total petroleum hydrocarbons.
TOG = total oil and grease.
MTBE = methyl-*tert*-butyl ether.
SVOCs = semivolatile organic compounds.
VOCs = volatile organic compounds.
PCBs = polychlorinated biphenyls.
ppm = parts per million.
8020 = analysis performed according to U.S. EPA Method 8020.
8270 = analysis performed according to U.S. EPA Method 8270A or C.
8010 = analysis performed according to U.S. EPA Method 8010B.
8082 = analysis performed according to U.S. EPA Method 8082.

NA = not analyzed.
ND = all compounds not detected.
< = concentrations not detected at or above the detection limit shown.
(a) laboratory noted that while the results were within the quantitation range; the chromatographic pattern was not typical of fuel.
(b) U.S. EPA Method 8260B analysis performed for VOCs.
(c) The maximum SVOC detection limit is 85 ppm and associated with 2,4-dichlorophenol, benzoic acid, 2-nitroaniline, 3-nitroaniline, 2,4-dinitrophenol, 4-nitrophenol, 4-nitroaniline, 4,6-dinitro-2-methylphenol, and pentachlorophenol.
= sample removed via overexcavation activities.

Table 2-8. Hydraulic Lift Soil Analytical Data (Metals)

Sample Description	Sample Depth (feet)	Date Sampled	Cadmium (ppm)	Total Chromium (ppm)	Total Lead (ppm)	Nickel (ppm)	Zinc (ppm)
Hydraulic Lift Removal							
H-N-10	10	04/19/00	<5	**18**	**89**	**23**	**36**
H-N-N5	5	04/19/00	<5	**23**	<5	**25**	**31**
H-N-S5	5	04/19/00	<5	**11**	<5	**12**	**29**
H-N-E5	5	04/19/00	<5	**9.9**	<5	**9.6**	**25**
H-N-W5	5	04/19/00	<5	**22**	<5	**29**	**30**
H-Mid-10	10	04/19/00	<5	**17**	<5	**24**	**26**
H-S-10	10	04/19/00	<5	**16**	**5.6**	**21**	**20**
H-4-10	10	04/25/00	<5	**26**	**7.5**	**24**	**25**
Hydraulic Lift Control Line Removal							
CL-N-2	2	04/19/00	<5	**11**	**11**	**18**	**49**
CL-Mid-2	2	04/25/00	<5	**12**	**19**	**17**	**40**
CL-S-2	2	04/25/00	<5	**9.7**	**7.8**	**9.6**	**29**
Drum-1-3.5[(a)]	3.5	04/25/00	<5	**13**	**600**	**5.7**	**33**
Drum-1-5[(a)]	5	05/02/00	NA	NA	**95**	NA	NA
Residential PRG - Soil (ppm)			**9**	**210**	**400**	**1,500**	**23,000**
TTLC - Soil (ppm)			**100**	**2,500**	**1,000**	**2,000**	**5,000**

ppm = parts per million.
< = compound not detected at or above detection limit shown.
NA = not analyzed.
PRG = preliminary remediation goals (U.S. EPA, 2000d).
TTLC = total threshold limit concentration; Title 22 California Code of Regulations.
= sample location removed as a result of overexcavation activities.
(a) H-4 control line sample.

Table 2-9. Oil/Water Separator Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs)

Sample Description	Sample Depth (feet)	Date Sampled	TPH-G (ppm)	TPH-O (ppm)	TPH-D (ppm)	TOG (ppm)	Benzene (ppm)	Toluene (ppm)	Ethyl-benzene (ppm)	Xylenes (ppm)	MTBE EPA 8020 (ppm)	SVOCs EPA 8270[g] (ppm)	PCBs EPA 8082 (ppm)	VOCs EPA 8010 (ppm)
Oil/Water Separator 1 Removal														
OS-N-9	9	04/19/00	<1	NA	**2.8**[a]	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND[e]	ND	ND
OS-S-9	9	04/19/00	<1	NA	**5.3**[a]	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND[e]	ND	ND
OS-E-3	3	04/19/00	**1,300**	NA	**660**[a]	**940**	<0.25	<0.25	**0.68**	**4.2**	<2.5	ND[e]	ND	ND
Oil/Water Separator 1 Overexcavation														
OS-OX-E3.5	3.5	04/25/00	<1	NA	**50**[a]	**150**	<0.005	<0.005	<0.005	<0.005	<0.05	ND[e]	ND	ND[f]
Floor Drain Line Removal (Oil/Water Separator 1 Influent Line)														
DL-1-5.5	5.5	04/18/00	**1.4**	NA	**1.8**[a]	<25	<0.005	<0.005	**0.015**	**0.18**	<0.05	ND	NA	ND
DL-2-3.5	3.5	04/18/00	<1	NA	<1	**120**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
DL-3-3.5	3.5	04/18/00	<1	NA	<1	**35**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
DL-4-3.5	3.5	04/18/00	<1	NA	<1	**260**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
DL-5-3	3	04/18/00	<1	NA	<1	**70**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Oil/Water Separator 2 Removal														
OS2-N-3.5	3.5	04/25/00	**140**	NA	**3,300**[a]	**2,300**	<0.1	**0.12**	**0.33**	**3.3**	<1	[b],[e]	ND	ND
OS2-W-3.5	3.5	04/25/00	**110**	NA	**3,700**[a]	**6,300**	**0.017**	**0.036**	**0.24**	**0.90**	<0.125	[c],[e]	ND	ND
OS2-S-3.5	3.5	04/25/00	<1	NA	**6.7**[a]	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND[e]	ND	ND
OS2-E-3.5	3.5	04/25/00	<1	NA	**390**[a]	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND[e]	ND	ND
OS2-B-E5.5	5.5	04/25/00										ND		
OS2-B-W5.5	5.5	04/25/00										ND		
Oil Water Separator 2 Overexcavation														
OS2-E-6	6	04/27/00	**5.1**	NA	**100**[a]	**25**	<0.0125	**0.026**	**0.017**	**0.100**	<0.125	ND[e]	ND	ND
OS2-W-6	6	04/27/00	**1.9**	NA	**460**[a]	<25	<0.005	<0.005	**0.013**	**0.061**	<0.05	ND[e]	ND	ND
55-Gallon Drum Removal (Oil/Water Separator 2 Influent Line)														
Drum-1-3.5	3.5	04/25/00	<1	**2,700**[a]	**1,500**[a]	**1,100**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[f]
Drum-2-3.5	3.5	05/01/00	**300**	NA	**10,000**[a]	**11,000**	**0.077**	**0.86**	**1.5**	**12**	<0.5	ND	NA	ND
Drum-3-3.5	3.5	05/01/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Drum-4-3.5	3.5	04/25/00	<1	NA	**4.0**[a]	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[f]

Table 2-9. Oil/Water Separator Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs) (Continued)

Sample Description	Sample Depth (feet)	Date Sampled	TPH-G (ppm)	TPH-O (ppm)	TPH-D (ppm)	TOG (ppm)	Benzene (ppm)	Toluene (ppm)	Ethyl-benzene (ppm)	Xylenes (ppm)	MTBE EPA 8020 (ppm)	SVOCs EPA 8270[g] (ppm)	PCBs EPA 8082 (ppm)	VOCs EPA 8010 (ppm)
55-Gallon Drum Overexcavation (Oil/Water Separator 2 Influent Line)														
Drum-1-5	5	05/02/00	NA	**66**	**55[a]**	**170**	NA	NA	NA	NA	NA	NA	NA	NA
Drum2-OX-5.5	5.5	05/11/00	**43**	NA	**950[a]**	**4,300**	<0.0125	<0.0125	**0.064**	**1.0**	<0.125	ND	NA	ND
Drum-1-OX-S3	3	05/11/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Drum-1-OX-NE3	3	05/11/00	**18[a]**	NA	**2,300[a]**	**3,200**	<0.0125	<0.0125	<0.0125	**0.025**	<0.125	ND	NA	ND
Drum2-OX-E3	3	05/11/00	**82**	NA	**920[a]**	**2,200**	<0.05	**0.052**	**0.79**	**0.21**	<0.5	ND	NA	ND
Influent Line to Oil/Water Separator 2														
INF-1-2	2	04/25/00	<1	NA	**130[a]**	**760**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[f]
INF-2-2	2	04/25/00	<1	NA	**790[a]**	**800**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[f]
INF-3-2	2	05/01/00	<1	NA	**2,400[a]**	**1,800**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
INF-4-2	2	05/01/00	<1	NA	**790[a]**	**510**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
INF-5-2	2	05/01/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Effluent Line from Oil/ Water Separator 2														
EFF-1-5	5	04/28/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-2-5	5	04/28/00	<1	NA	<1	**30**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-2-E3	3	05/01/00	**260**	NA	**8,000[a]**	**1,900**	<0.05	**0.074**	**0.24**	**3.8**	<0.5	ND	NA	ND
EFF-2-W3	3	05/01/00	<1	NA	<1	**25**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-3-6	6	05/01/00	<1	NA	**130[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-4-E3	3	05/01/00	**160**	NA	**400[a]**	**1,100**	**0.074**	**0.054**	**0.57**	**2.4**	<0.25	ND	NA	ND
EFF-4-W3	3	05/01/00	<1	NA	**2.6[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-4-6	6	05/01/00	<1	NA	**9.1[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-5-6	6	05/02/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-6-3E	3	06/21/00	**4.4[a]**	NA	**3,300[a]**	**2,900**	<0.0125	<0.0125	<0.0125	**0.032**	<0.125	ND	NA	ND
EFF-6-6	6	06/21/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-6-3W	3	06/21/00	<1	NA	**4,000[a]**	**2,300**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Exploratory Trench – Northern														
ET-B-5	5	04/27/00	<1	NA	**1.1[a]**	<25	**0.020**	<0.005	<0.005	<0.005	**0.061**	ND	NA	ND
ET-S-3	3	04/27/00	<1	NA	**2.7[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND

Table 2-9. Oil/Water Separator Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs) (Continued)

Sample Description	Sample Depth (feet)	Date Sampled	TPH-G (ppm)	TPH-O (ppm)	TPH-D (ppm)	TOG (ppm)	Benzene (ppm)	Toluene (ppm)	Ethyl-benzene (ppm)	Xylenes (ppm)	MTBE EPA 8020 (ppm)	SVOCs EPA 8270[g] (ppm)	PCBs EPA 8082 (ppm)	VOCs EPA 8010 (ppm)
Exploratory Trench - Effluent Trench Extension														
EFF-NE-3	3	05/04/00	**14**	NA	**1,800[a]**	**1,500**	<0.025	<0.025	**0.091**	**0.68**	<0.25	**(d)**	NA	ND
EFF-N-3	3	06/21/00	<1	NA	**56**	**85**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
EFF-N-6	6	06/21/00	<1	NA	<1	**30**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Test Pit Excavations														
TP-1-3	3	05/04/00	<1	NA	**2.7[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
TP-1-5	5	05/04/00	**7.3**	NA	**3.0[a]**	<25	**0.05**	**0.034**	**0.027**	**0.17**	**0.14**	ND	NA	ND
TP-2-3	3	05/04/00	<1	NA	**7.6[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
TP-2-5	5	05/04/00	<1	NA	<1	<25	**0.008**	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
Sewer Excavation														
SEW-1-5	5	05/02/00	<1	NA	**1.2[a]**	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
SEW-2-5	5	05/02/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND
SEW-3-5	5	05/02/00	<1	NA	<1	<25	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND

TPH-G = gasoline range total petroleum hydrocarbons.
TPH-D = diesel range total petroleum hydrocarbons.
TPH-O = hydraulic oil range total petroleum hydrocarbons.
TOG = total oil and grease.
MTBE = methyl tertiary butyl ether.
SVOCs = semivolatile organic compounds.
VOCs = volatile organic compounds.
PCBs = polychlorinated biphenyls.
ppm = parts per million.
8020 = analysis performed according to U.S. EPA Method 8020.
8270 = analysis performed according to U.S. EPA Method 8270A or C.
8010 = analysis performed according to U.S. EPA Method 8010B.
8082 = analysis performed according to U.S. EPA Method 8082.

NA = not analyzed.
ND = all compounds not detected.
< = concentrations not detected at or above the detection limit shown.
(a) laboratory noted that while the results were within the quantitation range; the chromatographic pattern was not typical of fuel.
(b) napthalene, 2-methylnaphthalene, phenanthrene and pyrene were detected at 1.6, 2.9, 0.64 and 0.54 ppm, respectively.
(c) napthalene, phenanthrene, fluoranthene and pyrene were detected at 0.93, 0.19, 0.14 and 0.20 ppm, respectively.
(d) napthalene detected at 1.47 ppm.
(e) analysis for creosote resulted in ND.
(f) U.S. EPA Method 8260B analysis performed for VOCs.
(g) The maximum SVOC detection limit is 170 ppm and associated with 2,4-dichlorophenol, benzoic acid, 2-nitroaniline, 3-nitroaniline, 2,4-dinitrophenol, 4-nitrophenol, 4-nitroaniline, 4,6-dinitro-2-methylphenol, and pentachlorophenol.
= sample location removed as a result of overexcavation activities.

Table 2-10. Oil/Water Separator Soil Analytical Data (Metals)

Sample Description	Sample Depth (feet)	Date Sampled	Cadmium (ppm)	Total Chromium (ppm)	Total Lead (ppm)	Nickel (ppm)	Zinc (ppm)
Oil/Water Separator 1 Removal							
OS-N-9	9	04/19/00	<5	**21**	<5	**36**	**33**
OS-S-9	9	04/19/00	<5	**15**	**24**	**19**	**33**
OS-E-3	3	04/19/00	<5	**7.9**	**5.7**	**10**	**32**
Oil/Water Separator 1 Overexcavation							
OS-OX-E3.5	3.5	04/25/00	<5	**10**	**11**	**13**	**27**
Floor Drain Line Removal (Oil/Water Separator 1 Influent Line)							
DL-1-5.5	5.5	04/19/00	<5	**20**	**8.9**	**24**	**38**
DL-2-3.5	3.5	04/18/00	<5	**9.2**	**12**	**10**	**39**
DL-3-3.5	3.5	04/18/00	<5	**9.4**	**14**	**13**	**93**
DL-4-3.5	3.5	04/18/00	<5	**11**	**14**	**18**	**110**
DL-5-3	3	04/18/00	<5	**10**	**13**	**14**	**49**
Oil/Water Separator 2 Removal							
OS2-N-3.5	3.5	04/25/00	<5	**13**	**460**	**14**	**61**
OS2-W-3.5	3.5	04/25/00	<5	**10**	**27**	**12**	**28**
OS2-S-3.5	3.5	04/25/00	<5	**6.6**	**10**	**20**	**24**
OS2-E-3.5	3.5	04/25/00	<5	**10**	**9.7**	**13**	**31**
Oil/Water Separator 2 Overexcavation							
OS2-E-6	6	04/27/00	<5	**15**	**13**	**17**	**40**
OS2-W-6	6	04/27/00	<5	**19**	**9.1**	**22**	**30**
55-Gallon Drum Removal (Oil/Water Separator 2 Influent Line)							
Drum-1-3.5	3.5	04/25/00	<5	**13**	**600**	**5.7**	**33**
Drum-2-3.5	3.5	05/01/00	<5	**9.8**	**48**	**13**	**29**
Drum-3-3.5	3.5	05/01/00	<5	**9.2**	**6.1**	**11**	**28**
Drum-4-3.5	3.5	04/25/00	<5	**8.5**	**13**	**12**	**30**
55-Gallon Drum Overexcavation (Oil/Water Separator 2 Influent Line)							
Drum-1-5	5	05/02/00	NA	NA	**95**	NA	NA
Drum2-OX-5.5	5.5	05/11/00	<5	**300**	**530**	**380**	**72**
Drum1-OX-S3	3	05/11/00	<5	**9.6**	**5.9**	**12**	**27**
Drum1-OX-NE3	3	05/11/00	<5	**400**	<5	**580**	**39**
Drum1-OX-S3	3	05/11/00	<5	**9.6**	**5.9**	**12**	**27**
Drum2-OX-E3	3	05/11/00	<5	**11**	**280**	**11**	**40**
Influent Line to Oil/Water Separator 2							
INF-1-2	2	04/25/00	<5	**57**	**120**	**31**	**50**
INF-2-2	2	04/25/00	<5	**9.0**	**460**	**13**	**42**
INF-2-4	4	05/03/00	NA	NA	**6.9**	NA	NA
INF-3-2	2	05/01/00	<5	**10**	**220**	**8.1**	**26**
INF-4-2	2	05/01/00	<5	**9.8**	**43**	**13**	**36**
INF-5-2	2	05/01/00	<5	**12**	**5.3**	**17**	**36**

Table 2-10. Oil/Water Separator Soil Analytical Data (Metals) (Continued)

Sample Description	Sample Depth (feet)	Date Sampled	Cadmium (ppm)	Total Chromium (ppm)	Total Lead (ppm)	Nickel (ppm)	Zinc (ppm)
Effluent Line from Oil/Water Separator 2							
EFF-1-5	5	04/28/00	<5	**10**	**11**	**8.0**	**32**
EFF-2-5	5	04/28/00	<5	**20**	**9.3**	**21**	**30**
EFF-2-E3	3	05/01/00	<5	**13**	**390**	**14**	**53**
EFF-2-W3	3	05/01/00	<5	**9.6**	**7.2**	**15**	**34**
EFF-3-6	6	05/01/00	<5	**20**	**7.4**	**24**	**33**
EFF-4-E3	3	05/01/00	<5	**7.9**	**850**	**10**	**140**
EFF-4-W3	3	05/01/00	<5	**9.6**	**6.7**	**10**	**20**
EFF-4-6	6	05/01/00	<5	**21**	<5	**19**	**27**
EFF-5-6	6	05/02/00	<5	**18**	<5	**22**	**26**
EFF-6-3E	3	06/21/00	<5	**9.2**	**200**	**13**	**37**
EFF-6-6	6	06/21/00	<5	**24**	<5	**22**	**27**
EFF-6-3W	3	06/21/00	<5	**11**	**670**	**14**	**44**
Exploratory Trench - Northern							
ET-B-5	5	04/27/00	<5	**11**	**8.3**	**14**	**33**
ET-S-3	3	04/27/00	<5	**9.9**	**9.0**	**13**	**34**
Exploratory Trench - Northern							
EFF-NE-3	3	05/04/00	<5	**13**	**35**	**16**	**29**
EFF-N-3	3	06/21/00	<5	**12**	<5	**15**	**28**
EFF-N-6	6	06/21/00	<5	**19**	<5	**20**	**26**
Test Pit Excavations							
TP-1-3	3	05/04/00	<5	**14**	**19**	**16**	**31**
TP-1-5	5	05/04/00	<5	**21**	**19**	**25**	**42**
TP-2-3	3	05/04/00	<5	**12**	**14**	**14**	**32**
TP-2-5	5	05/04/00	<5	**23**	**15**	**27**	**50**
Sewer Excavation							
SEW-1-5	5	05/02/00	<5	**9.7**	**6.0**	**13**	**26**
SEW-2-5	5	05/02/00	<5	**23**	<5	**23**	**33**
SEW-3-5	5	05/02/00	<5	**20**	<5	**25**	**41**
Residential PRG - Soil (ppm)			**9**	**210**	**400**	**1,500**	**23,000**
TTLC - Soil (ppm)			**100**	**2,500**	**1,000**	**2,000**	**5,000**

ppm = parts per million.
< = compound not detected at or above detection limit shown.
NA = not analyzed.
PRG = preliminary remediation goals (U.S. EPA, 2000d).
TTLC = total threshold limit concentration; Title 22 California Code of Regulations.

Table 2-11. OWS2 Product Analytical Data (Petroleum Hydrocarbons)

Sample Description	Date Sampled	Benzene (ppm)	Toluene (ppm)	Ethyl-Benzene (ppm)	Xylenes (ppm)	MTBE (ppm)	TRPH (ppm)	TPH Aviation Gas (ppm)	TPH Gasoline (ppm)	TPH Mineral Spirits (ppm)	TPH Bunker Oil (ppm)	TPH Diesel (ppm)	TPH Fuel Oil (ppm)	TPH Hydraulic Oil (ppm)	TPH Jet A Fuel (ppm)	TPH Kerosene (ppm)	TPH Motor Oil (ppm)	TPH Stoddard Solvent (ppm)
Prod	04/27/00	**56**	**120**	**520**	**3,000**	<485	**140,000**	<4,850	**130,000**	<4,850	<52,000	<4,000	<52,000	<52,000	<4,000	<4,000	**170,000**	<4,000

TRPH = total recoverable petroleum hydrocarbons.
TPH = total petroleum hydrocarbons.
MTBE = methyl-*tert*-butyl ether.
ppm = parts per million.
< = compound not detected at or above detection limit shown.
Prod = product recovered from oil/water separator 2 excavation area, grab sample from sidewall seep.

Table 2-12. OWS2 Water Analytical Data (Petroleum Hydrocarbons, SVOCs and VOCs)

Sample Description	Date Sampled	TPH-G (ppb)	TPH-D (ppb)	TOG (ppb)	Benzene (ppb)	Toluene (ppb)	Ethyl-benzene (ppb)	Xylenes (ppb)	MTBE EPA 8020 (ppb)	SVOCs EPA 8270C[(b)] (ppb)	VOCs EPA 8010B (ppb)
OS2	05/09/00	<50	**730** [(a)]	**34,000**	<0.5	<0.5	<0.5	<0.5	<5	ND	ND

TPH-G = gasoline range total petroleum hydrocarbons.
TPH-D = diesel range total petroleum hydrocarbons.
TOG = total oil and grease.
MTBE = methyl-*tert*-butyl ether.
SVOCs = semivolatile organic compounds.
VOCs = volatile organic compounds.
ppb = parts per billion.
8020 = analysis performed according to U.S. EPA Method 8020.
8270C = analysis performed according to U.S. EPA Method 8270C.
8010B = analysis performed according to U.S. EPA Method 8010B.
ND = all compounds not detected.
< = concentrations not detected at or above the detection limit shown.
(a) laboratory noted that while the results were within the quantitation range; the chromatographic pattern was not typical of fuel.
(b) The maximum SVOC detection limit is 250 ppb and associated with benzoic acid.

Table 2-13. OWS2 Water Analytical Data (Metals)

Sample Description	Date Sampled	Cadmium (ppm)	Total Chromium (ppm)	Total Lead (ppm)	Nickel (ppm)	Zinc (ppm)
OS2	05/09/00	<0.005	<0.005	**0.48**	**0.015**	**0.048**

ppm = parts per million.
< = compound not detected at or above detection limit shown.

Table 2-14. Waste Oil Line Soil Analytical Data (Petroleum Hydrocarbons, SVOCs, PCBs, and VOCs)

Sample Description	Sample Depth (feet)	Date Sampled	TPH-G (ppm)	TPH-O (ppm)	TPH-D (ppm)	TOG (ppm)	Benzene (ppm)	Toluene (ppm)	Ethyl-benzene (ppm)	Xylenes (ppm)	MTBE EPA 8020 (ppm)	SVOCs EPA 8270[c] (ppm)	PCBs EPA 8082 (ppm)	VOCs EPA 8010 (ppm)
WO-1-2.5	2.5	04/25/00	**5.6**	NA	**660[a]**	**1,600**	<0.01	**0.019**	**0.027**	**0.22**	<0.1	ND	NA	ND[b]
WO-1-5	5	05/02/00	NA	NA	NA	**750**	NA	NA	NA	NA	NA	NA	NA	NA
WO-2-2.5	2.5	04/25/00	<1	NA	**25[a]**	**50**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[b]
WO-3-2.5	2.5	04/25/00	<1	NA	**1,400**	**700**	<0.005	<0.005	<0.005	<0.005	<0.05	ND	NA	ND[b]
WO-3-5	5	05/02/00	NA	NA	<1	NA	NA	NA	NA	NA	NA	NA	NA	NA

TPH-G = gasoline range total petroleum hydrocarbons.
TPH-D = diesel range total petroleum hydrocarbons.
TPH-O = hydraulic oil range total petroleum hydrocarbons.
TOG = total oil and grease.
MTBE = methyl-*tert*-butyl ether.
SVOCs = semivolatile organic compounds.
VOCs = volatile organic compounds.
PCBs = polychlorinated biphenyls.
ppm = parts per million.
8020 = analysis performed according to U.S. EPA Method 8020.
8270 = analysis performed according to U.S. EPA Method 8270A or C.
8010 = analysis performed according to U.S. EPA Method 8010B.
8082 = analysis performed according to U.S. EPA Method 8082.
NA = not analyzed.
ND = all compounds not detected.
< = concentrations not detected at or above the detection limit shown.
(a) laboratory noted that while the results were within the quantitation range; the chromatographic pattern was not typical of fuel.
(b) U.S. EPA Method 8260B analysis performed for VOCs.
(c) The maximum detection limit of SVOCs for soils that were not overexcavated is 1.7 ppm and associated with 2,4-dichlorophenol, benzoic acid, 2-nitroaniline, 3-nitroaniline, 2,4-dinitrophenol, 4-nitrophenol, 4-nitroaniline, 4,6-dinitro-2-methylphenol, and pentachlorophenol.
= sample location removed as a result of overexcavation activities.

Table 2-15. Waste Oil Line Soil Analytical Data (Metals)

Sample Description	Sample Depth (feet)	Date Sampled	Cadmium (ppm)	Total Chromium (ppm)	Total Lead (ppm)	Nickel (ppm)	Zinc (ppm)
Waste Oil Line Removal							
WO-1-2.5	2.5	04/25/00	<5	**7.1**	**90**	**8.9**	**34**
WO-2-2.5	2.5	04/25/00	<5	**9.3**	**11**	**13**	**35**
WO-3-2.5	2.5	04/25/00	<5	**15**	**16,000**	**14**	**1,200**
WO-3-5	2.5	05/02/00	NA	NA	<5	NA	NA
Residential PRG - Soil (ppm)			**9**	**210**	**400**	**1,500**	**23,000**
TTLC - Soil (ppm)			**100**	**2,500**	**1,000**	**2,000**	**5,000**

ppm = parts per million.
< = compound not detected at or above detection limit shown.
NA = not analyzed.
PRG = preliminary remediation goals (U.S. EPA, 2000d).
TTLC = total threshold limit concentration; Title 22 California Code of Regulations.
= sample removed via overexcavation activities.

Table 2-16. Analytical Results of Groundwater Collected During the SCAPS Investigation at the NEX Service Station

Sample ID	Sample Date	TPH-G (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)	MTBE (µg/L)
DODHNW14	5/17/96	59	8,900	13,000	1,300	7,300	1,700
DODHNW17	5/17/96	140	9,800	620	1,100	2,800	340,000
DODHNW18	5/17/96	220	12,000	29,000	3,300	19,000	250,000
DODHNW19	5/17/96	0.063	<0.5	1.6	<0.5	2.0	36
DODHNW15	5/20/96	0.059	3.3	18	<0.5	2.1	<5.0
DODHNW16	5/20/96	<0.050	<0.5	20	<0.5	<1.0	<5.0
DODHNW20	5/20/96	140	9,400	25,000	3,100	18,000	56,000
DODHNW21	5/20/96	150	8,800	29,000	4,100	24,000	31,000
DODHNW30	5/21/96	<0.050	<0.5	0.54	<0.5	<1.0	9.3

Table 2-17. Analytical Results of Soil Samples Collected During the SCAPS Investigation at the NEX Service Station

Sample ID	Sample Date	TRPH (mg/kg)	TPH-G (mg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethylben-zene (µg/kg)	Xylenes (µg/kg)	MTBE (µg/kg)
DODHNS22-1	5/20/96	<1	9.4	550	61	75	470	19,000
DODHNS23-1	5/20/96	160	1,500	7,600	50,000	23,000	130,000	93,000
DODHNS24-1	5/20/96	5,500	870	8,400	38,000	13,000	71,000	17,000
DODHNS29-1	5/21/96	10,000	31,000	350,000	2,400,000	660,000	3,400,000	2,700,000

Table 2-18. Analytical Results of Groundwater Samples Collected During the March 1998 Geoprobe™ Investigation

Sample Location	Date Collected	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)	MTBE (µg/L)
GP-E	3/30/98	<10	<10	<10	16	880
GP-F	4/2/99	<0.5	<0.5	<0.5	<0.5	0.75
GP-G	3/31/98	<0.5	<0.5	<0.5	<0.5	0.72
GP-H	3/31/98	<0.5	<0.5	<0.5	<0.5	60
GP-I	3/31/98	<0.5	<0.5	<0.5	<0.5	150
GP-J	3/31/98	<0.5	<0.5	<0.5	<0.5	7.4
GP-L	3/31/98	<0.5	<0.5	<0.5	<0.5	<0.5
GP-N	3/31/98	<0.5	<0.5	<0.5	<0.5	33
GP-O	3/31/98	<0.5	<0.5	<0.5	<0.5	63
GP-P	3/31/98	<0.5	<0.5	<0.5	<0.5	5.8
GP-Q	3/31/98	<0.5	<0.5	<0.5	<0.5	<0.5
GP-R	4/2/99	<25	<25	<25	<25	4,300
GP-S	4/1/98	<0.5	<0.5	<0.5	<0.5	<0.5

Table 2-19. Analytical Results of Groundwater Samples Collected During the April/May 1998 CPT Investigation

Sample Location	Date Collected	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)	MTBE (µg/L)
CPT-1	4/30/98	<0.5	<0.5	<0.5	<0.5	9.7
CPT-2A	4/30/98	<0.5	<0.5	<0.5	<0.5	4,600
CPT-3	4/30/98	<0.5	<0.5	<0.5	<0.5	9,100
CPT-4	4/30/98	<0.5	<0.5	<0.5	<0.5	3,300
CPT-5	4/30/98	<0.5	<0.5	<0.5	<0.5	5,500
CPT-6	4/30/98	<0.5	<0.5	<0.5	<0.5	160
CPT-7	4/30/98	<0.5	<0.5	<0.5	<0.5	56
CPT-8[(a)]	4/30/98	NA	NA	NA	NA	NA
CPT-9	4/30/98	<0.5	<0.5	<0.5	<0.5	<0.5
CPT-10[(a)]	4/30/98	NA	NA	NA	NA	NA
CPT-11	5/1/98	<0.5	<0.5	<0.5	<0.5	<0.5
CPT-12	5/1/98	<0.5	<0.5	<0.5	<0.5	<0.5
CPT-13	5/1/98	<0.5	<0.5	<0.5	<0.5	<0.5
CPT-14	5/1/98	<0.5	<0.5	<0.5	<0.5	<0.5

(a) Groundwater sample could not be collected due to dryness.

Table 2-20. Analytical Results of Groundwater Samples Collected During the August 1998 CPT Investigation

Sample Location	Date Collected	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylenes (µg/L)	MTBE (µg/L)
CPT-A1	8/3/98	<0.5	<0.5	<0.5	<1	<1
CPT-A2	8/3/98	<0.5	<0.5	<0.5	<1	<1
CPT-B1	8/3/98	<0.5	<0.5	<0.5	<1	<1
CPT-C1	8/3/98	<0.5	<0.5	<0.5	<1	19
CPT-D1	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-E1	8/4/98	<0.5	<0.5	<0.5	<1	2,100
CPT-F2	8/4/98	<0.5	0.61	<0.5	<1	600
CPT-G1A	8/4/98	<0.5	<0.5	<0.5	<1	<1
CPT-G2[(a)]	8/4/98	NA	NA	NA	NA	NA
CPT-G3	8/4/98	<0.5	<0.5	<0.5	<1	23
CPT-H1[(a)]	8/5/98	NA	NA	NA	NA	NA
CPT-H2	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-H3	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-J1	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-J2	8/6/98	<0.5	<0.5	<0.5	<1	6.6
CPT-J3	8/6/98	<0.5	<0.5	<0.5	<1	48
CPT-J4	8/6/98	<0.5	<0.5	<0.5	<1	5.7
CPT-J5	8/6/98	<0.5	<0.5	<0.5	<1	<1
CPT-K1	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-K2	8/5/98	<0.5	<0.5	<0.5	<1	26
CPT-K3	8/5/98	<0.5	<0.5	<0.5	<1	<1
CPT-L1	8/6/98	<0.5	<0.5	<0.5	<1	9.4
CPT-L2[(a)]	8/6/98	NA	NA	NA	NA	NA
B833-STW-006	8/5/98	<0.5	<0.5	<0.5	<1	3.7
B833-STW-007	8/6/98	<0.5	<0.5	<0.5	<1	<1

(a) Groundwater sample could not be collected due to dryness.

Table 2-21. Analytical Results of Groundwater Samples Collected from Permanent Monitoring Wells Located on Former Hamilton Army Airfield Property

Well ID	Collection Date	MTBE Concentration (μg/L)
PZ-1	6/19/98	47
PZ-2	6/19/98	130
PZ-4[(a)]	6/20/98	<0.5
1MW-2	6/20/98	<0.5
1MW-4A	7/6/98	18
MW-92-38	7/6/98	78
MW-92-39	7/6/98	0.72
GMP-15	7/15/98	2.8
PZ-7	7/15/98	3.3
PZ-9	7/15/98	2.5
1MW-5	8/5/98	3.3
GMP-16	8/5/98	<1.0
PZ-5	8/6/98	1.4

(a) PZ-4 is screened in bedrock; therefore, adjacent well 1MW-4A will be used to collect a more representative groundwater sample.

Table 2-22. Soil Sampling Results from the Sale Area, September 2000

Sample ID	MTBE (µg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	*m,p*-Xylene (µg/kg)	*o*-Xylene (µg/kg)	TPH-G (mg/kg)
SB-1A-5.5	300J	600	<580	80J	290J	51J	2
SB-1A-9.5	65	<5.8	<5.8	<5.8	<5.8	<5.8	0.1J
SB-2A-5.5	60	5J	2J	1J	4J	2J	0.1J
SB-2A-9.5	196	<5.1	<5.1	<5.1	<5.1	<5.1	0.04J
SB-5A-5.5	3,000	1,000	980J	2,000	7,700	3,000	0.1J
SB-5A-9.5	2,000	<1,200	110J	1,000	5,500	7,300	120
SB-6A-6	6,400	500J	210J	140J	570J	110J	1
SB-6A-9.5	420J	120J	<590	260J	180J	<590	270
SB-7A-5.5	161	0.5J	<5.6	<5.6	12	20	0.2J
SB-8A-5.5	230J	<590	<590	<590	<590	<590	3.5
SB-8A-9.5	460J	<590	<590	<590	<590	<590	0.06J
SB-9A-6	8,900	<1,300	<1,300	<1,300	150J	<1,300	4.3
SB-9A-9.5	160J	<550	<550	<550	<550	<550	12J
SB-10A-5.5	2,500	<600	58J	<600	800	350J	2
SB-10A-9.5	430J	<600	49J	<600	<600	<600	2.7
SB-11A-5.5	238	4J	0.8J	<5.8	65	55	1J
SB11A-9.5	191	<5.8	<5.8	<5.8	<5.8	<5.8	0.05J
SB-12A-5.5	218	<6.0	<6.0	<6.0	9	7	0.04J
SB-12A-8	22	<5.2	<5.2	<5.2	0.7J	1J	0.06J
SB-13A-12[(a)]	<12,000	<12,000	120,000	110,000	435,000	150,000	2,000
SB-13A-6	1,500	<570	<570	<570	<570	<570	0.6J
SB-13A-9.5	350J	<560	<560	<560	<560	<560	2
SB-14A-6	2,400	<600	<600	<600	160J	170J	3.0
SB-14A-9	137	1J	1J	2J	5J	2J	0.4J
SB-15A-5.5	1,000	79J	<610	<610	100J	<610	0.5J
SB-15A-9.5	146	<5.7	<5.7	<5.7	<5.7	<5.7	0.06J
SB-16A-5.5	900	<620	<620	<620	<620	<620	0.3J
SB-16A-9.5	55	<5.8	<5.8	<5.8	<5.8	<5.8	0.08J
SB-17A-6	7,200	1,000	2,000	340J	1,000	390J	0.8J
SB-17A-9.5	2,000	<1,200	<1,200	200J	130J	<1,200	740
SB-18A-10.5	<7.5	0.9J	<7.5	<7.5	0.9J	<7.5	0.8J
SB-18A-5.5	<590	<590	53J	54J	270J	160J	2.4
SB-19A-6	6,600	370J	150J	270J	540J	110J	2
SB-19A-9.5	1,000	<580	<580	<580	<580	<580	0.2J
SB-20A-6	1,300	99J	49J	<570	82J	<570	0.4J
SB-20A-9.5	600	<580	<580	<580	<580	<580	0.05J
SB-21A-5.5	NA	NA	NA	NA	NA	NA	0.6J
SB-22A-6	110	<6.1	2J	<6.1	<6.1	<6.1	0.03J
SB-22A-9.5	237	<5.3	<5.3	<5.3	<5.3	<5.3	0.04J
MW-5A-6	224	<5.2	<5.2	<5.2	<5.2	<5.2	0.4J
MW-5A-9.5	252	7	0.6J	<6.3	0.6J	<6.3	0.2J
MW-6A-6	1,360	6J	1J	0.8J	4J	1J	2
MW-6A-9.5	<2,900	<2,900	30,000	20,000	97,500	36,000	800
MW-7A-6	<29,000	<29,000	<29,000	16,000J	130,000	93,000	450J
MW-7A-9.5	<13,000	3,800J	59,000	42,000	210,000	75,000	2,100
MW-8A-6	4J	<5.5	<5.5	<5.5	<5.5	<5.5	0.1J

J = estimated value.

NA = not analyzed.

(a) Sample SB-13A-12 was collected below the water table; therefore, concentrations are not representative of unsaturated soils.

Table 2-23. Soil Sampling Results for BTEX and MTBE in the PBC Area, September 2000

Sample ID	MTBE (µg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	*m,p*-Xylene (µg/kg)	*o*-Xylene (µg/kg)
SB-1D-5.5	<1,200	<1,200	<1,200	780J	4,400	1,000
SB-1D-9.5	2J	<6.0	<6.0	<6.0	<6.0	<6.0
SB-2D-5.5	23	3J	<4.7	6.0	8	107
SB-2D-10	<5.3	0.8J	<5.3	<5.3	0.6J	<5.3
SB-3D-5.5	<1,200	250J	<1,200	5,700	12,000	<1,200
SB-3D-9.5	1,200	49J	<580	140J	130J	<580
SB-4D-5.5	<5.2	0.6J	<5.2	<5.2	<5.2	<5.2
SB-4D-10	<1,100	<1,100	<1,100	<1,100	<1,100	<1,100
SB-5D-5.5	162	<4.9	<4.9	<4.9	<4.9	<4.9
SB-5D-10	157	<4.5	<4.5	<4.5	<4.5	<4.5
SB-6D-5.5	3J	<5.8	<5.8	0.7J	2J	0.6J
SB-6D-9.5	<6.1	1J	0.5J	0.8J	3J	0.8J
SB-7D-10	<590	<590	<590	<590	<590	<590
SB-7D-5.5	<4.5	<4.5	<4.5	<4.5	<4.5	<4.5
SB-8D-10	<5.7	74	15	55	93	28
SB-8D-5.5	<6.8	<6.8	0.8J	<6.8	<6.8	<6.8
SB-9D-10	<7.2	<7.2	0.7J	0.8J	1J	<7.2
SB-9D-5.5	<6.2	<6.2	<6.2	<6.2	<6.2	<6.2
SB-10D-5.5	45	<6.2	<6.2	<6.2	<6.2	<6.2
SB-10D-9.5	57	<5.5	<5.5	<5.5	<5.5	<5.5
SB-11D-5.5	<5.4	<5.4	0.6J	<5.4	<5.4	<5.4
SB-11D-9.5	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1
SB-12D-5.5	<5.9	<5.9	<5.9	<5.9	<5.9	<5.9
SB-12D-9.5	<5.8	<5.8	<5.8	<5.8	<5.8	<5.8
SB-13D-5.5	<610	<610	<610	530J	240J	<610
SB-13D-9.5	<1,100	<1,100	<1,100	730J	220J	<1,100
SB-14D-5.5	42	<5.8	<5.8	<5.8	<5.8	<5.8
SB-14D-9.5	22	<4.8	<4.8	<4.8	<4.8	<4.8
SB-15D-5.5	<6.1	<6.1	<6.1	<6.1	<6.1	<6.1
SB-15D-9.5	7	<6.0	<6.0	<6.0	<6.0	<6.0
SB-16D-6	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0
SB-16D-9.5	<5.7	<5.7	<5.7	<5.7	<5.7	<5.7

J = estimated value.

Table 2-24. Soil Sampling Results for TPH Constituents in the PBC Area, September 2000

Sample ID	TPH-G (mg/kg)	TPH-D (mg/kg)	JP-5 (mg/kg)	TPH-MO (mg/kg)
SB-1D-5.5	0.5J	<5.9	8	NA
SB-1D-9.5	0.03J	<5.9	<5.9	NA
SB-2D-5.5	38	<5.8	22	NA
SB-2D-9.5	21J	<5.6	110	NA
SB-3D-5.5	480	<5.9	100	NA
SB-3D-9.5	4.9	<5.8	231	NA
SB-4D-5.5	0.04J	<5.9	NA	<12
SB-4D-9.5	29J	<5.5	18	NA
SB-5D-5.5	0.1J	<5.8	<5.8	NA
SB-5D-9.5	0.02J	<5.8	<5.8	NA
SB-6D-5.5	0.1J	<5.8	<5.8	NA
SB-6D-9.5	2	<5.8	34	NA
SB-7D-10	280	38	NA	<12
SB-7D-5.5	0.3J	<5.6	NA	190
SB-8D-10	2	100J	NA	700
SB-8D-5.5	0.3J	300	NA	2,200
SB-9D-10	1J	<6.3	NA	12J
SB-9D-5.5	0.02J	200	NA	1,300
SB-10D-5.5	0.05J	<5.8	NA	NA
SB-10D-9.5	<1.2	<5.8	NA	NA
SB-11D-5.5	0.3J	<6.2	NA	NA
SB-11D-9.5	0.02J	<5.9	NA	NA
SB-12D-5.5	<1.3	<6.3	<6.3	NA
SB-12D-9.5	<1.2	<6.1	NA	NA
SB-13D-5.5	3.7	<6.1	9	NA
SB-13D-9.5	340	<28	403	NA
SB-14D-5.5	0.06J	<6.1	NA	NA
SB-14D-9.5	0.02J	<6.1	NA	NA
SB-15D-5.5	<1.2	<6.0	NA	NA
SB-15D-9.5	<1.2	<6.2	NA	NA
SB-16D-5.5	0.05J	NA	NA	NA
SB-16D-9.5	0.3J	NA	NA	NA

J = estimated value.
NA = not analyzed.

Table 2-25. Sampling and Analytical Methods for Periodic Monitoring

Analyte	Method	Container	Sample Size	Preservation	Holding Time
Groundwater					
BTEX, MTBE	SW-8260B	Borosilicate glass	3 × 40 mL VOA vials[(b)]	HCl to pH <2, @ 4°C	14 days
TPH (purgeable)	*California LUFT Manual*[(a)]	Borosilicate glass	3 × 40 mL VOA vials[(b)]	HCl to pH <2, @ 4°C	14 days
Surface Water					
BTEX, MTBE	SW-8260B	Borosilicate glass	3 × 40 mL VOA vials	HCl to pH <2, @ 4°C	14 days

(a) Source: SWRCB, 1989.
(b) One set of three VOA vials is sufficient for all groundwater analysis with the exception of additional VOA vials collected for lower laboratory detection limits

Table 2-26. Laboratory Practical Quantitation Limits Based on Clean Matrices for Periodic Monitoring

Analyte	Reporting Limit for Water
TPH (purgeable)	0.05 mg/L
BTEX	0.5 µg/L
MTBE	0.5 µg/L

Table 2-27. QC Samples

Type of Sample	Number of Samples
Field duplicates	10% of total samples collected
Equipment rinsate[(a)]	20% of total samples collected
Trip blank	1 per cooler
Field blank	1 per day
Laboratory QA[(b)]	5%

(a) Required to verify decontamination between samples where nondedicated equipment is used.
(b) For matrix spike/matrix spike duplicate analysis.

Table 2-28. Groundwater Monitoring Network and Decision Criteria by Objective[a]

Location	Monitoring Wells	Decision Criteria
Transect		
Area A (970 Source Area)	970-MW1, MW-5A, MW-6A, MW-1A MW-7A	Concentration trends which show a general decrease or do not increase over time indicate that a continuing source to groundwater does not exist; consistently increasing concentrations indicate that a potential source to groundwater exists.
Area D (957 Source Area)	MW-1D, MP-1D, 957-MW4, 957-MW3	
Area B	MW-4B, MW-1B, 970-MW4, MW-3B	If consistently increasing concentrations are observed, the potential impacts to downgradient receptors will be evaluated; consistently decreasing or stable concentrations indicate that internal plume migration is not occurring in these areas.
Property boundary (State Access Road)	MW-M1, MW-M10, MW-M9, MW-M8, MW-M16	
Downgradient MTBE transect	IT-2MW-2, IT-1MW-4A, IT-MW-92-38, IT-MW-92-39, MW-M25	
Perimeter		
Benzene plume perimeter	NA-0, 970-MW1, 970-MW2, 957-MW1, 957-MW3, 970-MW3, MW-3B, MW-10A	Concentrations remaining below detection limits at perimeter wells of the respective plumes indicate that the extent of the plume is not expanding; if benzene or MTBE is consistently detected in wells in which it previously had not been detected, this may be an indication of potential plume migration.
MTBE plume perimeter	NA-0, MW-4B, MW-6B, MW-2D, MW-2E, MW-M1, PZ-3, PZ-4, MW-M19, MW-M11, IT-2MW-2, IT-PZ-5, MW-M12, MW-M13, IT-GMP-18, IT-EW-91-1[b], MW-M25, MW-M24, MW-M16, MW-M2, 970-MW3, MW-3B	
Centerline		
Centerline of plume from NA-0 to IT-GMP-17 (approximately 2,800 ft downgradient)	NA-0, NA-1, MW-1A, 970-MW5, MW-4A, 970-MW4, NA-4, NA-6, NA-7, 957-MW4, MW-1E, 957-MW1, MW-M3, MW-M9, PZ-1, IT-MW-92-38, MW-20, MW-21, MW-22, MW-23, IT-PZ-9, IT-GMP-17	Concentrations will be compared to established risk levels to ensure that they are within acceptable levels; if consistent increases in concentration are observed, a determination of the potential impacts will be made and the monitoring network reevaluated.

Table 2-28. Groundwater Monitoring Network and Decision Criteria by Objective (Continued)

Location	Monitoring Wells	Decision Criteria
Development Area MTBE Monitoring		
Development area north of State Access Road	PZ-1, PZ-3, PZ-4, MW-M11, MW-M15, IT-2MW-1, IT-PZ-5, IT-2MW-2, IT-1MW-4A, IT-MW-92-38, IT-MW-92-39, IT-GMP-15, EW-91-1[(b)], MW-M12, IT-PZ-7, MW-M13, IT-PZ-9, IT-GMP-17, MW-M14, MW-M17, MW-18, MW-M19, MW-M20, MW-M21, MW-M22, MW-M23, MW-M24, MW-M25, MW-M26, MW-M27, IT-GMP-16, IT-GMP-18	MTBE concentrations will be compared to residential risk values to ensure that concentrations are protective of future residents; consistently increasing concentrations (one full cycle) will be indicative of internal plume migration.
Special Features		
Daycare center	970-MW3, MW-3B	If concentrations do not exceed residential risk levels, no further action is warranted; if changing concentrations indicate that risk levels will likely be exceeded in the future, further evaluation or more extensive monitoring may be warranted.
Property boundary (State Access Road)	MW-M1, MW-M10, MW-M9, MW-M8, MW-M16	Consistently increasing concentrations (one full cycle) will be indicative of internal plume migration; consistently decreasing or stable concentrations (one full cycle) will indicate that elevated concentrations are not migrating across the property boundary.
Pacheco Creek vicinity	IT-PZ-5, IT-2MW-2, IT-1MW-4A, IT-2MW-1, MW-M17, MW-M18	Decreasing concentrations will indicate that the extent of impact to Pacheco Creek will likely decrease; increasing concentrations will indicate that future impact to Pacheco Creek may increase (if the surrounding groundwater is in fact the source of impact).
Bedrock wells	MW-9A, MW-3D	Comparison of constituent concentrations detected in bedrock wells to nearby shallower screened wells will determine impact to fractured bedrock.
Former UST 970-3 tank pit excavation	MW-8A	Concentration trends, which show a general decrease or do not increase over time, indicate that a continuing source to groundwater does not exist; consistently increasing concentrations indicate that a potential source to groundwater exists.
Nested well pairs	MW-M20 (S and D), MW-M14 (S and D), MW-M25 (S and D), MW-M26 (S and D), MW-M27 (S and D)	Comparable concentrations between samples from shallow and deep intervals will indicate that MTBE is distributed equally between upper and lower aquifer zones; varying concentrations will indicate stratification of MTBE in the aquifer zone which could potentially be associated with surface water infiltration.

(a) This table updates the original groundwater monitoring network provided in Table 3 of the *Groundwater Monitoring Plan* (Battelle, 2000a)
(b) Semiannual monitoring to ensure nondetect.

Table 2-29. Surface Water Monitoring Network and Decision Criteria[(a)]

Location	Sample ID	Objective	Decision Criteria
Upstream of Site	PC-SW-1	Establish concentrations in Pacheco Creek before it encounters the Site	MTBE concentrations detected upgradient of the Site indicate that another source is contributing to MTBE in Pacheco Creek.
Within the MTBE plume (just after outfall from culvert)	PC-SW-2	Determine if MTBE enters the creek along its subsurface run	If MTBE concentrations at the outfall of the culvert are greater than concentrations at the upstream location, this indicates that MTBE is entering the creek through one of the culverts; the presence of MTBE at this location is not necessarily associated with Former UST Site 957/970 because other areas also drain into the creek.
Within the MTBE plume	PC-SW-5	Determine if MTBE-impacted groundwater interacts with surface water of Pacheco Creek in the area of IT-2MW-1	If MTBE concentrations at the surface water sampling location compare to those detected in IT-2MW-1 a determination can be made of groundwater-surface water interaction.
Immediately downstream of MTBE plume	PC-SW-3	Evaluate the presence and persistence of MTBE in Pacheco Creek	If MTBE concentrations decrease from the immediate downstream location to the further downstream location, this indicates that the processes of volatilization, photodegradation, biodegradation, and/or dilution are causing a reduction in MTBE concentrations in Pacheco Creek.
Further downstream of MTBE plume	PC-SW-4		
Individual culvert outlet upstream of PC-SW-2	PC-SW-CE	Identify MTBE concentrations in water originating from individual culverts entering the creek in this area	If MTBE is detected at the location of the culvert outfall, this indicates it as a likely source of MTBE to Pacheco Creek.

(a) This table updates the original surface water monitoring network provided in Table 4 of the *Groundwater Monitoring Plan* (Battelle, 2000a).

Table 2-30. Surface Water Sampling Analytical Results

Sample ID	Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	MTBE (µg/L)
PC-SW-1	06/21/00	NA	NA	NA	NA	<0.50
	08/06/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/07/00	<0.50	<0.50	<0.50	<1.0	<0.50
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-2	06/21/00	NA	NA	NA	NA	190
	08/06/00	<0.50	<0.50	<0.50	<1.0	100
	11/07/00	<0.50	<0.50	<0.50	<1.0	22
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**3.6**
PC-SW-5	**02/26/01**	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**6.6**
PC-SW-3	06/21/00	NA	NA	NA	NA	14
	08/06/00	<0.50	<0.50	<0.50	<1.0	1.1
	11/07/00	<0.50	<0.50	<0.50	<1.0	6.0
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**6.4**
PC-SW-4	06/21/00	NA	NA	NA	NA	0.69
	08/06/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/07/00	<0.50	<0.50	<0.50	<1.0	0.60
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**24**
PC-SW-C1	07/10/00	NA	NA	NA	NA	<0.50
	08/06/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/07/00	<0.50	<0.50	<0.50	<1.0	<0.50
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-C2	07/10/00	NA	NA	NA	NA	<0.50
	08/06/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/07/00	<0.50	<0.50	<0.50	<1.0	<0.50
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-CW	07/10/00	NA	NA	NA	NA	<0.50
	09/08/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/07/00	<0.50	<0.50	<0.50	<1.0	<0.50
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-CE[(a)]	07/10/00	NA	NA	NA	NA	2,400
	09/08/00	<0.50	<0.50	<0.50	<1.0	1,300
	11/07/00	<0.50	<0.50	<0.50	<1.0	150
	02/26/01	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**330**

Boldface indicates latest sampling event.
(a) Sample collected from within storm sewer outfall, not from surface water flowing in Pacheco Creek.
NA = not analyzed.

Table 2-31. Total Risks to Potential Receptors in the Sale Area and PBC Area for Former UST Site 957/970[a]

Exposure Pathway	Sale Area		PBC Area			
	Occupational Receptor		Age-Adjusted Residential Receptor		Child Residential Receptor	
	Risk	Hazard Indices	Risk	Hazard Indices	Risk	Hazard Indices
Direct Exposure with Soil [b]	2.30E-07	1.86E-02	1.29E-07	2.35E-03	8.92E-08	2.12E-02
Inhalation of Gasoline Constituents from Soil in Outdoor Air[c]	8.44E-10	5.24E-01	1.67E-10	3.72E-02	1.67E-10	3.72E-02
Inhalation of Gasoline Constituents from Soil in Outdoor Air[d]	3.13E-09	5.24E-01	6.18E-10	3.72E-02	6.18E-10	3.72E-02
Inhalation of Gasoline Constituents from Groundwater in Outdoor Air[c]	1.22E-09	7.01E-02	2.05E-09	9.82E-02	2.05E-09	9.82E-02
Inhalation of Gasoline Constituents from Groundwater in Outdoor Air[d]	4.38E-09	7.01E-02	7.36E-09	9.82E-02	7.36E-09	9.82E-02
Inhalation of Gasoline Constituents in Indoor Air [c,e]	2.34E-06	2.13E-02	1.34E-07	3.49E-01	1.34E-07	3.49E-01
Inhalation of Gasoline Constituents in Indoor Air [d,e]	8.02E-06	2.13E-02	4.94E-07	3.49E-01	4.94E-07	3.49E-01
TOTAL[c]	**2.57E-06**	**6.34E-01**	**2.65E-07**	**5.08E-01**	**2.26E-07**	**5.05E-01**
TOTAL[d]	**8.26E-06**	**6.34E-01**	**6.31E-07**	**5.08E-01**	**5.91E-07**	**5.05E-01**

(a) Total risks based on Final Revised Risk Assessment (Battelle 2001c).
(b) Exposure routes include incidental ingestion and dermal contact.
(c) Inhalation risk based on federal unit risk factor for benzene.
(d) Inhalation risk based on Cal-EPA unit risk factor for benzene.
(e) Indoor air risks include the combined effects of volatilization from impacted soil and groundwater. Values correspond to the maximum indoor air risk/hazard in the Sale Area and the PBC Area. Indoor air risks were calculated using the U.S. EPA/DTSC indoor air risk model and soil-gas data collected in the fall of 2000.

Table 2-32. Summary of Excavation Worker Risks from Exposure to Impacted Soil[a]

Exposure Pathway	Sale Area		PBC Area	
	Risk	Hazard Indices	Risk	Hazard Indices
Inhalation of Gasoline Constituents in Outdoor Air [b]	4.78E-07	1.13E+03	5.60E-08	5.20E+01
Inhalation of Gasoline Constituents in Outdoor Air [c]	1.73E-06	1.13E+03	2.03E-07	5.20E+01
Direct Contact with Gasoline Constituents in Soils	2.06E-10	4.95E-03	2.36E-11	4.04E-04
TOTAL[b]	**4.78E-07**	**1.13E+03**	**5.61E-08**	**5.20E+01**
TOTAL[c]	**1.73E-06**	**1.13E+03**	**2.03E-07**	**5.20E+01**

(a) Risks based on Final Revised Risk Assessment (Battelle, 2001c).
(b) Inhalation risk based on federal unit risk factor for benzene.
(c) Inhalation risk based on Cal-EPA unit risk factor for benzene.

Table 2-33. Conceptual Site Model for Ecological Risk Assessment

Environmental Medium of Concern	Receptor Group	Potential Exposure Routes	Potentially Complete Pathway?	Exposure Likely to Result in Toxicity?
Soil	Grassland and riparian	Ingestion	No – MTBE does not partition strongly to soil	NA
Sediment	Aquatic and riparian	Ingestion	No – MTBE does not partition strongly to sediment	NA
Air	Grassland and riparian	Inhalation of soil gas	No – MTBE in soil gas is below detection limit at ground surface in area with highest GW concentration	NA
Water	Grassland	Ingestion	Yes – MTBE detected in Pacheco Creek	No –- Pacheco Creek may not be only drinking water source; also, MTBE concentrations decreased rapidly downstream
	Riparian	Ingestion	Yes – MTBE detected in Pacheco Creek	No – Pacheco Creek may not be only drinking water source; also, MTBE concentrations decreased rapidly downstream
	Aquatic	Direct contact	Yes – MTBE detected in Pacheco Creek	No – maximum MTBE concentration (2,400 µg/L) is below freshwater chronic WQO (66,000 µg/L); also, MTBE concentrations decreased rapidly downstream

GW = groundwater.
WQO = Water quality objective (aquatic life criteria).

Section 3.0: INTERIM REMEDIAL ACTION

Air sparging and soil vapor extraction were implemented in an interim remedial action in areas in which the highest hydrocarbon concentrations were observed in 1997 and 1998 in groundwater. The goal of the interim action was aggressive treatment and removal of "hot spot" areas and mass reduction. The interim action was performed because initial concentrations of benzene and MTBE exceeded protective concentrations as listed in the Tier 1 RBCA Assessment and lookup table values listed in ASTM E 1739 – 95 (RBCA Applied at Petroleum Release Sites). The following sections include a technology description, a description of the interim remedial action, and the results of system operation.

3.1 Air Sparging and Soil Vapor Extraction Technology Description

In situ air sparging (IAS) is the injection of pressurized air directly into an aquifer. The injected air delivers oxygen to the groundwater and strips volatile contaminants from the groundwater. The air flows through permeable pathways in the saturated soil column driven toward the water table surface by buoyant forces. The shape and nature of the airflow pathways is determined by soil particle and sediment layering characteristics.

In situ air sparging removes hydrocarbons from saturated soil sediments by two primary mechanisms: (1) biodegradation: increased dissolved oxygen (DO) supports and enhances in situ biodegradation of hydrocarbons by indigenous microbes, and (2) stripping: volatile hydrocarbons partition into the vapor phase and are carried to the vadose zone with the air stream. The relative contributions of each of these removal mechanisms are dependent on site characteristics, contaminant type and concentration, system design, and operational parameters.

The concentration of hydrocarbons and oxygen in the vapor stream reaching the vadose zone varies depending on the following:

- Depth of the sparge well screen
- Concentration of dissolved hydrocarbon in the groundwater
- Henry's law constant of dissolved hydrocarbons
- Presence and concentration of sorbed hydrocarbon trapped below the water table
- Concentration of DO in groundwater
- Surface area of interface between sparged air streams and groundwater and sorbed soil sites
- Proximity of sparged airstreams and hydrocarbon reservoirs.

In many IAS applications, the vapor stream reaching the vadose zone is a biologically reactive mixture of hydrocarbons and oxygen that microbes can utilize. Indigenous soil bacteria aerobically respire using oxygen as an electron acceptor and the hydrocarbons as an energy and carbon source. The soil volume in which this degradation occurs is referred to as an in situ bioreactor that in many cases can be exploited and optimized to effectively destroy the vapor stream. The ability of the vadose zone to degrade residual vapors (its biodegradation capacity) is dependent on the type and number of indigenous soil microbes, the type and concentration of hydrocarbons, and the physical characteristics of the vadose zone soils (depth, porosity, specific surface area, heterogeneity, and anisotropy). If the

vadose zone soils can be exploited to destroy the residual vapor stream, no vapor collection and treatment systems are required.

SVE systems are commonly coupled to IAS systems where the biodegradation capacity of the vadose zone is inadequate or unknown, or where the solutes to be removed are known to be recalcitrant to aerobic biodegradation. The SVE system consists of wells screened in the vadose zone and an extraction blower that imposes a vacuum on the soil voids near the well. Vapor is withdrawn to the surface and treated prior to discharge.

3.2 Implementation

At Former UST Site 957/970, a coupled IAS/SVE system was installed to reduce the mass of hydrocarbon in selected areas having elevated concentrations. (The selected areas were designated as Areas A, B, D, and E. Areas A and B are located in the vicinity of former UST tank complex 970, within the Sale Area. Areas D and E are located near former UST 957, within the PBC Area. Areas D and E are both small and sometimes are referred to together as Area DE.) This effort was designed to reduce the potential of the groundwater plume to migrate and reduce hydrocarbon concentrations. The SVE system accelerated volatilization of hydrocarbons from the smear zone and vadose zone soils, and prevented the potential emission of sparged vapors to the atmosphere or subsurface migration to potential receptors.

The IAS/SVE system initially consisted of 10 air sparging wells and 6 SVE wells installed in May 1998. Sparge wells were screened as low as possible in the saturated permeable layer to allow air to traverse the maximum possible distance through the impacted aquifer sediments. SVE wells were screened across the water table to accommodate fluctuations in groundwater levels. Subsequent groundwater monitoring events revealed areas of elevated hydrocarbon concentrations outside of the areas for which the original air sparging and SVE systems were designed. For this reason, eight additional sparge wells and seven additional SVE wells were installed in October 1998 to remove gasoline from these areas. Additional wells were connected to the existing air sparging and SVE manifolds. Figure 3-1 shows locations of air sparging and SVE wells in Areas A, B, and DE. Construction details are listed in Table 3-1.

The major components of the IAS system (Figure 3-2) included two 25-horsepower (hp) air compressors and an injection airflow manifold panel for each compressor. The compressors were connected to the airflow manifold panels through a regulator and high-pressure gauge. The manifold panel consisted of the following components for each sparge well: a valve, a flowmeter (1 to 14 cfm), a regulator, and a pressure gauge (0 to 30 psi). Airflow and delivery pressure to each sparge well were controlled at the manifold panel. The panel mounts on the manifold were connected to the sparge wells with 1-in.-diameter, high-pressure air hose and associated fittings.

The major components associated with the SVE system (Figure 3-2) included a 30-gallon moisture knockout drum for each SVE well, and an off-gas treatment system with a blower unit with a capacity of 500 standard cubic feet per minute (scfm). SVE wells were connected to the off-gas treatment system with 2-inch-diameter polyvinyl chloride (PVC) pipe and hose. A sampling port and vacuum gauge were installed on each knockout drum. A flowmeter and valve were installed in line from each SVE well to monitor and control the flow at each individual well. Sampling ports were installed on the pipe conducting vapor from each knockout drum, pipes conducting vapor from each area (A, B, D, and E), and on the overall combined flow manifold conducting vapor from the entire system.

The SVE off-gas was treated by a Vapor Check Vac 50 with a 500-scfm flow capacity. The system initially was operated as a standard thermal oxidizer; however, as hydrocarbon concentrations in the off-gas stream decreased it was converted to a catalytic oxidizer by inserting a catalytic module. The

treatment unit included a process blower. As a thermal oxidizer, the unit operated at approximately 1,400°C; however, the operational temperature was decreased to approximately 600°C when operated in catalytic mode. TPH-G destruction efficiency was maintained at >98% to comply with an air discharge permit issued by the Bay Area Air Quality Management District (BAAQMD).

3.3 Results

Significant mass removal was achieved through the operation of air sparging and soil vapor extraction systems. A summary of soil vapor extraction flowrates, influent and effluent concentrations, mass removed, and destruction efficiency are presented in Table 3-2. An estimated 23,000 lbs of gasoline were calculated to have been removed through the soil vapor extraction system. In general, TPH-G, BTEX, and MTBE concentrations in the off-gas stream decreased substantially since system startup (Figure 3-3). The last sampling event (October 5, 1999) did reveal a noticeable TPH removal rate of 50 lbs/day calculated based on off-gas concentrations and average system flowrate. This removal rate was increased over those observed during summer months and likely is associated with the seasonal low water table level in late autumn. Low water table levels result in a larger cross-section area available for gas flow as well as exposure of deeper soils that are only above water during low water table events. These deeper soil locations are the least impacted by mass removal, and when exposed can contribute significant amounts of TPH to the extracted vapor stream. The SVE system TPH-G removal rate had decreased to about 3 lbs/day during periods of higher water table levels earlier in the year. For this reason, it had been determined that the recovery potential of the existing system had been met unless extraction would take place only during seasonal low water levels. Additional extraction wells would have been required for the system to achieve significant additional hydrocarbon removal throughout the year. Because, risk assessment activities indicated that concentrations at the Site did not exceed risk-based screening levels, the air sparging and SVE systems were shut down in early October 1999. Analytical results for process vapor samples are included in Appendix N.

Groundwater samples were collected from monitoring wells and air sparging wells prior to startup of remedial activities to get baseline concentrations. The initial (preremediation) sampling took place in May 1998. Quarterly groundwater monitoring events were conducted in which monitoring wells were sampled, but air sparging wells were not intended for routine plume monitoring, and were not sampled during the quarterly sampling events. Groundwater samples were collected from monitoring and sparge wells again one year later (May 1999) and analyzed to determine the effects of remedial activities on groundwater concentrations. System expansion wells were not installed until October 1998; therefore, initial sampling data for these wells is from November 1998, and the corresponding one-year sampling event took place in November 1999. Table 3-3 presents the MTBE and benzene concentrations obtained from the air sparging wells in 1998 and 1999, and shows that in the majority of air sparging wells MTBE and benzene concentrations decreased following one year of system operation. Groundwater monitoring data from air sparging wells is included in Appendix L and laboratory analytical reports are included as Appendix M.

The interim remedial action system objectives were to reduce concentrations in hot spots while site-specific investigations and evaluations were being performed to assess the risk to human health and the environment presented by gasoline constituents at the Site. The system was effective at removing gasoline and reducing concentrations, thus decreasing the risks presented by gasoline constituents at the Site. The primary risk drivers were benzene and MTBE, and these compounds therefore were tracked carefully.

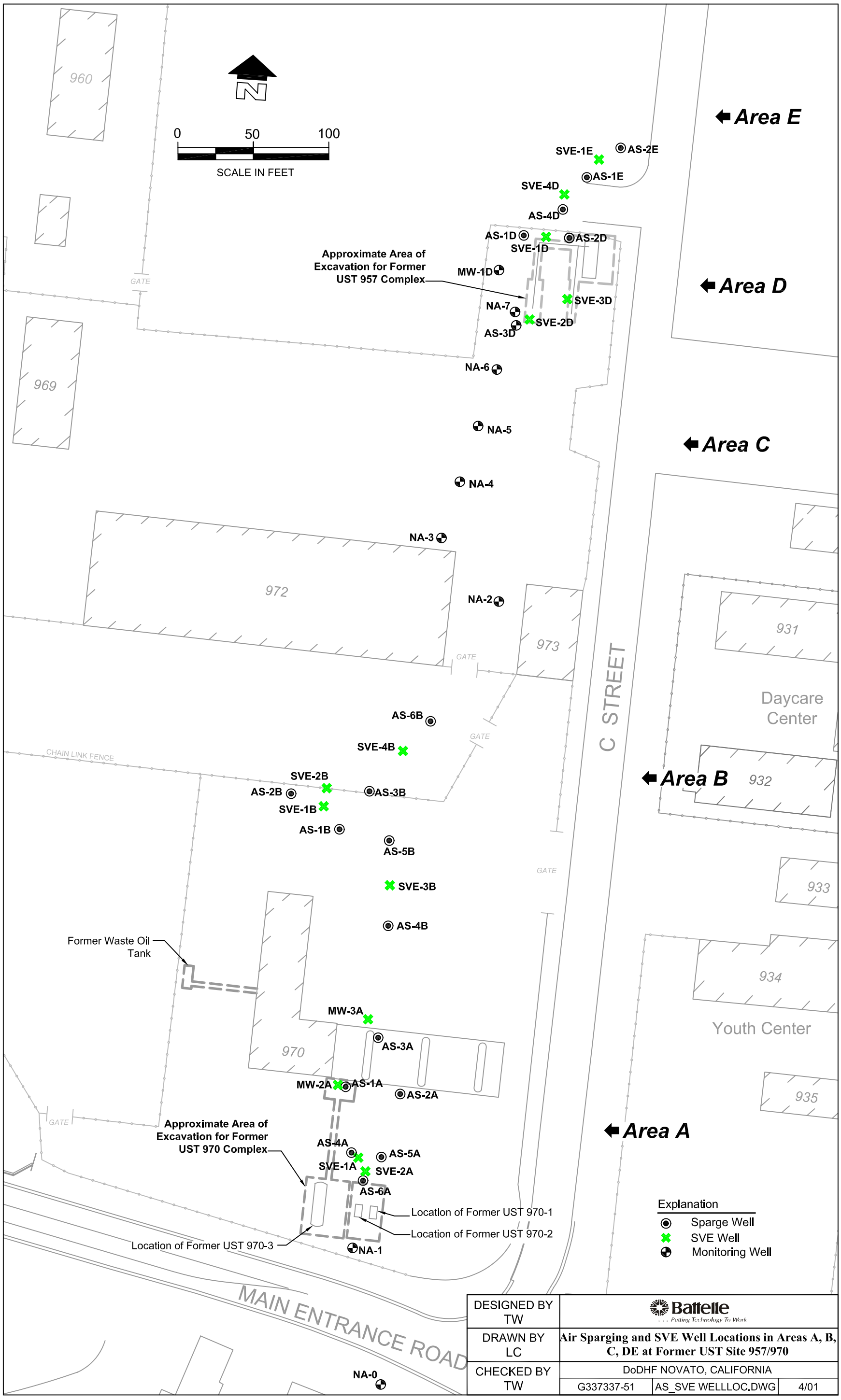
Groundwater concentrations in sparge wells located within Area A averaged approximately 99,000 µg/L for MTBE and 6,600 µg/L for benzene preceding system operation. After one year of operation, the average concentrations of MTBE and benzene within Area A decreased to approximately

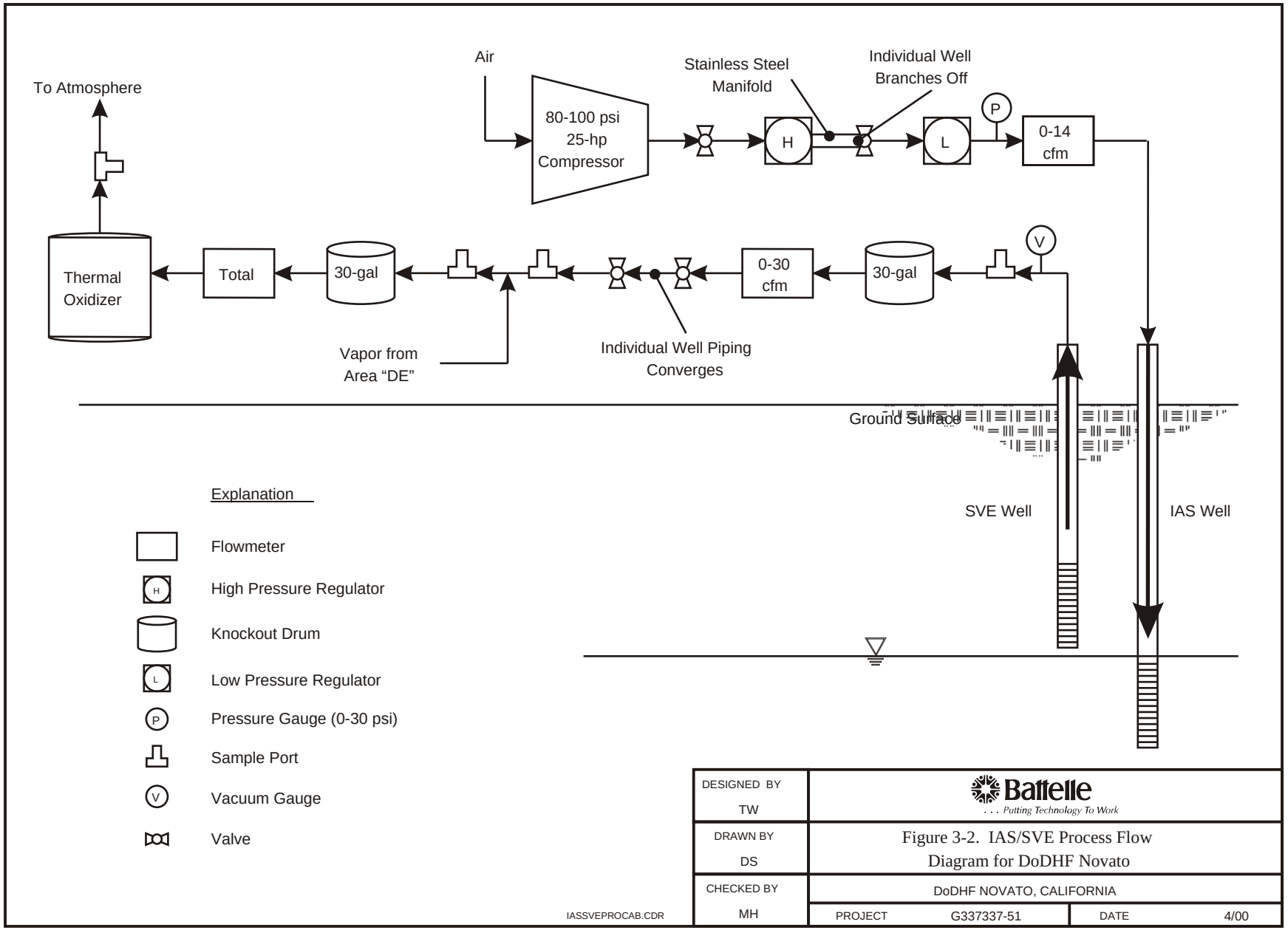
20,000 µg/L and 860 µg/L, respectively. This decrease calculates to an average reduction of approximately 80% MTBE and 86% benzene in Area A wells. Quarterly monitoring results indicate that MTBE and benzene concentrations have continued to decrease over the 1.5 years after system shutdown.

Groundwater concentrations in the sparge wells within Area B showed a similar reduction to the sparge wells in Area A, with the exception of AS-3B. The average initial concentrations of MTBE and benzene in wells located within Area B were approximately 58,000 µg/L and 3,000 µg/L, respectively. Following one year of active remediation, the average concentrations of MTBE and benzene were 17,000 µg/L and 230 µg/L, respectively. Within Area B (excluding AS-3B), the average concentrations of MTBE and benzene decreased by 70% and 92%, respectively, after one year of system operation. Groundwater monitoring results obtained from adjacent monitoring wells, 970 MW-4 and MW-5B, confirm the reduction in concentration of MTBE and benzene. Although the MTBE concentration has increased slightly in AS-3B, the benzene concentration decreased by more than 90% over the same period.

Groundwater monitoring results from Area DE do not exhibit a clear pattern in reduction of MTBE concentrations; however, benzene concentrations in all Area DE wells have decreased by approximately 90% after one year of system operation. The average initial concentrations of MTBE and benzene within Area DE were approximately 28,000 µg/L and 590 µg/L, respectively. After one year of operation, the average concentrations of MTBE and benzene within Area DE were approximately 20,000 µg/L and 30 µg/L, respectively. MTBE concentrations within the initially installed sparge wells in Area D (AS-1D and AS-2D) were seen to increase after one year of operation; however a significant reduction in benzene was observed in those wells during the same time period. On the contrary, a reduction in MTBE concentrations in system expansion sparge wells was observed after one year of operation. On average, a greater than 90% reduction in MTBE and benzene concentrations was observed in system expansion sparge wells in Area DE from 1998 to 1999. These apparent discrepancies can be explained by intraplume migration of MTBE carried in groundwater from one area to another.

Quarterly groundwater monitoring data collected subsequent to IAS/SVE system shutdown was used to assess the potential rebound of gasoline constituent concentrations in groundwater. Figures 3-4, 3-5, and 3-6 show benzene and MTBE concentrations in transect wells located within Area A, Area B, and Area DE, respectively (see Figure 2-18). MW-1A, which is located approximately 12 ft downgradient of the former UST 970 tank complex, showed significant decreases in benzene and MTBE concentrations during interim remedial actions (Figure 3-4). Following system shutdown in October 1999, benzene and MTBE concentrations in MW-1A have remained at low levels during six quarterly groundwater monitoring events, indicating that rebound of gasoline constituents in Area A is not occurring. Transect wells MW-5A, MW-6A, and MW-7A (also shown in Figure 3-4) were installed during remedial investigation activities in September 2000 at the RWQCB's request and have shown consistent concentrations of benzene and MTBE since the wells were first sampled in November 2000. Figure 3-5 shows that gasoline constituents in transect wells within Area B were significantly decreased during system operation and have remained low following system shutdown, also indicating that no rebound of concentrations is occurring in Area B. Fluctuating benzene and MTBE concentrations have been detected in transect wells located in Area DE during interim remedial action activities and after system shutdown (Figure 3-6). In general, no significant increases in concentrations have been found during quarterly monitoring activities, but there also has been no consistent trend of decreasing concentrations. The fluctuating benzene and MTBE concentrations in Area DE transect wells may be a result of the area south of Area DE (referred to as Area C) not being treated during interim remedial activities. Area C was not treated to provide an opportunity to observe the natural attenuation of gasoline constituents over time without interference from the interim remedial action system.


960
969
GATE
0
50
100
SCALE IN FEET
SVE-1E
AS-2E
AS-1E
SVE-4D
AS-4D
AS-1D
AS-2D
SVE-1D
Approximate Area of Excavation for Former UST 957 Complex
MW-1D
SVE-3D
NA-7
SVE-2D
AS-3D
NA-6
NA-5
NA-4
NA-3
NA-2
972
973
GATE
AS-6B
GATE
SVE-4B
CHAIN LINK FENCE
SVE-2B
AS-2B
AS-3B
SVE-1B
AS-1B
AS-5B
GATE
SVE-3B
AS-4B
Former Waste Oil Tank
MW-3A
AS-3A
970
MW-2A
AS-1A
AS-2A
GATE
Approximate Area of Excavation for Former UST 970 Complex
AS-4A
AS-5A
SVE-1A
SVE-2A
AS-6A
Location of Former UST 970-1
Location of Former UST 970-2
Location of Former UST 970-3
NA-1
NA-0
MAIN ENTRANCE ROAD
C STREET
Area E
Area D
Area C
Area B
Area A
931
Daycare Center
932
933
934
Youth Center
935
Explanation
Sparge Well
SVE Well
Monitoring Well
DESIGNED BY TW
DRAWN BY LC
CHECKED BY TW
Battelle
. . . Putting Technology To Work
Air Sparging and SVE Well Locations in Areas A, B, C, DE at Former UST Site 957/970
DoDHF NOVATO, CALIFORNIA
G337337-51
AS_SVE WELLLOC.DWG
4/01



DESIGNED BY TW	Battelle … Putting Technology To Work		
DRAWN BY DS	Figure 3-2. IAS/SVE Process Flow Diagram for DoDHF Novato		
CHECKED BY MH	DoDHF NOVATO, CALIFORNIA		
IASSVEPROCAB.CDR	PROJECT G337337-51	DATE	4/00

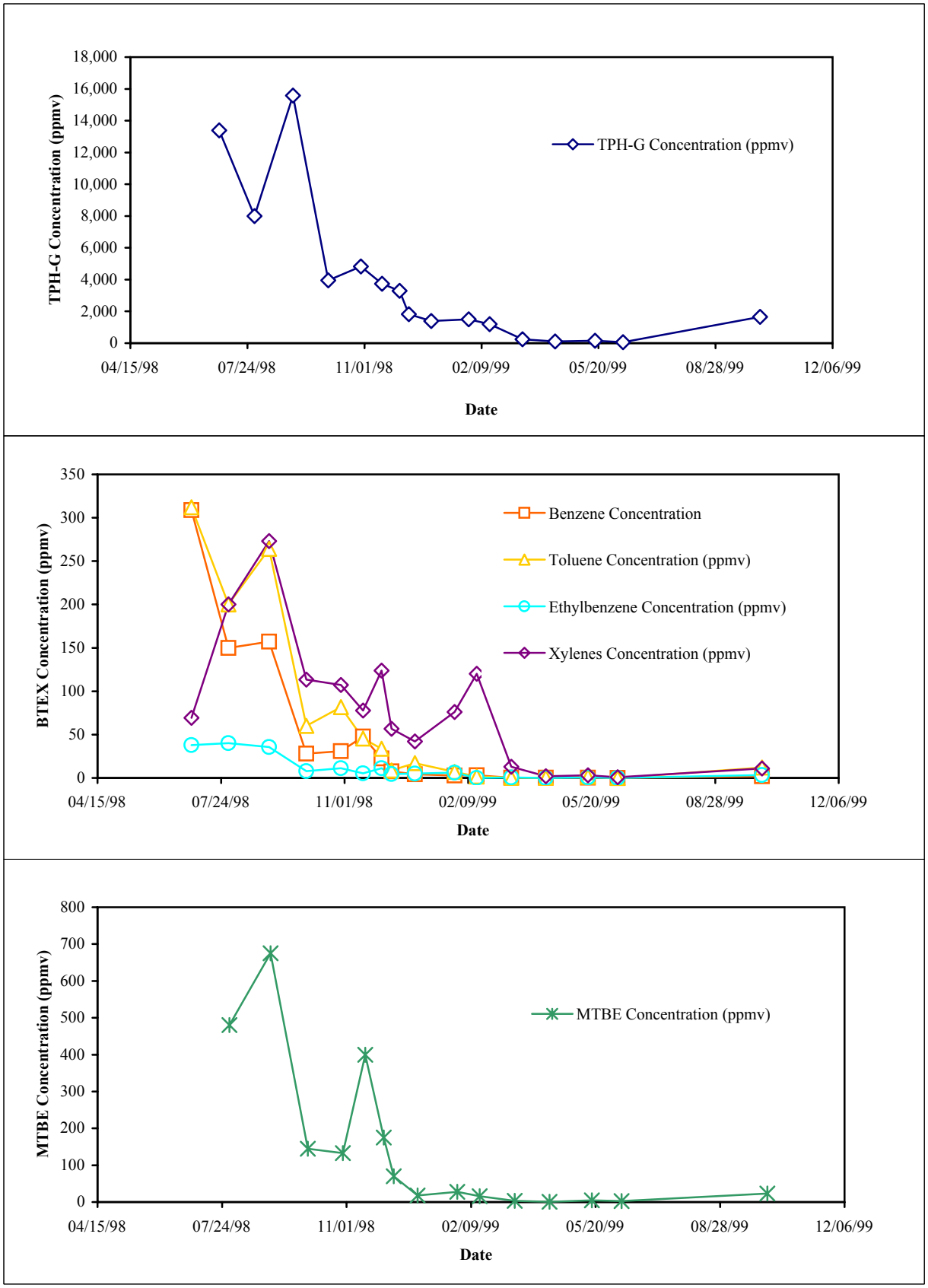
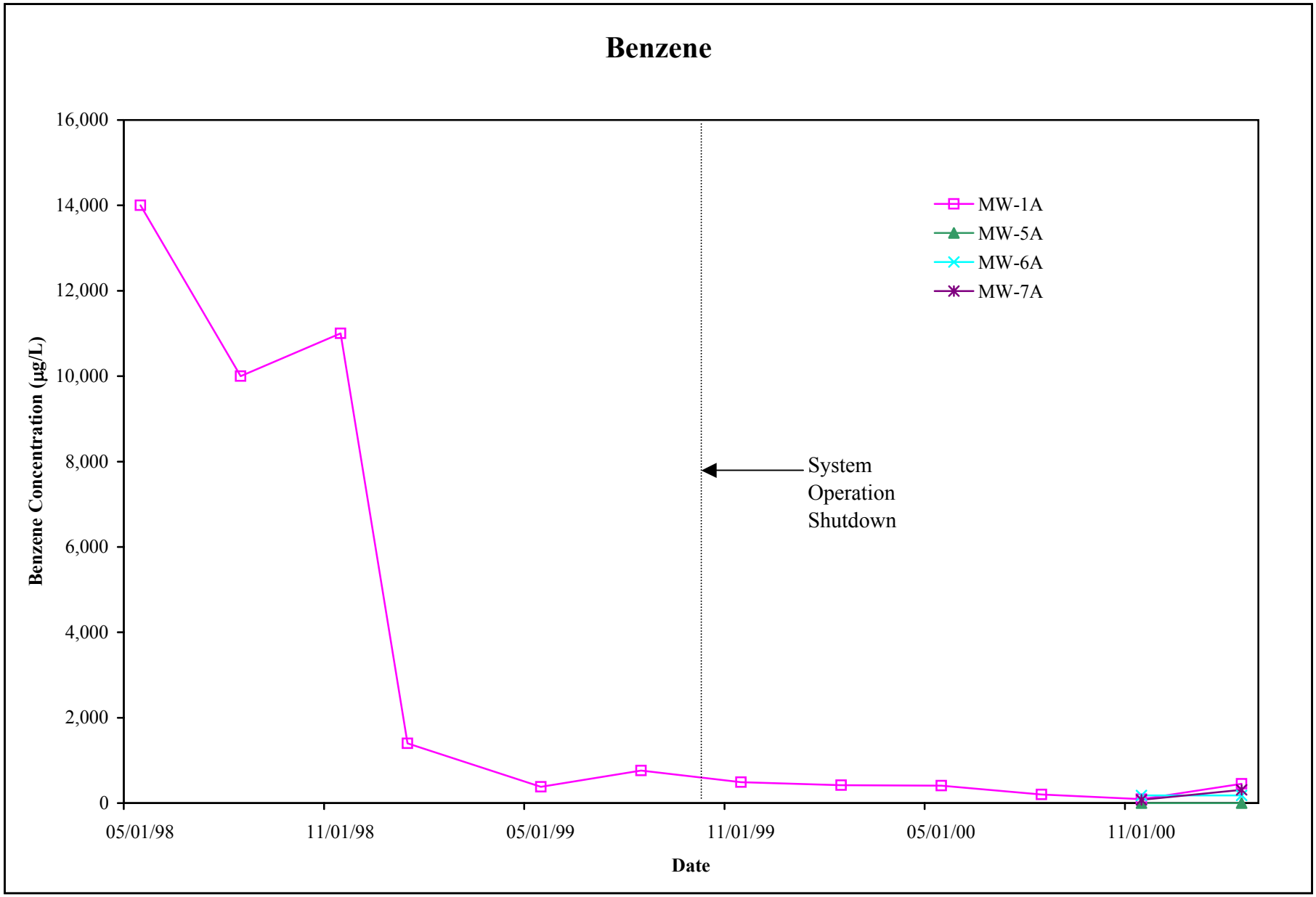
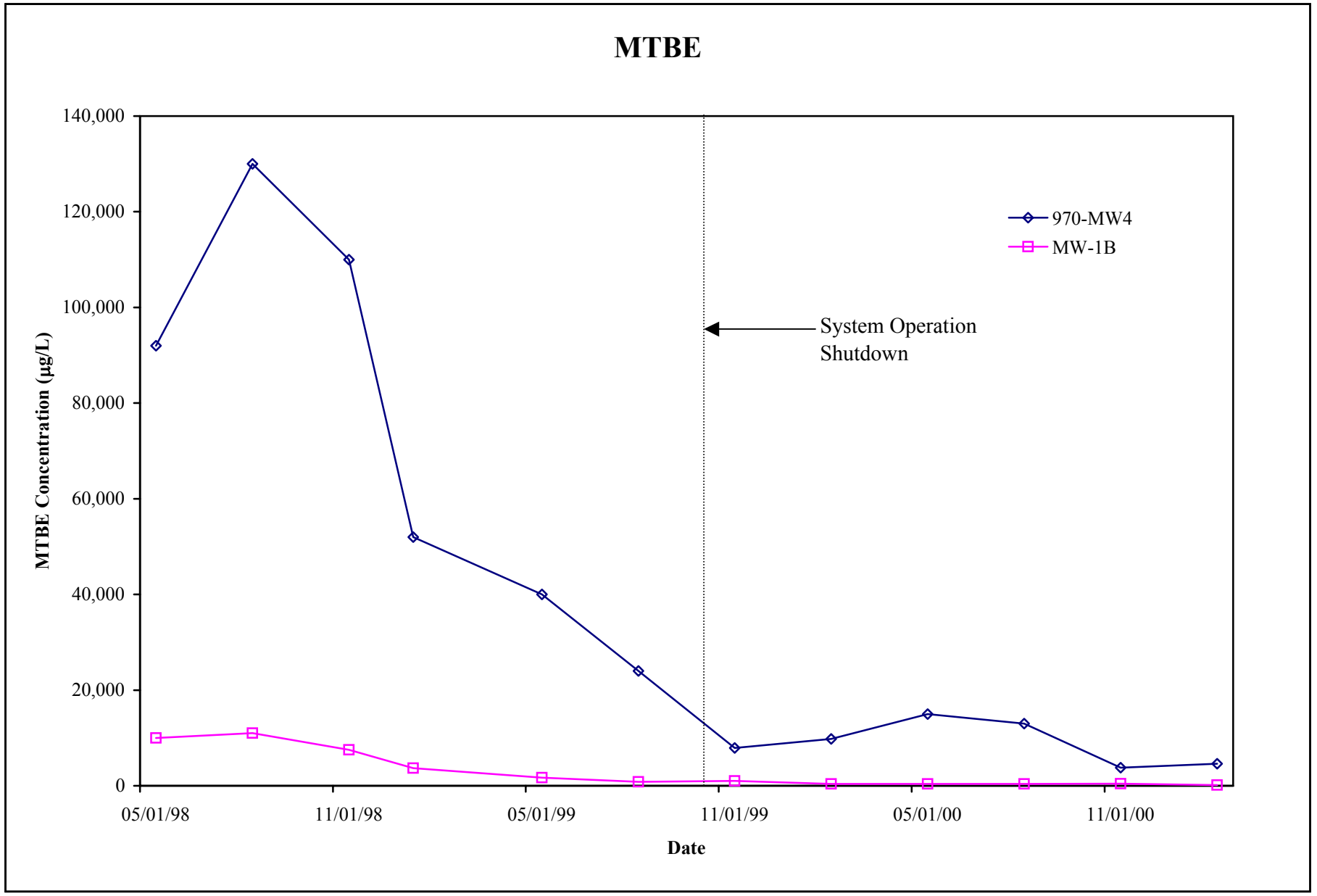


Figure 3-3. Influent TPH-G, BTEX, and MTBE Concentrations Over Time


Benzene
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Benzene Concentration (µg/L)
05/01/98
11/01/98
05/01/99
11/01/99
05/01/00
11/01/00
Date
MW-1A
MW-5A
MW-6A
MW-7A
System
Operation
Shutdown


MTBE
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
MTBE Concentration (µg/L)
05/01/98
11/01/98
05/01/99
11/01/99
05/01/00
11/01/00
Date
970-MW4
MW-1B
System Operation
Shutdown

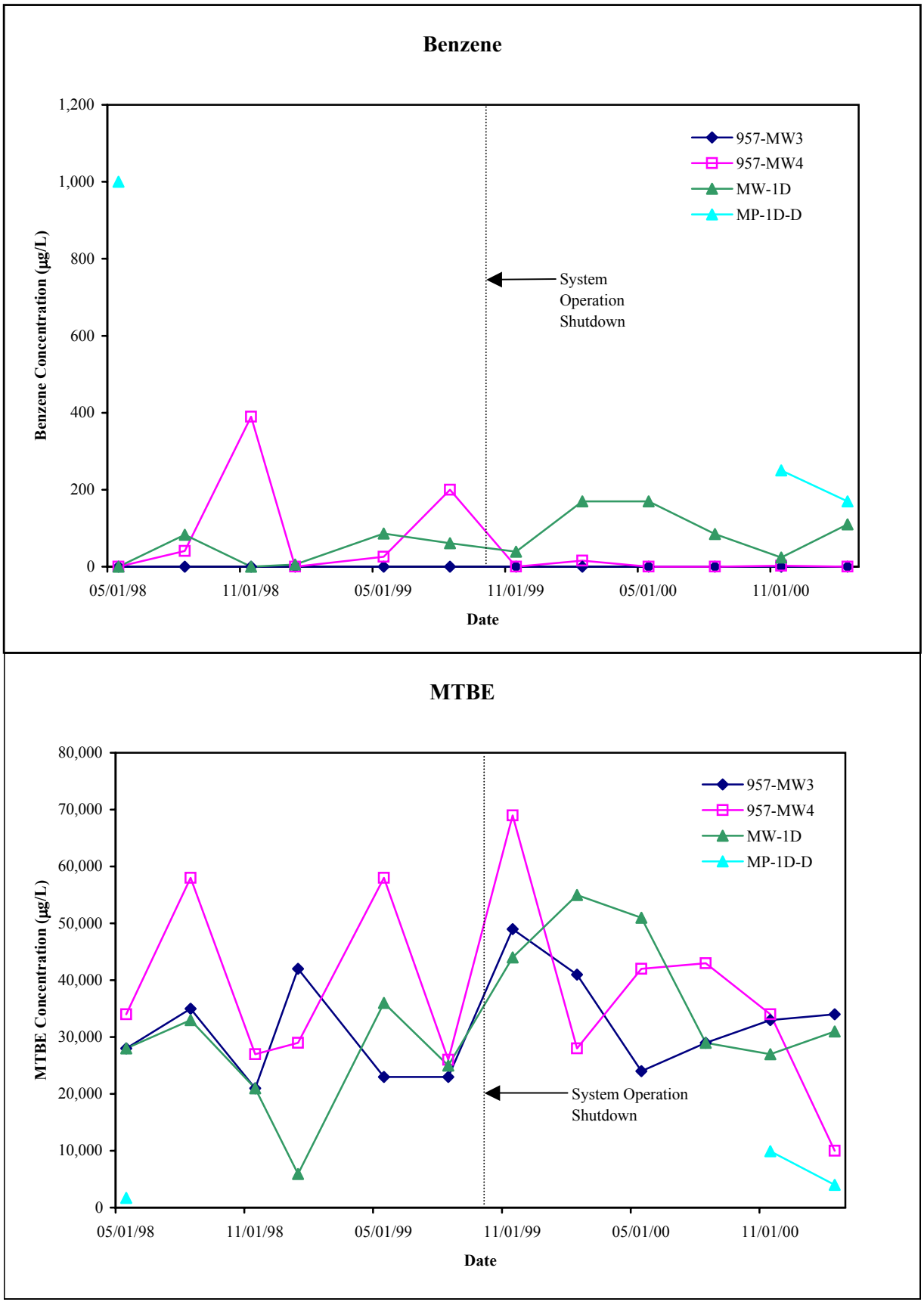


Figure 3-6. Area DE (Former UST 957 Source Area) Benzene and MTBE Time Series Graphs for Transect Wells

Table 3-1. Construction Details for Air Sparging and SVE Wells at Former UST Site 957/970

Well ID	Type of Installation	Date of Installation	Construction Material	Screen Slot Size	Borehole Depth (ft bgs)	Screened Area (ft bgs)
AS-1A	Air sparging	5/98	1-in. PVC	20 slot	18	13-15
AS-2A	Air sparging	5/98	1-in. PVC	20 slot	17.5	13-15
AS-3A	Air sparging	5/98	1-in. PVC	20 slot	17	13.5-15.5
AS-4A	Air sparging	10/98	1-in. PVC	40 slot	18	15.5-17.5
AS-5A	Air sparging	10/98	1-in. PVC	40 slot	19	16-18
AS-6A	Air sparging	10/98	1-in. PVC	40 slot	18	14-16
MW-2A	SVE	5/98	2-in. PVC	10 slot	14.5	4.5-14.5
MW-3A	SVE	5/98	2-in. PVC	10 slot	15	5-15
SVE-2A	SVE	10/98	4-in. PVC	40 slot	19	5-15
SVE-1A	SVE	10/98	4-in. PVC	40 slot	17	4.5-14.5
AS-1B	Air sparging	5/98	1-in. PVC	20 slot	15	11-13
AS-2B	Air sparging	5/98	1-in. PVC	20 slot	14	10.5-12.5
AS-3B	Air sparging	5/98	1-in. PVC	20 slot	15	12.5-14.5
AS-4B	Air sparging	10/98	1-in. PVC	40 slot	19	13-15
AS-5B	Air sparging	10/98	1-in. PVC	40 slot	19	14-16
AS-6B	Air sparging	10/98	1-in. PVC	40 slot	19	15-17
SVE-1B	SVE	5/98	2-in. PVC	10 slot	15	4.5-14.5
SVE-2B	SVE	5/98	2-in. PVC	10 slot	15	4.5-14.5
SVE-3B	SVE	10/98	4-in. PVC	40 slot	19	6.5-16.5
SVE-4B	SVE	10/98	4-in. PVC	40 slot	17	4.5-14.5
AS-1D	Air sparging	5/98	1-in. PVC	20 slot	14.5	12-14
AS-2D	Air sparging	5/98	1-in. PVC	20 slot	15	11.5-13.5
AS-3D	Air sparging	10/98	1-in. PVC	40 slot	17.5	13.5-15.5
AS-4D	Air sparging	10/98	1-in. PVC	40 slot	18.5	13-15
SVE-1D	SVE	5/98	2-in. PVC	10 slot	15	5-15
SVE-2D	SVE	10/98	4-in. PVC	40 slot	17	5-15
SVE-3D	SVE	10/98	4-in. PVC	40 slot	17	4.5-14.5
SVE-4D	SVE	10/98	4-in. PVC	40 slot	16	5-15
AS-1E	Air sparging	5/98	1-in. PVC	20 slot	16	12.5-14.5
AS-2E	Air sparging	5/98	1-in. PVC	20 slot	16.5	14-16
SVE-1E	SVE	5/98	2-in. PVC	10 slot	15	5-15

Table 3-2. Soil Vapor Extraction System Summary

Date	Flowrate (scfm)	Influent TPH-G (ppmv)	Effluent TPH-G (ppmv)	TPH-G Removal Rate (lb/day)	TPH-G Destruction Efficiency (%)	Total TPH-G Removed (lbs)	Total Benzene Removed (lbs)	Total Toluene Removed (lbs)	Total Ethylbenzene Removed (lbs)	Total Xylenes Removed (lbs)	Total MTBE Removed (lbs)
06/25/98	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
06/30/98	21	13,390	30.7	107	99.8	335	6	8	1	2	NA
07/30/98	74	8,000	22.0	193	99.7	5,342	95	124	21	72	325
09/01/98	28	15,585	1.1	229	100.0	9,121	135	196	35	157	497
10/01/98	84	3,951	1.1	208	100.0	14,473	177	282	48	275	705
10/29/98	90	4,829	87.8	145	98.2	17,505	193	329	56	360	794
11/16/98	65	3,732	39.5	126	98.9	18,307	199	341	58	380	840
12/01/98	65	3,293	72.4	87	97.8	19,312	208	352	60	412	917
12/09/98	55	1,822	10.3	58	99.4	19,425	208	353	61	416	922
12/28/98	55	1,400	13.0	34	99.1	19,904	210	357	62	433	934
01/29/99	46	1,500	3.1	28	99.8	20,453	211	361	65	458	942
02/16/99	46	1,200	12.0	23	99.0	20,893	212	362	66	493	949
03/16/99	55	240	4.7	14	98.0	21,243	212	363	66	530	953
04/13/99	65	100	2.8	3.9	97.2	21,352	212	363	66	535	954
05/17/99	65	150	1.2	3.1	99.2	21,457	213	363	66	538	957
06/10/99	75	61	1.2	2.8	98.0	21,524	213	364	67	539	959
10/05/99	80	1,660	34.0	50	98.0	22,948	214	374	70	549	977

scfm = Standard cubic feet per minute, standard temperature and pressure (STP).
ppmv = Parts per million, volume - data reported in milligrams per cubic meter and converted at STP.
lb/day = Pounds per day.
N/A = Not available.
Notes: Molecular weight of TPH-G is assumed to be 95. Molecular weight of BTEX and MTBE is 78.1, 92.1, 106.2, 106.2, and 88.15, respectively. When the specified compound was not detected, 1/2 the detection limit was used in the table.

Table 3-3. MTBE and Benzene Concentration in Sparge Wells – Initial and Following One Year of Operation

Well ID	MTBE Concentration (μg/L)		Benzene Concentration (μg/L)	
	Initial (1998)	One year (1999)	Initial (1998)	One year (1999)
Area A				
AS-1A[(a)]	280,000	23,000	13,000	4,200
AS-2A[(a)]	26,000	11,000	2,000	52
AS-3A[(a)]	85,000	4,500	5,300	390
AS-4A[(b)]	36,000	83	<500	<0.5
AS-5A[(b)]	37,000	920	<500	6.1
AS-6A[(b)]	130,000	82,000	18,000	26
Area B				
AS-1B[(a)]	46,000	24,000	4,700	970
AS-2B[(a)]	220	55	110	7.5
AS-3B[(a)]	53,000	64,000	4,500	23
AS-4B[(b)]	25,000	1,800	3,100	13
AS-5B[(b)]	95,000	5,100	3,400	300
AS-6B[(b)]	130,000	6,900	1,900	<0.5
Area DE				
AS-1D[(a)]	19,000	36,000	2,000	96
AS-2D[(a)]	26	29	46	22
AS-3D[(a)]	63,000	29,000	500	5.2
AS-4D[(b)]	52,000	3,200	430	1.1
AS-1E[(a)]	5,900	3,800	290	31
AS-2E[(a)]	31,000	46,000	<250	<20

(a) Original system sparge well – sampled in May 1998 and May 1999.
(b) System expansion sparge well – sampled in October 1998 and October 1999.

Section 4.0: CONCEPTUAL SITE MODEL AND NATURE AND EXTENT

This section describes the conceptual site model based on lithological data collected to date and the current nature and extent of gasoline constituents in soil and groundwater at the Site.

4.1 Conceptual Site Model Development

All available characterization data collected through the first quarter of 2001 was used to develop and update a conceptual site model representing typical conditions at the Site. Figure 4-1 is a generalized diagram depicting site conditions and the conceptual site model. The graphic representations of the conceptual site model were developed to represent site features, soil layering, aquifer characteristics, future site uses, and potential receptors (for risk assessment purposes). These representations embody all available site characterization information. The conceptual site model was updated as new information became available. The graphic depiction of the 3-D conceptual site model was constructed and visualized using EarthVision™ software (DGI, 1997), but additional maps and cross sections have been developed and evaluated to advance the understanding of key site conditions relevant to recent inputs to the conceptual site model.

The benefit of using EarthVision™ to build a 3-D depiction of the conceptual site model is that it can be viewed from any angle and manipulated or sliced in numerous ways in order to illustrate the hydrostratigraphic relationships present at the Site. The electronic 3-D image can be viewed from any perspective to see more clearly the trends and relationships between the primary soil layers. Figure 4-2 is a perspective view of the 3-D block diagram looking northeast at the Site. Figure 4-3 is a north-south cross-sectional view along the approximate centerline axis of the dissolved gasoline constituent plumes; whereas Figure 4-4 is an east-west cross-sectional view perpendicular to the plume axis, and therefore perpendicular to groundwater flow. The relationship between the slope of the land surface and the slope of the water table is clearly shown in Figure 4-3. The increase in saturated thickness going from south to north is evident as the bedrock surface, acting as the base of the aquifer, slopes downward from south to north at a steeper gradient than the water table elevations. Figure 4-5 shows the top of the water table with the vadose zone removed. The color-filled contours show the general trend of the groundwater flow from south to north with highs represented by orange, and lows represented by blue.

The following sections (4.1.1 through 4.1.2) describe in detail the information that forms the basis of the conceptual site model. The understanding of the geology and hydrogeology of the Site is based on soil lithology information gathered from core sampling, visual log information, CPT characterization data, and water level data. Well logs and water level data are provided in Appendices F and I, respectively. CPT test data for investigations conducted in April/May 1998 and August 1998 are provided in Appendix C and CPT test data collected during the remedial investigation (Battelle, 2001b) are provided in Appendix E. The description of aquifer characteristics was based on aquifer testing, water quality parameters measured and recorded while purging wells for sampling, and groundwater monitoring results. The locations of monitoring wells, air sparging wells, soil vapor extraction wells, soil-gas monitoring points and CPT pushes referenced in this section are shown in Figure 4-6. The characterization data upon which the conceptual site model is based were collected within an area that is approximately 1,000 ft by 3,000 ft in dimension, which approximates the boundaries of the dissolved MTBE plume.

4.1.1 Description of Conceptual Site Model Region. The Site lies within the Coast Range geomorphic province of northern California. Subparallel mountain ranges, alluviated intermontane valleys, and active northwest-oriented strike-slip faults characterize the province. Surface geology includes Quaternary sediments (Bay Mud, alluvium, and colluvium) that overlie Cretaceous Franciscan

bedrock. The Franciscan bedrock is generally hard, massive, and slightly fractured. In several upland areas that surround the Site, Franciscan bedrock crops out in isolated hills. A comprehensive summary of information pertaining to bedrock conditions at the Site is included in Attachment 3.

4.1.2 Primary Soil Layer Units. Based on geologic characterization data, three primary soil layer units were identified at the Site. The three units include the following:

- unsaturated alluvial fill
- saturated alluvial fill
- Franciscan bedrock.

The Site lithology is based on observations made during well installation and during three CPT investigations; two conducted in 1998 (see Section 2.2.2), and a third conducted in 2000 (see Section 2.2.3 and general description below).

Subsurface characterization efforts indicate that heterogeneous conditions predominate across the Site with sand, silt, gravel, and clays present in varying proportions and depths. Despite the heterogeneous conditions, soils can be delineated stratigraphically into three general layers. The actual depths of contacts between soil layers observed during drilling and sampling and cone penetration testing are summarized in Table 4-1. These lithologic data indicate that the top soil layer across the Site, which extends from ground surface to depths ranging from 1.5 to about 9.5 ft bgs, consists mostly of a sandy alluvial fill material. A sandy clay fill is then encountered from about 5 to 7 ft bgs. Sandy soils are then encountered at depths ranging from 7 to 15 ft bgs. These soils are part of the aquifer zone and generally consist of clayey to gravelly sands, but clay lenses are known to be present throughout this aquifer zone. The aquifer is underlain by bedrock, which is typically encountered at approximately 15 ft bgs in the former UST source areas. However, the depth to bedrock deepens northward and is encountered at locations north of State Access Road at depths greater than 30 ft bgs. Observations made during the August 1998 CPT investigation show a water-bearing (aquifer) layer ranging from approximately 10 to 15 ft bgs and consisting primarily of silt ranging from clayey silt to sandy silt. These CPT data appear to indicate that the aquifer is finer grained than it was observed to be in various core samples collected during drilling. Because visual field observations made by trained geologists, and grain-size analyses performed on a number of actual soil core samples indicate sandy soils are present, it is assumed conservatively that the aquifer is generally coarser grained than some of the CPT data seem to imply.

Sets of hydrostratigraphic cross sections, along with an associated cross-section trace map have been constructed (see Figures 4-6 through 4-12). These cross sections present more detail on the continuity and geometry of the site's layering, stratigraphy, and bedrock topography. Figure 4-6 presents a cross section trace map. It shows the alignment of the six cross sections. Figure 4-7 is cross section A-A', oriented north-south extending from the Main Entrance Road south of the former UST locations, northward to the area near the former bunkers, near the foot of Ammo Hill. The cross-section, which is aligned with the general groundwater flow direction, illustrates the dip of bedrock and overlying alluvial sediments across this area. It also depicts the three major soil layers encountered during drilling and sampling. The top of weathered bedrock also is depicted, which is a very irregular surface in areas defined by greater well coverage. The surface or top of weathered bedrock is significant because it, along with the distribution of hydraulic conductivity in the aquifer, influences the direction of groundwater flow. Cross sections B-B', C-C', D-D' E-E', and F-F' are oriented west - east, perpendicular to A-A'. Collectively these west-east cross sections lack a consistent trend in bedrock topography.

In September 2000, a very detailed third CPT investigation was conducted in an area east of Building 971 (former commissary building) and south of State Access Road. This investigation was performed to evaluate subsurface lithology and groundwater quality in an area directly along the axis of

the MTBE plume, upgradient of monitoring wells MW-M8, -M9, -M10, and -M16. This work was performed to determine if a sand channel was present in this area which may be serving as a conduit or preferential pathway for the northward-migrating MTBE plume. During this detailed investigation, a total of 42 CPT pushes along 4 transects were performed to total depths ranging from 15.58 to 31.66 ft bgs. Lithologic information was collected during each of the CPT pushes, and logs of depth vs. lithology were plotted for each push (see Appendix E). These logs were used to construct a series of four cross sections, one along each of the east-west oriented transects. Three additional cross sections were constructed perpendicular to the transects. Figure 4-13 shows the traces of each of the seven cross sections. The cross sections presented as Figures 4-14 through 4-17 show the lithological information collected during this CPT investigation oriented in the east-west direction. The same information is presented in cross sections 4-18 through 4-20, which are oriented north-south.

Results from this effort reveal that a zone of relatively coarser-grained sediments is present within the eastern half of the area of investigation, and that this zone appears to be transmitting the MTBE in groundwater northward. Although this area was found to be heterogeneous, soil-types and layers found in this area correlate with those found during previous characterization work in and around the former source areas. Due to the drop in bedrock topography, which slopes to the north, the contacts of generalized soil layers found in this new study area are encountered several feet deeper below ground surface, than is the case in and around the former UST source areas. There is a sandy zone extending from ground surface to depths as great as 10 to 11 ft bgs. Below this zone is a clayey sand zone that extends to about 15 ft bgs, followed by the well-sorted, more permeable sand zone, extending to 15-20 ft bgs. Finally, the CPT pushes encountered weathered bedrock at depths ranging from about 17 to 22 ft bgs. Pushes into weathered bedrock encountered sediments that were predominantly clay. CPT measurements implied that the weathered bedrock lacked sufficient permeability to enable Hydropunch™ sampling.

Alluvial Fill

An alluvial unit directly overlies the highly weathered and fractured Franciscan bedrock throughout the majority of Site 957/970. This layer consists of poorly consolidated interfingering deposits of clay, silt, sand, and gravel. A permeable, locally interconnected sand layer was encountered in many of the borings during well installation. Soil samples collected from Site 957/970 during numerous sampling events were analyzed for physical characteristics including bulk density, porosity, and grain-size distribution. The soil porosity values across the Site were derived from laboratory analyses of bulk density. Soil porosity averages 55.6%, although effective porosity is considerably lower in much of the Site's soils. Grain-size distribution results are presented in Table 4-2. The sand percentage within the alluvial fill layer ranges from 39 to 86% based on grain-size distribution tests and the visual logging of core samples. The alluvial fill consists of saturated and unsaturated zones. Characteristics of each zone are described briefly below.

Alluvial Fill - Unsaturated Zone. The depth to groundwater in the alluvial fill, and the resulting thickness of the unsaturated or vadose zone, varies seasonally by approximately 5 ft as determined by a series of water level data collected during the site characterization effort. As would be expected, the unsaturated zone is thinnest in early spring (March/April) during the period when groundwater levels are generally at their highest. The unsaturated zone is thickest in the late fall (November/December) when the water table is generally at its lowest levels.

Alluvial Fill - Saturated Zone. Groundwater in the alluvial fill is unconfined across the Site. From March to December 1998, the depth to groundwater varied from a minimum of 3 ft bgs to a maximum of 13 ft bgs across the Site. A water table elevation contour map that shows the general direction of groundwater flow across the Site in May 1999 is presented in Figure 4-21. Higher

groundwater elevations are evident during the late winter/early spring months. A set of quarterly groundwater level data is presented in tabular and graphic form in Appendix I. A series of water table elevation maps, which are also presented in Appendix I have been constructed using a total of thirteen sets of quarterly water level data collected across the Site from 1998 to 2001. Maps for more recent monitoring events are based on data from a greater number of monitoring wells. Seasonal changes in water levels are evident when comparing these maps. The general, overall direction of groundwater flow maintains a northward direction, and the set of maps indicate that groundwater flowing across the former source areas tends to converge as it flows northward toward wells north of State Access Road, and toward Pacheco Creek.

The unconfined aquifer has an approximate thickness ranging from 0 ft to over 25 ft across the Site (Figure 4-22). The direction of groundwater flow is generally toward the north. Hydraulic gradient values calculated from the flowpath lines shown in Figure 4-21 range from 0.0075 to 0.0200. The flowpath gradients and associated potential flow velocities are shown in Table 4-3. The groundwater flow path numbers identified in Table 4-3 are displayed on Figure 4-21.

Franciscan Bedrock

The Franciscan Formation is the bedrock unit that underlies the alluvial fill (see Attachment 3). The Franciscan Formation is blue-gray bedrock consisting of fine- to medium-grained sandstone that has been slightly altered by metamorphism sealing its primary porosity (IT, 1998). The bedrock, where weathered, is light brown or altered to clay. The sandstone is often fractured, creating secondary porosity, and the fractures are commonly filled by either calcite or silica material. Therefore, because there is very low effective porosity and little available pore volume, the Franciscan Bedrock is not a significant source or transmitter of groundwater at this Site. Rather, the bedrock acts as an aquitard or barrier to downward groundwater flow from the overlying unconfined aquifer.

Most borings drilled during site characterization were terminated at the contact between the alluvial fill and the top of bedrock. Bedrock was encountered as shallow as 4.6 ft bgs and as deep as 19 ft bgs at the Site. Depth to bedrock for the network of wells installed by the Navy in April 1998 is shown in Table 4-1. The high variability in the depths at which bedrock is encountered indicates a roughly eroded and weathered bedrock top or surface. Therefore, the contoured elevations of the bedrock surface (as shown in Figure 4-23) are only a representation of the actual bedrock surface and may not account for local crests or troughs in the actual topography of the bedrock surface. As can be seen from Figure 4-23, the bedrock surface slopes down from approximately 40 ft amsl in the southern portion of the Site, to below mean sea level on former HAAF property. In general, the depth to bedrock increases from south to north and from east to west at the Site.

In October 2000, two monitoring wells were drilled to total depths of 31 and 32 ft and completed in bedrock (Battelle, 2001b). Both wells have 5-ft-long screens; the tops of these screens were set 6 ft below the top of bedrock. Top of bedrock was defined by the depth at which refusal was encountered during split-spoon sampling. Overlying weathered bedrock and soils are generally clayey. The top of bedrock and its lithology was confirmed in subsequent rock core samples collected prior to well installation. Groundwater in both wells was sampled after development. Both wells were found to contain high levels of MTBE and low levels of benzene. The two wells were located to evaluate groundwater conditions in the fractured bedrock at the two former UST sources. Based on the rock core, the interval of bedrock that has been screened in both wells possesses the typical characteristics of the Franciscan bedrock: a dense, very well cemented, massive, slightly metamorphosed quartz sandstone, possessing low effective porosity. There was minor amounts of fracturing observed in the core at the shallower portion of the screened interval.

When bailed, both of these bedrock wells recharged very slowly and yielded very low volumes of groundwater. Because the rock cores show bedrock to be dense and impermeable, as confirmed by the low rate at which they recover after bailing, it seems likely that the hydrocarbons in groundwater collected in these wells originates from fractures and perhaps from the very bottom portion of the overlying alluvial aquifer (see Attachment 3). If that is the case, sampling results indicate that bedrock is potentially in hydraulic communication with the alluvial aquifer, at least when groundwater in the competent bedrock is bailed down severely. It is also possible that bedrock groundwater contains hydrocarbons, at least in the immediate area of the former USTs. Given that the Site is very close to base level, it is unlikely that there is a strong downward hydraulic gradient, so downward groundwater transport via advection is not likely to be occurring anywhere in the area of study. If this is true, then any gasoline constituents in bedrock are likely to have originated by diffusion. The very low hydraulic conductivity exhibited by bedrock, implies that groundwater collected in these two bedrock wells is not moving downward vertically, because the underlying competent bedrock is too impermeable. Groundwater in bedrock also would not likely move laterally downgradient, because the weathered bedrock is too clayey.

4.1.3 Groundwater Flow System Description. The basic components of the groundwater flow system were defined based on site characterization data. This section describes the characteristics of the aquifer and the hydraulic and physical parameters that were used to conceptualize the groundwater flow system.

Aquifer Description

In the area of the Site, the unconfined alluvial aquifer rests on top of the eroded bedrock valley of the Franciscan Formation. The bedrock valley is formed in between bedrock hillsides that open wider to the north and eventually release their surface water into San Pablo Bay in the distant downgradient direction. Upgradient, near the former UST areas, the valley is only a few hundred feet wide and has a steeper gradient than in the lowlands surrounding the base of Ammo Hill where the water table flattens considerably. Ammo Hill is a solitary bedrock hill north of the Site protruding through the alluvial sediments near the center of the bedrock valley. This hill forces the groundwater in the alluvial aquifer to flow around it; it diverges flow to the northwest and northeast (IT, 1998).

The alluvial valley making up the aquifer begins several hundred feet south of the Site and gradually widens from south to north. The saturated thickness of the aquifer is generally only a few feet in the area of the Site, but increases to greater than 25 ft thick to the north of the Site in an area just south of Ammo Hill. Seasonal fluctuations of a few feet are observed in the saturated thickness across the Site, and the fluctuations are associated with precipitation rates.

Groundwater recharge in the alluvial aquifer originates primarily from precipitation. There is also a significant amount of groundwater flux from portions of the aquifer that are upgradient in this bedrock valley. Figure 4-24 shows the water level hydrographs in relation to precipitation for the period from March 1998 to May 1999. This figure shows a significant correlation between precipitation and groundwater elevations. The groundwater elevations increase after an increase in precipitation, indicating that the primary source of recharge is precipitation. Monitoring well 957-MW1 showed a difference of up to 4 ft in water table elevation between the lowest (November 1998) and highest (March 1998) water level measurements.

Pacheco Creek is the primary surface water drainage feature of the valley near the Site. It is contained within a man-made culvert system extending to the northern portion of the Site. This underground culvert limits surface water/groundwater interactions in the immediate vicinity of the Site. However, where the area culvert does not exist (i.e., former HAAF property), it is likely that the creek is a

losing stream, or a source of groundwater recharge during dryer periods, and is a gaining stream, or a recipient of discharging groundwater during wetter months (IT, 1998). However, such interaction is likely limited because Pacheco Creek flows in a concrete-lined culvert from its point of outfall from the underground culvert to beyond the extent of the MTBE-impacted groundwater. The creek discharges into Ignacio Reservoir, east of Ammo Hill, which in turn, ultimately discharges to San Pablo Bay.

Hydraulic/Physical Parameters

The hydraulic and physical parameters pertain only to the conceptual site model area and to the primary unconfined aquifer. The values presented are typical average values across the Site and may not be indicative of all areas within the aquifer system due to the local heterogeneities across the Site. The parameters include hydraulic conductivity, salinity, bulk density, and porosity.

Hydraulic Conductivity. Numerous hydraulic conductivity values have been measured at the Site based on results of aquifer pumping tests and slug tests. Data from the NEX service station area consists primarily of pumping tests and slug tests performed by the Navy in June 1998. Table 4-4 displays the results of the slug testing for the nine selected wells. Each well was tested three times to determine an average conductivity value. The slug tests indicate a range of average conductivity values between 1.3 and 22.0 ft per day. Pump test results from two wells (MW-1A and VW-2B) yielded a conductivity range of 3.10 to 11.7 ft per day, respectively. The pumping rate for the 24-hour test at MW-1A was set at 1 L/minute, with MW-2A and 970-MW5 selected as observation wells. VW-2B was pumped for 12 hours at 0.9 L/minute, with MP-1B-L and VW-2B used as observation wells.

A 24-hour pumping test was conducted by IT (IT, 1998) in well W-12 located east of Ammo Hill more than one-half mile north of the NEX service station. All aquifer testing in the northern portions of the Site indicated a low to moderate hydraulic conductivity range of 0.288 to 7.2 ft per day (IT, 1998). Therefore, hydraulic conductivity values may be slightly higher in the upgradient NEX service station area in comparison to the areas to the north and hydraulically downgradient, but values in both areas are within the same order of magnitude.

The Navy did not investigate hydraulic conductivity values in the underlying bedrock. However, there may be groundwater in the fractured bedrock at the Site. A hydraulic conductivity value of 0.173 ft per day was measured for monitoring well 1MW-08 which is screened in bedrock (IT, 1998).

Salinity. Groundwater from 10 locations was analyzed for total dissolved solids (TDS). Analytical results for these samples are presented in Table 4-5. The average TDS concentration for all samples was 624 mg/L. The TDS concentration was below 1,000 mg/L for all samples.

The TDS in the aquifer underlying the Site was one of the parameters used to assess the quality of the aquifer as a drinking water source. The TDS concentrations observed in the former service station area (and given in the Table 4-5) are below the maximum 3,000 mg/L criterion for acceptable drinking water based on guidelines provided in SWRCB Resolution No. 88-63 (SWRCB, 1988).

Bulk Density. Bulk density, total organic carbon (TOC), and porosity measurements were assessed from 31 soil samples taken at various depths from 20 borehole locations (Figure 4-6) across the Site (Table 4-6). The bulk density values range from 1.00 to 1.55 g/cm^3, with the average being approximately 1.30 g/cm^3. The sample depths correspond to depths representing the unconfined aquifer zone sediments at the Site. Bulk density values from 12 samples from areas in the northern portions of the Site range from approximately 0.9 to 1.9 g/cm^3 (IT, 1998). Bulk density was used with other soil properties in intermediate calculations for determining total volume and mass of groundwater and groundwater solutes at the Site. Soil laboratory analytical reports can be found in Appendix H.

Porosity. Table 4-6 contains porosity measurements from samples taken at various depths from numerous borehole locations across the Site (Figure 4-6). The values range from 41.50 to 87.5 percent for the silty sand aquifer zone. These values are slightly higher than one would expect for typical silty sand-grain-sized sediments as can be seen in Table 4-7. Table 4-7 is a listing from Domenico and Schwartz (1990) of estimates of porosity based on sediment or rock type. Porosity also was used with other soil properties in intermediate calculations for determining total volume and mass of groundwater and groundwater solutes at the Site. Soil laboratory analytical reports can be found in Appendix H.

4.2 Current Nature and Extent of Gasoline Constituents

The current nature and extent of gasoline constituents in soil and groundwater at the Site are discussed in the following subsections.

4.2.1 Soil. The current nature and extent of gasoline constituents in soil at the Site was determined by the hydraulic lift excavation and removal activities within Building 970 conducted from April 17, 2000 to June 22, 2000 (Battelle and RRM, 2000) and soil sampling activities conducted in September 2000 during the remedial investigation (Battelle, 2001b) performed in compliance with RWQCB Order Task 2. The following subsections describe results of the hydraulic lift excavation and removal activities and remedial investigation as they apply to the current nature and extent of gasoline constituents in soil at the Site.

4.2.1.1 Building 970 Hydraulic Lift Excavation and Removal. A summary of the hydraulic lift excavation and removal activities conducted at Building 970 was presented in Section 2.1.1.5.2 of this CAP. The following discussion provides figures of analytical data for soil samples collected during the removal activities and summarizes the findings of the activities.

Analytical results for soil samples collected during the hydraulic lift removal activities were provided in Tables 2-7 through 2-10. Isopleth contours were not generated for the hydraulic lift excavation results due to the irregularity of sampling locations, excavations, and distribution of hydrocarbon-impacted soils (i.e., along the footer of Building 970). Soil sampling results for total petroleum hydrocarbons quantified as hydraulic oil (TPH-O), TPH-G, benzene, TPH-D, total oil and grease (TOG), lead, and chromium are presented in Figures 4-25 through 4-28. Petroleum hydrocarbon-impacted soil was encountered primarily along the oil/water separator system located in the northern and western portions of Building 970. The impact to soil is predominantly heavy-end petroleum hydrocarbons (including diesel, motor oil, and oil and grease), and metals including total chromium, nickel, and total lead in limited areas. The most significant impact was encountered within a shallow gravel fill material underlying the footer of the building. A significant difference in petroleum hydrocarbon and metals concentrations was noted between the heavily impacted gravel fill and the underlying native clay deposits, which served to limit the vertical extent of impact.

The hydraulic lift removal activities indicated that the primary source of impact to the subsurface was the oil/water separator system, specifically OWS1 and OWS2, and a broken effluent line, which was improperly repaired. The gravel fill surrounding the oil/water separator and associated piping likely provided a permeable lateral migration pathway for petroleum hydrocarbons, as evidenced by the general correlation between the distribution of gravel fill and impacted soil. Overexcavation activities were performed to the extent practicable to remove affected soils from those areas where analytical results indicated that the petroleum hydrocarbon soil cleanup level and/or total lead PRG for residential use were exceeded. Approximately 220 tons of soil were excavated and disposed at Class I or Class II landfills in accordance with state regulations. Complete removal of impacted soil was constrained by the limited work area inside the building and the potential to undermine building foundations. Therefore, residual petroleum hydrocarbons remain in soils underlying Building 970. Based on test pit exploration

and associated soil sampling, the lateral extent of residual petroleum hydrocarbons in soil is limited to soils underlying the northern and western perimeter footing foundation of the building. The estimated extent of residual petroleum hydrocarbons in soil is shown on Figure 4-29. A liberal estimate of the volume of hydrocarbon and metals-impacted soils remaining in place around Building 970 footings and walls is approximately 120 yd^3.

A comparison of maximum detected concentrations in soils that were left in place at Building 970 to applicable screening levels is presented in Table 4-8. Note that upper action limits from the *California LUFT Manual* (SWRCB, 1989) were used as screening levels for TPH-G and TPH-D because promulgated cleanup levels for TPH in soils had not been established by the RWQCB for the Site when the hydraulic lift removal activities were conducted. No action limits for TPH-O or TOG are established in the *California LUFT Manual;* therefore, the limit that was used for TPH-D (10,000 mg/kg) also was used for the longer chain hydrocarbons. No action limits were exceeded for any of the TPH ranges analyzed for in soil samples (Table 4-8). The Industrial PRG (U.S. EPA, 2000) for lead was exceeded in soils at one sampling location (EFF-4-E3) located near the footing of Building 970; however, no other Industrial PRGs were exceeded. Residential PRGs were exceeded only for lead in four locations, and for chromium in two locations. For this evaluation of screening levels, only maximum observed concentrations were considered. If average concentrations or upper confidence limits were to be considered, a larger margin of safety would result.

4.2.1.2 Remedial Investigation. A summary of the remedial investigation soil sampling activities was presented in Section 2.2.3.3 of this CAP. The following discussion presents isoconcentration maps of gasoline constituents in shallow and deep soils located in the vicinity of the former UST 970 complex (within the Sale Area) and former UST 957 (within the PBC Area) based on samples collected during the remedial investigation.

Analytical results for soil samples collected during the remedial investigation within the Sale Area were presented in Table 2-22. The locations in the Sale Area from which soil samples were obtained are presented in Figures 4-30 (for samples obtained from <8 ft bgs) and 4-31 (for samples obtained from >8 ft bgs). Figures 4-32 through 4-37 present the isocontours for TPH-G, benzene, toluene, ethylbenzene, total xylenes, and MTBE, respectively, for soil samples retrieved from <8 ft bgs in the Sale Area. Figures 4-38 through 4-43 present the isocontours for TPH-G, benzene, toluene, ethylbenzene, total xylenes, and MTBE, respectively, for soil samples retrieved from >8 ft bgs in the Sale Area. Generally, hydrocarbon concentrations in the Sale Area vary over several orders of magnitude, and variation is present both vertically and horizontally. Gasoline constituents were generally greater in concentration within the former UST cavity and adjacent areas. Benzene concentrations varied from 0.5 µg/kg in SB-7A to 3,800 µg/kg in MW-7A. Xylene and TPH-G concentrations were high at monitoring well locations MW-6A and MW-7A. MTBE concentrations in the Sale Area ranged from <7.5 µg/kg at SB-18A to 8,900 µg/kg at SB-9A. Toluene and ethylbenzene levels ranged from <1 µg/kg to 59,000 µg/kg, except for boring location SB-13A, which had a toluene concentration of 120,000 µg/kg and an ethylbenzene concentration of 110,000 µg/kg at a depth of 12 ft bgs (below the water table). Total xylenes concentrations ranged from less than 1 µg/kg in several borings to a maximum level of 12,800 µg/kg in soil boring SB-5A. TPH-G concentrations were generally less than 10 mg/kg in samples collected from the Sale Area. Eight samples had TPH-G concentrations over 10 mg/kg. Results appeared relatively elevated in boring location SB-13A at a depth of 12 ft bgs with total xylenes levels of 585,000 µg/kg and TPH-G levels of 2,000 mg/kg. However, this sample was obtained from below the water table and therefore was saturated at the time of collection. During drilling activities, no separate-phase hydrocarbons were observed in the Sale Area boring locations. Laboratory analytical data are presented in Appendix D.

Analytical results for soil samples collected during the remedial investigation in the PBC Area were presented in Tables 2-23 and 2-24. The locations in the PBC Area from which soil samples were obtained are presented in Figures 4-30 (for samples obtained from <8 ft bgs) and 4-31 (for samples obtained from >8 ft bgs). Figures 4-44 through 4-50 present the isocontours for TPH-G, benzene, toluene, ethylbenzene, total xylenes, MTBE, and TPH-D respectively, for soil samples retrieved from <8 ft bgs in the PBC Area. Figures 4-51 through 4-57 present the isocontours for TPH-G, benzene, toluene, ethylbenzene, total xylenes, MTBE, and TPH-D, respectively, for soil samples retrieved from >8 ft bgs in the PBC Area. The highest concentrations of gasoline constituents were detected at locations SB-1D and SB-3D. MTBE concentrations in the PBC Area ranged from less than detection in several borings to a maximum level of 1,200 μg/kg in SB-3D. Benzene was highest in SB-3D with a concentration of 250 μg/kg. Toluene concentrations ranged from less than 1 μg/kg in several borings to a maximum level of 15 μg/kg in SB-8D. Ethylbenzene concentrations ranged from less than 1 μg/kg in several borings to a maximum level of 5,700 μg/kg in SB-3D, and total xylenes ranged from less than detection in several borings to a maximum level of 12,000 μg/kg in SB-1D. TPH-MO concentrations were highest at SB-8D, with a concentration of 2,200 mg/kg. TPH-G concentrations ranged from 0.02 mg/kg in SB-5D to a maximum level of 480 mg/kg in SB-3D. TPH-D concentrations were detected up to 300 mg/kg in SB-8D with most other locations being less than detection. JP-5 was greatest in SB-13D and was detected at a concentration of 403 mg/kg. Similar to the Sale Area, hydrocarbon concentrations were greater in locations adjacent to the former UST cavity. No separate-phase hydrocarbons were observed in the PBC Area boring locations. Laboratory analytical data are presented in Appendix D.

Based on the isoconcentration maps of gasoline constituents in the Sale Area and the PBC Area and EarthVision™ modeling, TPH-G masses of approximately 58 kg and 3 kg were estimated to be present in soils in the Sale Area and the PBC Area, respectively, following the remedial investigation activities in September 2000 (see Table 4-9). Likewise, EarthVision® modeling of soil sample results collected in September 2000 indicated benzene masses of approximately 0.4 kg and 0.0 kg in soils within the Sale Area and the PBC Area, respectively (Table 4-9). EarthVision® modeling also indicated postremediation MTBE masses of 7.3 kg and 0.1 kg in soils within the Sale Area and the PBC Area, respectively.

Gasoline constituent concentrations found in unsaturated soils of the Sale Area and the PBC Area during the remedial investigation were evaluated for the potential risk posed to future receptors at the Site in the Draft Revised Risk Assessment (Battelle, 2001c). The results of the Draft Revised Risk Assessment are discussed in Section 5.2.5.

4.2.2 Groundwater. MTBE and benzene are the gasoline constituents of primary concern impacting the groundwater at the Site. Other gasoline constituents include toluene, ethylbenzene, and total xylenes; however, they are not considered to be risk drivers at the Site. The current extent of the plumes has been characterized and is summarized in this section. In addition, discussion is provided to address hydrocarbons found in: (1) monitoring wells installed during the remedial investigation (Battelle, 2001b) along a transect perpendicular to the general direction of groundwater flow and located just downgradient (within 10 ft) of the former UST 970 complex; (2) bedrock wells installed in the vicinity of the former UST 970 tank complex and former UST 957 during the remedial investigation to determine whether hydrocarbons have impacted the fractured bedrock underlying the alluvial aquifer; and (3) nested well pairs located on Former HAAF property, which were installed during the remedial investigation to determine if a variation of MTBE concentrations exists between the upper and lower levels of the aquifer.

4.2.2.1 MTBE. The MTBE groundwater plume contour map from February 2001 is presented in Figure 4-58. The contour map was developed from analytical results from groundwater samples collected

at permanent monitoring wells during the twelfth quarterly monitoring event. Over the twelve quarters of monitoring the general extent and shape of the MTBE plume has remained relatively constant, with the exception of some minor changes due to seasonal effects and modifications to the monitoring well network. The MTBE groundwater plume at the Site (Figure 4-58) currently extends approximately 3,000 ft along the north-south center plume axis. The width of the plume ranges from approximately 380 ft near the former UST 970 complex to over 1,000 ft at the most downgradient extent. In February 2001 there was a maximum MTBE concentration of 43,000 µg/L in a well located approximately 650 ft downgradient of the former UST 970 complex, and concentrations greater than 10,000 µg/L did not extend north of Navy property.

The maximum concentration of MTBE in groundwater during the February 2001 quarterly monitoring event (43,000 µg/L) constitutes an increase from the previous sampling event (35,000 µg/L in November 2000); however, it is still equal to that of the August 2000 sampling event. In addition, the maximum MTBE concentration during the February 2001 quarterly monitoring event was less than that observed during February 1999 and February 2000, indicating a long-term decreasing concentration trend once fluctuations associated with seasonal variation are ignored. The average concentration of MTBE in groundwater during the February 2001 monitoring event was 3,779 µg/L, which was less than that observed during the previous quarterly monitoring event (November 2000) and in previous February monitoring events.

The dissolved MTBE mass estimate calculated from data collected during February 2001 was 156 kg, which is greater than that detected during the previous quarterly monitoring event (November 2000). As described in the *Annual Site Status Report (for the Year 2000)* (Battelle, 2001a), the increase in MTBE mass observed from the August to November 2000 sampling events is related to additional data provided by wells that were replaced in September 2000. Wells did not exist at these locations for the three previous sampling events, and therefore could not be used in mass calculations. An increase was again observed from November 2000 to February 2001. Long-term trends in plume behavior should be made over seasonal cycles, that is, comparing data from months as near each other as possible, and separated by at least a full seasonal cycle (i.e., March 1998 may be compared to February 2001). Changes in data values from quarter to quarter offer little value for interpreting long-term plume trends.

4.2.2.2 Benzene. The benzene groundwater plume contour map from February 2001 is presented in Figure 4-58. The extent and shape of the benzene plume has remained relatively constant between each of the twelve quarterly monitoring events. The current extent of benzene in groundwater at the Site (Figure 4-58) is approximately 800 ft long along the plume centerline. The plume extends from south to north in the direction of groundwater flow and is approximately 200 ft wide along most of its length. A maximum concentration of 660 µg/L was detected in the groundwater at MW-4A in February 2001, located approximately 150 ft downgradient from the former UST 970 complex.

The maximum concentration of benzene in groundwater during the February 2001 quarterly monitoring event was 660 µg/L. This maximum concentration was less than half that observed during the preceding sampling event (November 2000). The maximum benzene concentration during the February 2001 quarterly monitoring event was less than that observed during February 1999 and February 2000, indicating a long-term decreasing concentration trend rather than fluctuations associated with seasonal variation. An average concentration of benzene in groundwater was calculated to be 31 µg/L. This average concentration was less than that observed during the previous quarterly monitoring event (November 2000) and in previous February monitoring events.

The dissolved benzene mass estimate calculated from data collected during February 2001 was 0.34 kg. This estimated benzene mass increased slightly from the previous sampling event (from

0.26 kg to 0.34 kg); however, the estimate remains significantly lower than the benzene mass estimates from February sampling events in the previous two years (2.3 kg in January 1999 and 0.74 kg in February 2000).

4.2.2.3 Other Gasoline Constituents. Other gasoline constituents that may be of interest but are not risk drivers at the Site include toluene, ethylbenzene, and xylenes. Figure 4-58 shows the concentration contours for each of these BTEX constituents for February 2001 and indicates that the plumes have the same approximate shape and extent as the benzene plume.

4.2.2.4 Gasoline Constituents in Wells Installed During the Remedial Investigation

Transect Wells Downgradient of the Former UST 970 Complex. Analytical results during the February 2001 quarterly sampling of newly installed monitoring wells (MW-5A, MW-6A, and MW-7A) located downgradient of the former UST 970 complex indicate the presence of MTBE at concentrations of 1,100 μg/L, 860 μg/L, and 8,100 μg/L, respectively. In addition, benzene was detected at concentrations of 180 μg/L and 310 μg/L in monitoring wells MW-6A and MW-7A, respectively. Other BTEX compounds were detected in MW-6A and MW-7A with the maximum concentration being 5,000 μg/L of total xylenes in MW-6A. February 2001 was the second time each of these newly installed wells were sampled, and consistent trends of gasoline constituent levels have not yet been identified. MTBE concentrations in MW-5A and MW-6A decreased from levels detected during the latest quarterly monitoring event (November 2000) while an increase from 400 μg/L to 8,100 μg/L of MTBE was reported in MW-7A. Benzene concentrations in MW-6A during November 2000 and February 2001 were both reported at 150 μg/L and benzene in MW-7A showed a slight increase (77 μg/L in November 2000 to 310 μg/L in February 2001). Concentrations in these wells will continue to be evaluated to distinguish long-term and seasonal trends.

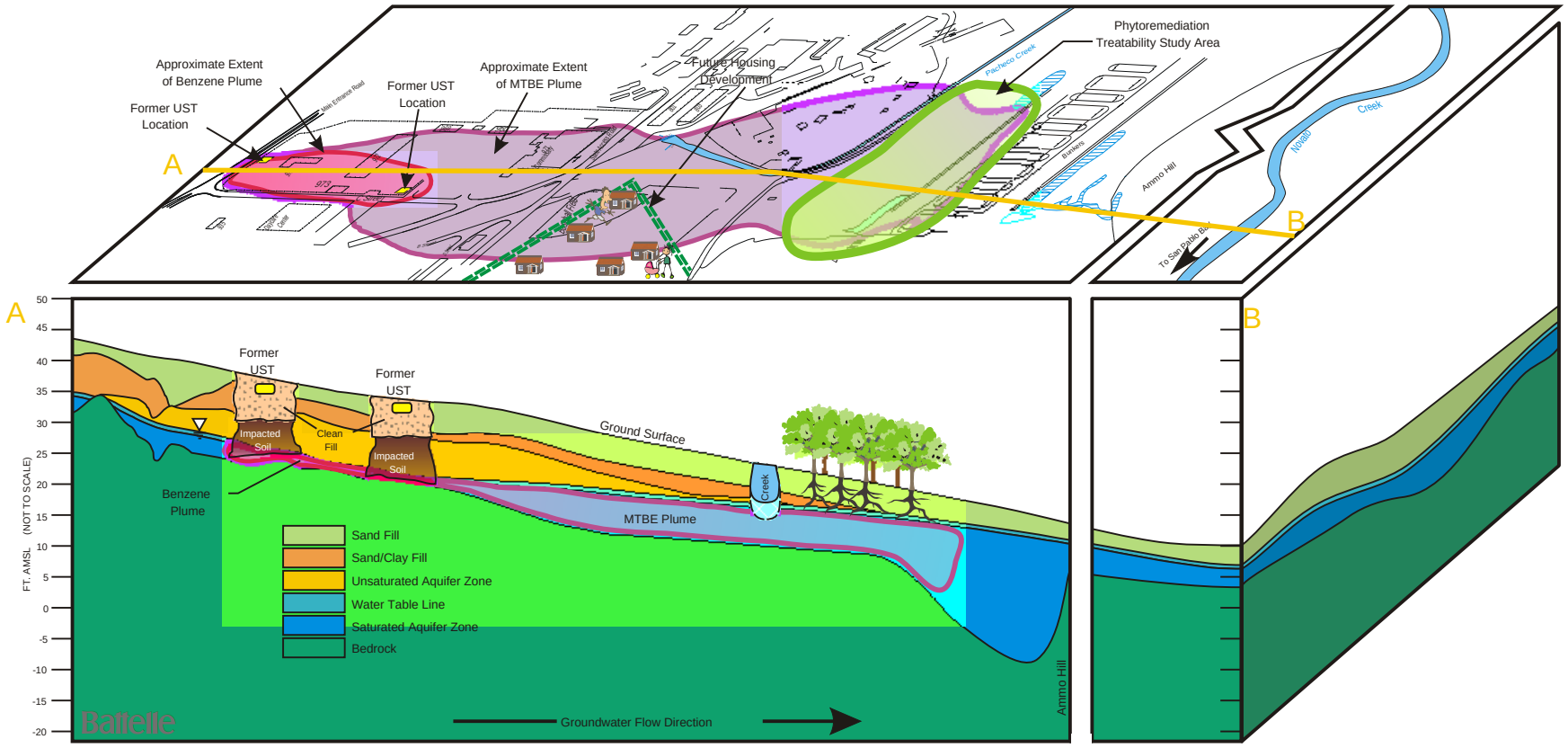
Bedrock Wells. Results of laboratory analyses performed on the groundwater samples collected from the bedrock wells (MW-9A and MW-3D) during the February 2001 quarterly monitoring event are presented in Table 4-10 and indicate that MTBE concentrations in wells MW-9A and MW-3D were reported at 600 μg/L and 43,000 μg/L, respectively; also, benzene levels in MW-9A and MW-3D were reported at 16 μg/L and <20 μg/L, respectively. MTBE concentrations in both wells have increased since the November 2000 sampling event. The benzene concentration also increased in MW-9A; a benzene concentration trend cannot be determined in MW-3D because of elevated detection limits for benzene. Monitoring well MW-5A is screened in the shallow aquifer and located approximately 13 ft upgradient of bedrock well MW-9A. The benzene and MTBE concentrations reported in MW-5A during February 2001 were <1.0 and 1,100 μg/L, respectively. Monitoring well 957-MW4 is screened in the shallow aquifer and located approximately 3 ft southwest of bedrock well MW-3D. Benzene and MTBE concentrations in monitoring well 957-MW4 both decreased from the November 2000 to the February 2001 sampling event (Table 4-10).

Overall, the bedrock wells (MW-9A and MW-3D) showed increasing concentrations, but the adjacent wells completed in the shallow aquifer (MW-5A and 957-MW4) both showed decreasing concentrations. Based on this information, it appears either that bedrock groundwater is and has been storing appreciable levels of MTBE as well as some benzene; and/or when these wells are purged during sampling, the wells are pulling impacted groundwater downward from the base of the alluvial aquifer or the underlying fracture zone.

It is unlikely that there are significant natural downward flow gradients in the areas of the two bedrock wells, so gasoline constituents were probably not carried down by natural advective flow. It is also unlikely that these gasoline constituents extend to greater depths at the Site. Core samples of the

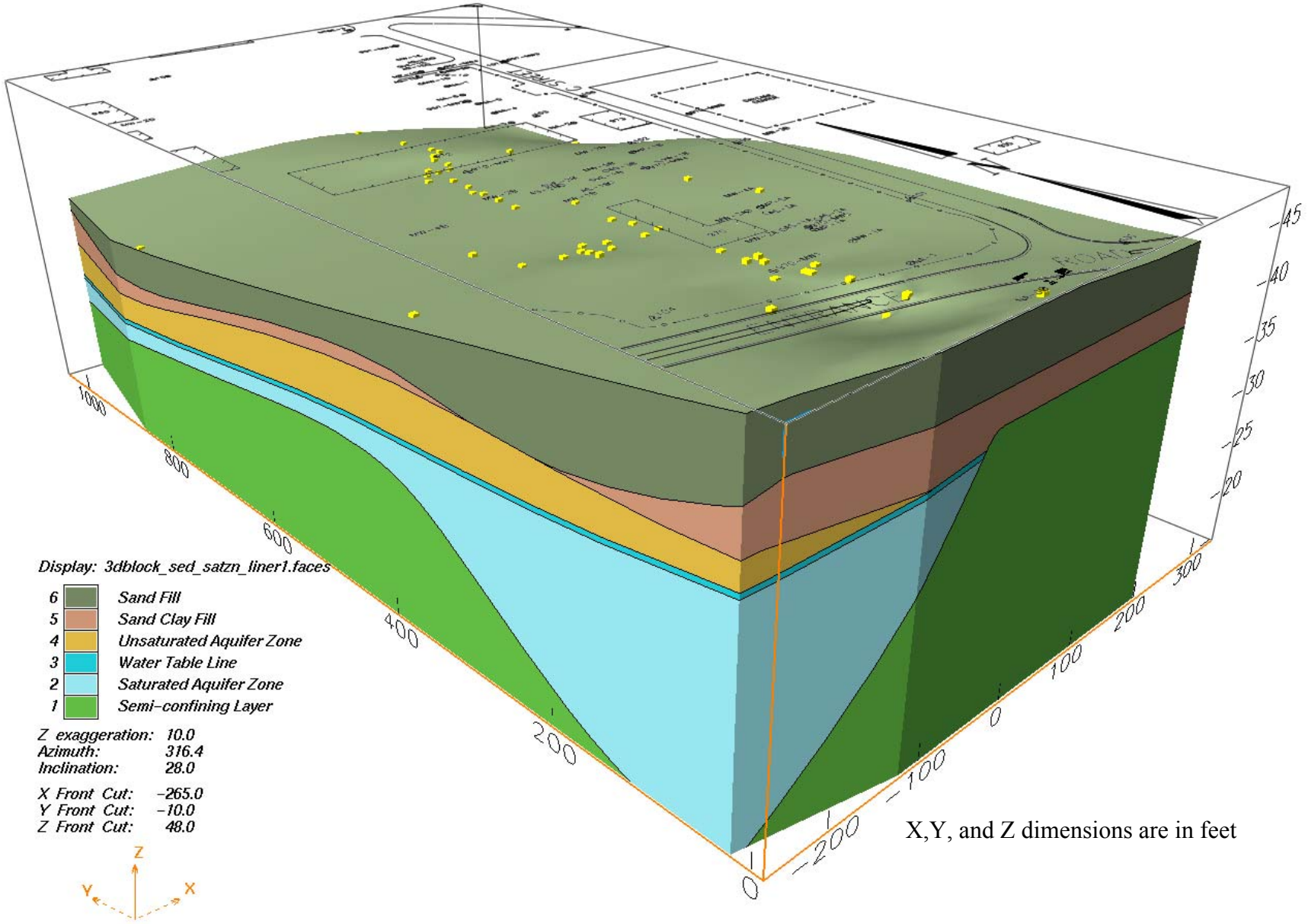
bedrock indicate that it is a dense, slightly metamorphosed quartzite sandstone that has low porosity and permeability (see Attachment 3). Both wells recharge very slowly (~24 hrs.) when they are bailed or pumped down during sampling. Future monitoring will be required to confirm the magnitude and persistence of this MTBE, and its impact on the fractured bedrock near the former UST locations. The information collected to date implies that the MTBE is likely associated with residual hydrocarbons, probably local to the former source areas.

Bi-level Nested Wells. Analytical results from the five nested well pairs, which were installed during the remedial investigation to determine if a variation of MTBE concentrations exists between the upper and lower levels of the aquifer, do not provide evidence of MTBE stratification (see Table 4-11). The shallow depth at MW-M20 could not be sampled due to dryness in February 2001; therefore, no comparison can be made for this well. MTBE concentrations of less than detection were observed both in MW-25S and MW-M25D; however, the detection limits ranged from 0.5 to 10 μg/L. Measurable concentrations of MTBE were reported in the other three well pairs and were consistent between the shallow and deep intervals. Concentrations of 39 and 30 μg/L were observed in MW-M14S and MW-M14D, respectively. The concentration of MTBE was reported at 370 and 320 μg/L in nested well pair MW-M26S and MW-M26D, respectively, and was reported at 1.7 μg/L in both shallow and deep intervals of nested well MW-M27. Though these limited data show that similar MTBE concentrations exist at varying aquifer depths, future monitoring will be performed to determine if seasonal variations may affect MTBE stratification.



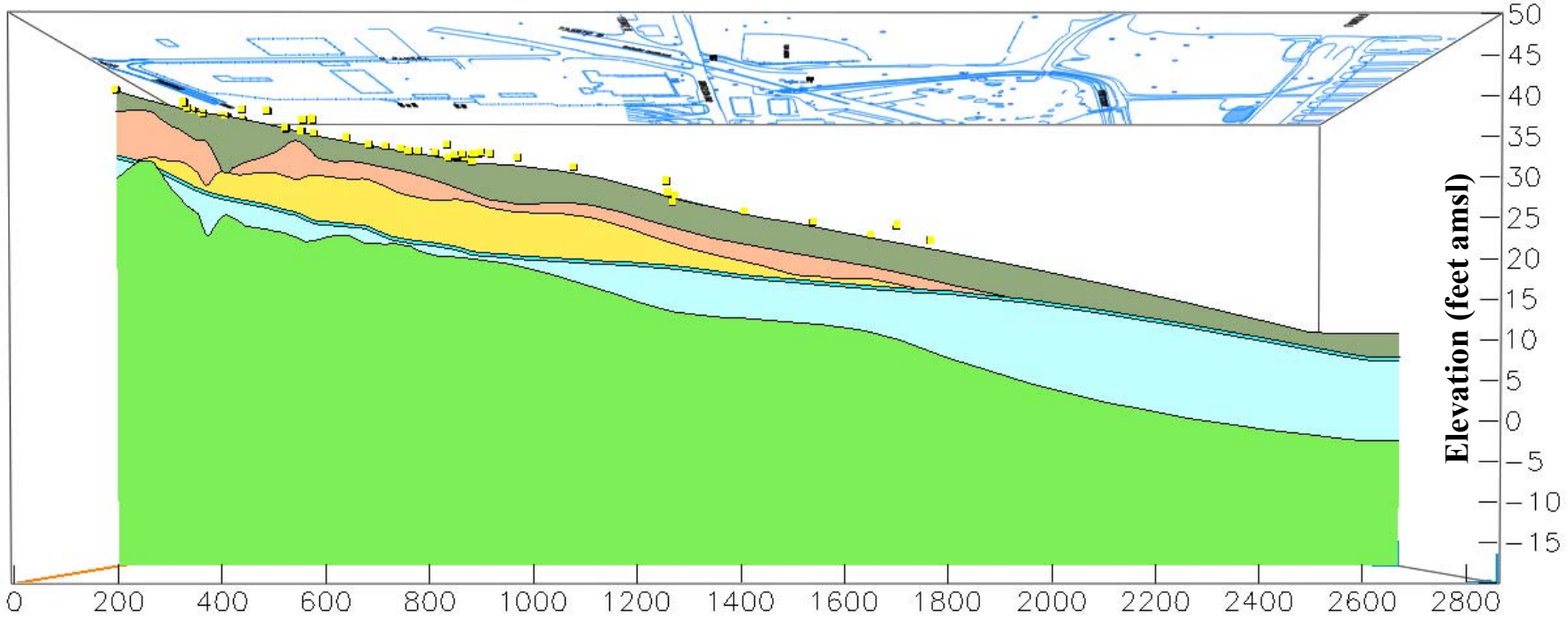
Not a cross section. Typical subsurface conditions.

Conceptual Model of Former UST Site 957/970



X,Y, and Z dimensions are in feet

South North

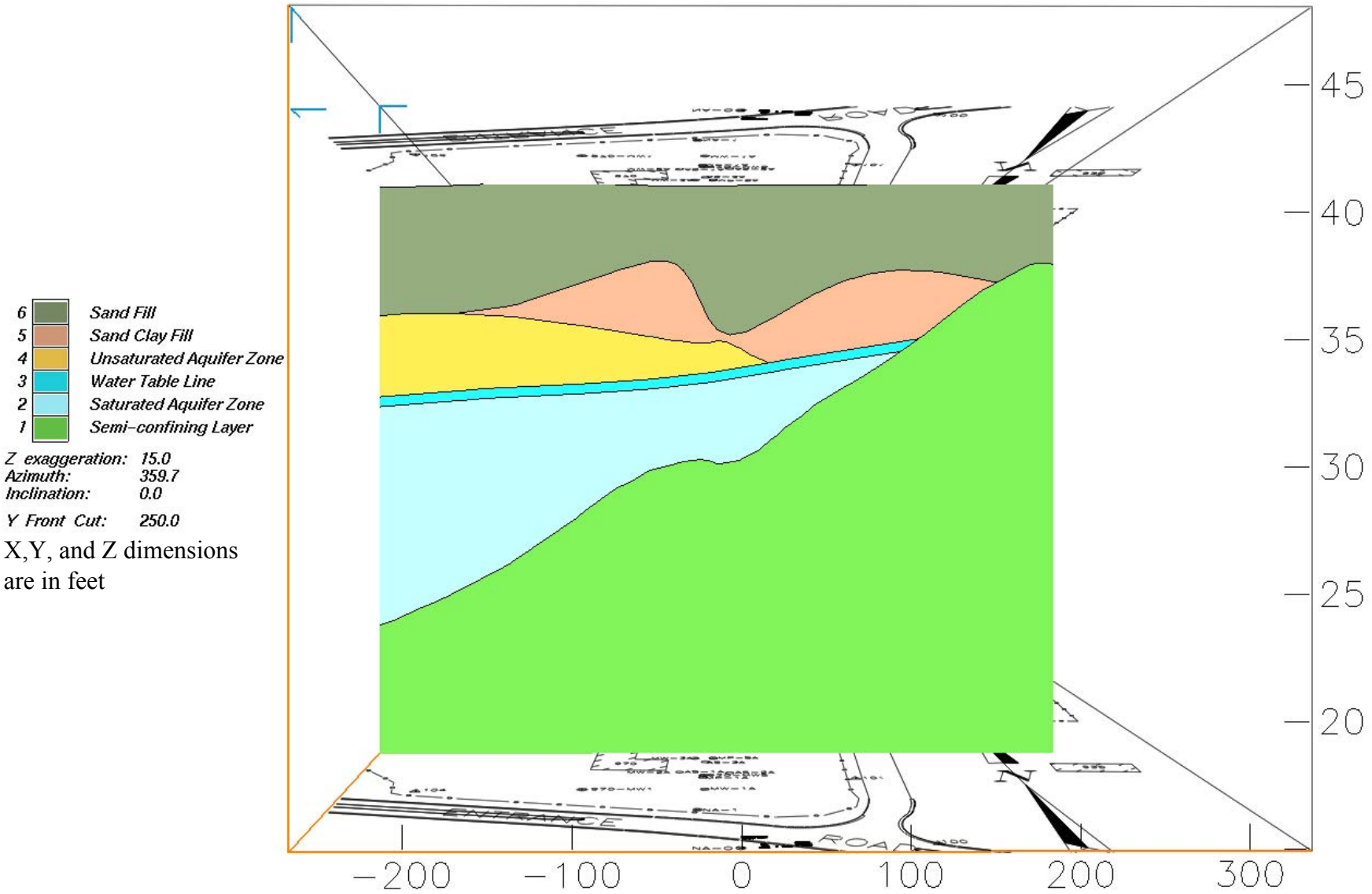


Display: 3dblock_concptmod.faces

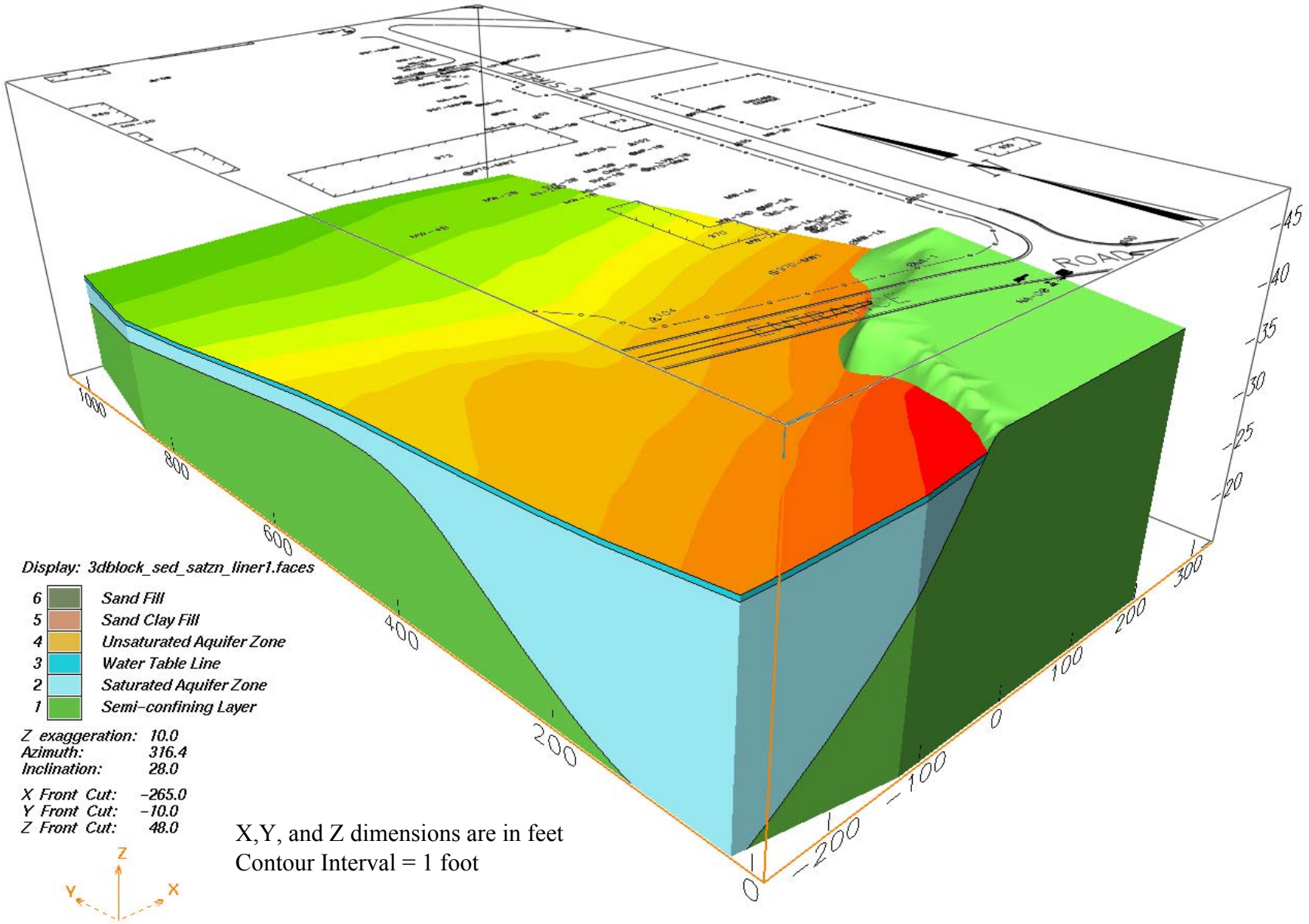
6	*Sand Fill*
5	*Sand Clay Fill*
4	*Unsaturated Aquifer Zone*
3	*Water Table Line*
2	*Saturated Aquifer Zone*
1	*Semi-confining Layer* (Bedrock)

Z exaggeration: 15.6
Azimuth: 89.8
Inclination: 0.85

X Front Cut: −5.0

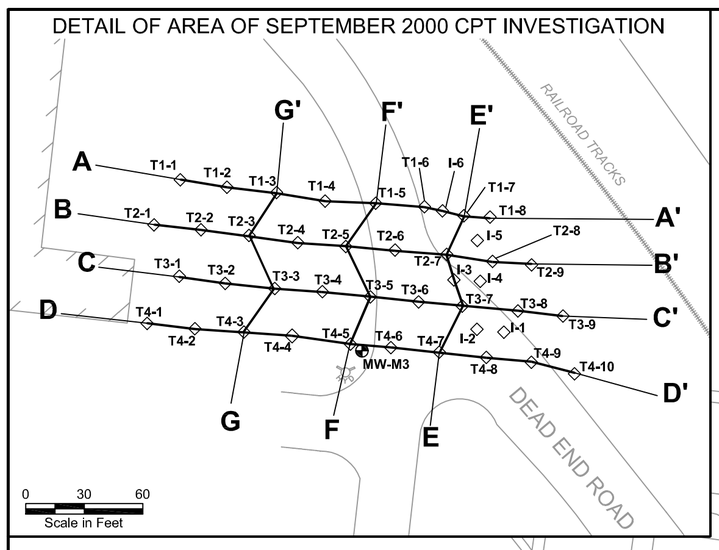


X,Y, and Z dimensions are in feet



X,Y, and Z dimensions are in feet
Contour Interval = 1 foot

DETAIL OF AREA OF SEPTEMBER 2000 CPT INVESTIGATION



AMMO HILL

LANDFILL 26

LANHAM VILLAGE

IT-MW-81
IT-PZ-16
IT-PZ-17
IT-PZ-15
IT-MW-92-41
IT-GMP-18
IT-GMP-17
IT-GMP-16
IT-GMP-15
IT-EW91-2
IT-EW91-1
IT-MW-92-38
IT-MW-92-39
MW-M12
CPT-H2
MW-M13
CPT-H1
CPT-H3
MW-M14
IT-1MW-5
IT-PZ-7
MW-M27
CPT-K3
A'
IT-PZ-9
CPT-K1
CPT-K2
MW-M26
CPT-G1
CPT-G1A
CPT-G2
CPT-G3
B
IT-PZ-5
IT-2MW-2
CPT-J1
IT-1MW-4A
IT-PZ-4
CPT-J5
MW-M11
CPT-J4
CPT-J3
CPT-J2
ITPZ-2
MW-M25
IT-1MW-2
B'
CPT-C2
IT-2MW-1
CPT-F2
CPT-C1
CPT-FI
B833-STW-006
B833-STW-007
MW-M19
CPT-B2
CPT-E1
MW-M18
MW-M23
TW-M2
MW-M15
MP-5/MP-6
CPT-1
MW-M22
TW-M1
CPT-L1
MW-M24
CPT-L2
MW-M21
CPT-B1
CPT-D1
CPT-14 (PZ-4)
MW-M17
CPT-6
IT-PZ-1
CPT-12 (PZ-3)
CPT-A1
CPT-2
GP-Q
GP-P
GP-O
GP-N
CPT-A2
CPT-8
CPT-13
CPT-7
CPT-5
MW-M4
GP-R
MW-M20
MP-7/MP-8
CPT-3 (PZ-1)
STATE ACCESS ROAD
C
CPT-9
MW-M1
GP-E
GP-F
GP-G
MW-M10
MW-M9
GP-H
GP-I
GP-J
MW-M8
MW-M7
GP-L
C'
MW-M16
CPT-10
CPT-11
MW-2E
971 COMMISSARY
RAILROAD TRACKS
B STREET
AREA OF SEPTEMBER 2000 CPT INVESTIGATION
(See Detailed View at Top Left)
957-MW1
MW-1E
SVE-1E
AS-2E
AS-1E
SVE-4D
MP-1D
AS-4D
AS-1D
SVE-1D
MW-1D
957-MW4
MW-3D
AS-2D
957-MW3
SG-18
SG-19
NA-7
SVE-3D
AS-3D
SG-17
SVE-2D
NA-6
957-MW2
NA-5
NA-4
NA-3
NA-2
SG-14
SG-13
970-MW2
SG-1/SG-2
MW-6B
960
969
972
973
930
931
932
933
934
935
915
803
801
1000
D
MW-2D
D'
MW-M2
GP-5
Approximate Area of Excavation for Former UST 957 Complex
Approximate Area of Excavation for Former UST 970 Complex
Former Waste Oil Tank
MW-10A
SG-12
AS-6B
VW-2B
SVE-4B
MP-1B
MW-2B
MW-5B
AS-3B
SVE-2B
AS-2B
SVE-1B
AS-1B
VW-1B
970-MW4
MW-1B
AS-5B
SG-16
SVE-3B
AS-4B
MW-4A
MW-3A
MP-2A
AS-3A
MW-2A
AS-1A
AS-2A
MP-1A
970-MW5
970-MW1
AS-4A
SVE-1A
AS-5A
MW-1A
SVE-2A
MW-9A
MW-5A
MW-7A
AS-6A
MW-8A
Location of Former UST 970-1
Location of Former UST 970-2
Location of Former UST 970-3
MW-6A
SG-15
NA-1
NA-0
A
E
MW-4B
E'
MW-3B
SG-11
SG-10
SG-9
Daycare Center
Youth Center
C STREET
WOOD FENCE
CHAIN LINK FENCE
GATE
MW-6B
SG-13
970-MW3
MW-M5
MW-M6
MW-M4
HIGHWAY 101
NAVE DRIVE
MAIN ENTRANCE ROAD
0 100 200
Scale in Feet

Explanation

- Monitoring Well
- Bedrock Monitoring Well
- Abandoned Well
- Sparge Well
- Vent Well
- SVE Well
- Soil Gas/Groundwater Monitoring Point
- Soil Gas Monitoring Point
- Piezometer
- Geoprobe
- CPT Boring
- A—A' Cross Section Transect

DESIGNED BY TW	Battelle … Putting Technology To Work	
DRAWN BY LC	**Figure 4-6. Subsurface Location Installation Map**	
CHECKED BY JK	DoDHF NOVATO, CALIFORNIA	
	G337337-51	FIG 4-6 WELLLOC.DWG 4/01

Cross Section A-A'
DoDHF Novato
(Main South-North Cross Section)

A
South

A'
North

F-F'

E-E'

D-D'

C-C'

B-B'

Area of Detailed
CPT Survey (9/00)

Elevation (ft amsl)

50
45
40
35
30
25
20
15
10
5
0
-5
-10

NA-0
NA-1
MW-1A
MW-5
MW-4A
970-MW4
NA-3
957-MW2
NA-4
NA-6
957-MW4
NA-7
MW-1E
957-MW1
MW-M3
MW-M9
MW-M5
MW-M6
MW-92-38
IT-PZ-9

TD = 12 ft bgs
TD = 14 ft bgs
TD = 17 ft bgs
TD = 16 ft bgs
TD = 20.5 ft bgs
TD = 20.5 ft bgs
TD = 15 ft bgs
TD = 14.5 ft bgs
TD = 15 ft bgs
TD = 15 ft bgs
TD = 18.5 ft bgs
TD = 20.5 ft bgs
TD = 18.25 ft bgs
TD = 15.5 ft bgs
TD = 16 ft bgs
TD = 15 ft bgs
TD = 15 ft bgs
TD = 26 ft bgs
TD = 24 ft bgs

Sand Fill
Sandy Clay Fill
Sandy/Clayey Silt
Weathered Bedrock
Ground Surface

Explanation

Maximum groundwater level (ft amsl), May 1998-Feb. 2000

Minimum groundwater level (ft amsl), May 1998-Feb. 2000

Screened interval

B-B' Cross section intersection point

Horizontal Scale in Feet

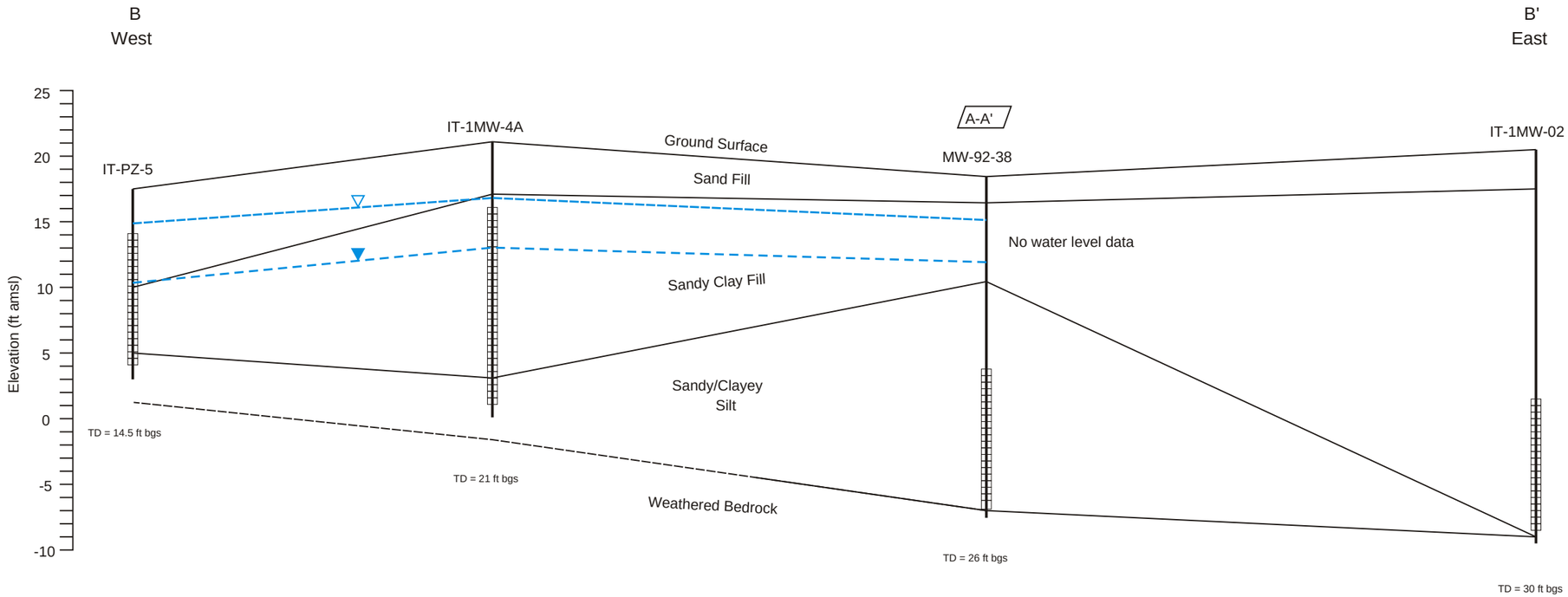
0 200 400

Vertical Exaggeration 20X

DESIGNED BY JH	Battelle . . . Putting Technology To Work		
DRAWN BY VS	Cross Section A-A'		
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA		
	PROJECT G337337-51	DATE 04/01	

XS A-A' 4-00.CDR

Cross Section B-B'
DoDHF Novato
(Northernmost Traverse)



Explanation

- Maximum groundwater level (ft amsl), May 1998-Feb. 2000
- Minimum groundwater level (ft amsl), May 1998-Feb. 2000
- Screened interval
- A-A' Cross section intersection point

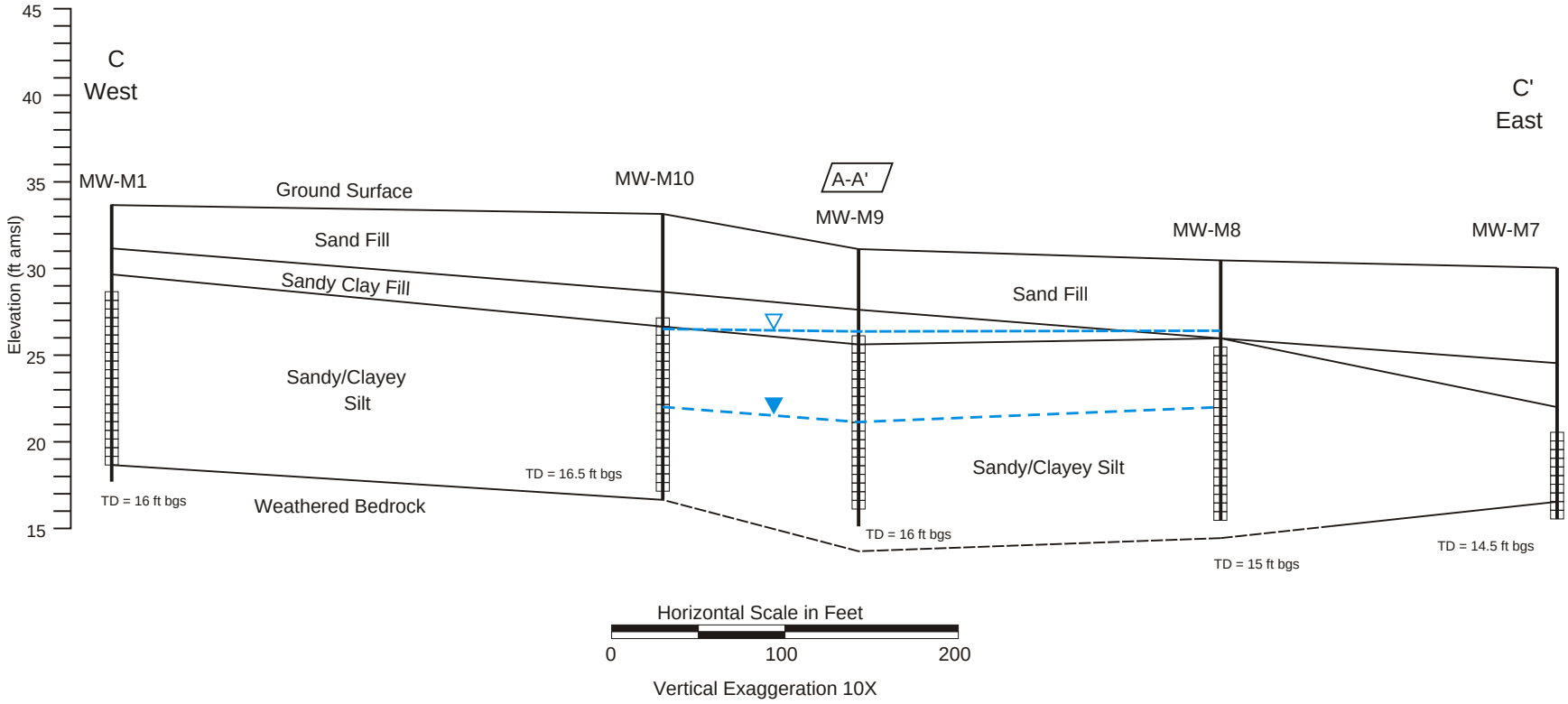
Horizontal Scale in Feet

0 100 200

Vertical Exaggeration 10X

DESIGNED BY JH	Battelle ... Putting Technology To Work
DRAWN BY DS	Cross Section B-B'
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA
XS B-B' 4-00.CDR	PROJECT G337337-51 DATE 04/01

Cross Section C-C'
DoDHF Novato



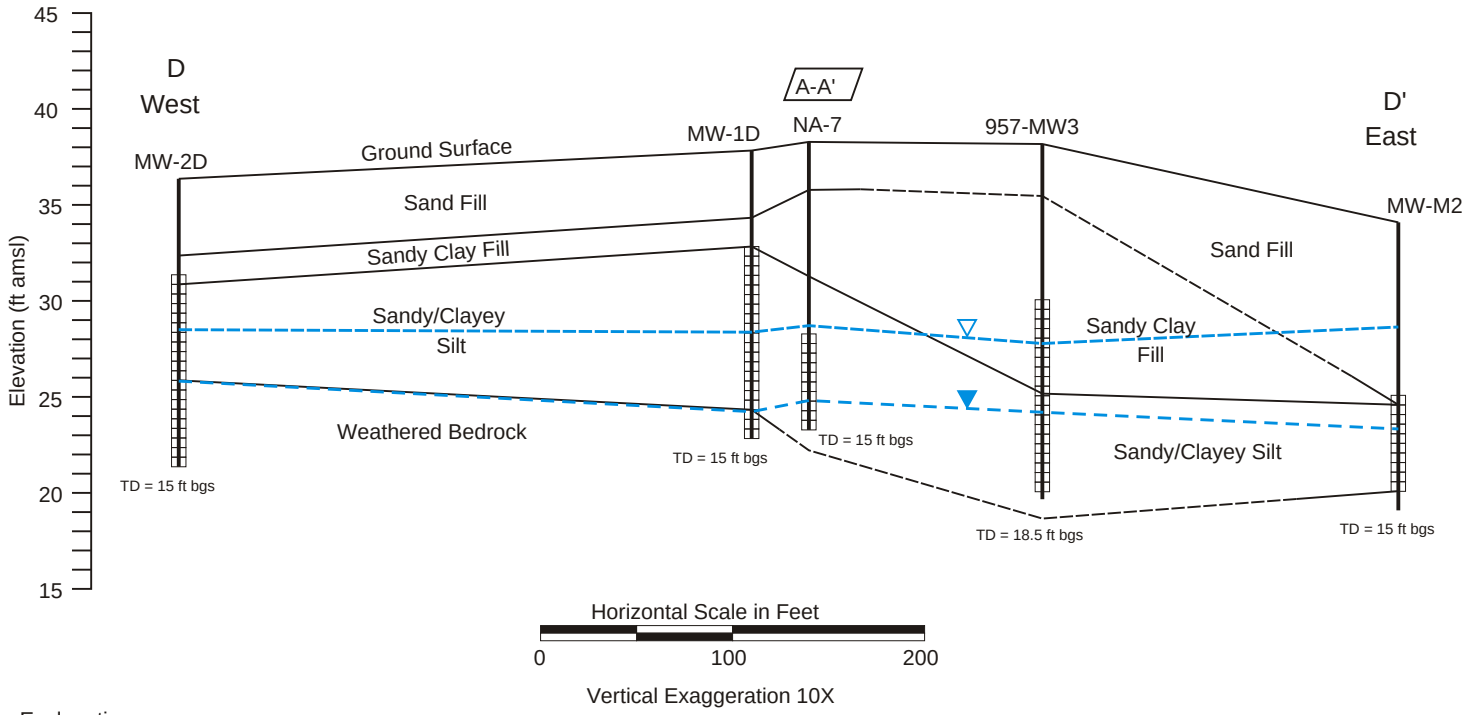
Explanation

- Maximum groundwater level (ft amsl), May 1998-Feb. 2000
- Minimum groundwater level (ft amsl), May 1998-Feb. 2000
- Screened interval
- A-A' Cross section intersection point

XS C-C' 4-00.CDR

DESIGNED BY SD	Battelle ... Putting Technology To Work
DRAWN BY DS	Cross Section C-C'
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA
	PROJECT G337737-51 DATE 04/01

Cross Section D-D'
DoDHF Novato



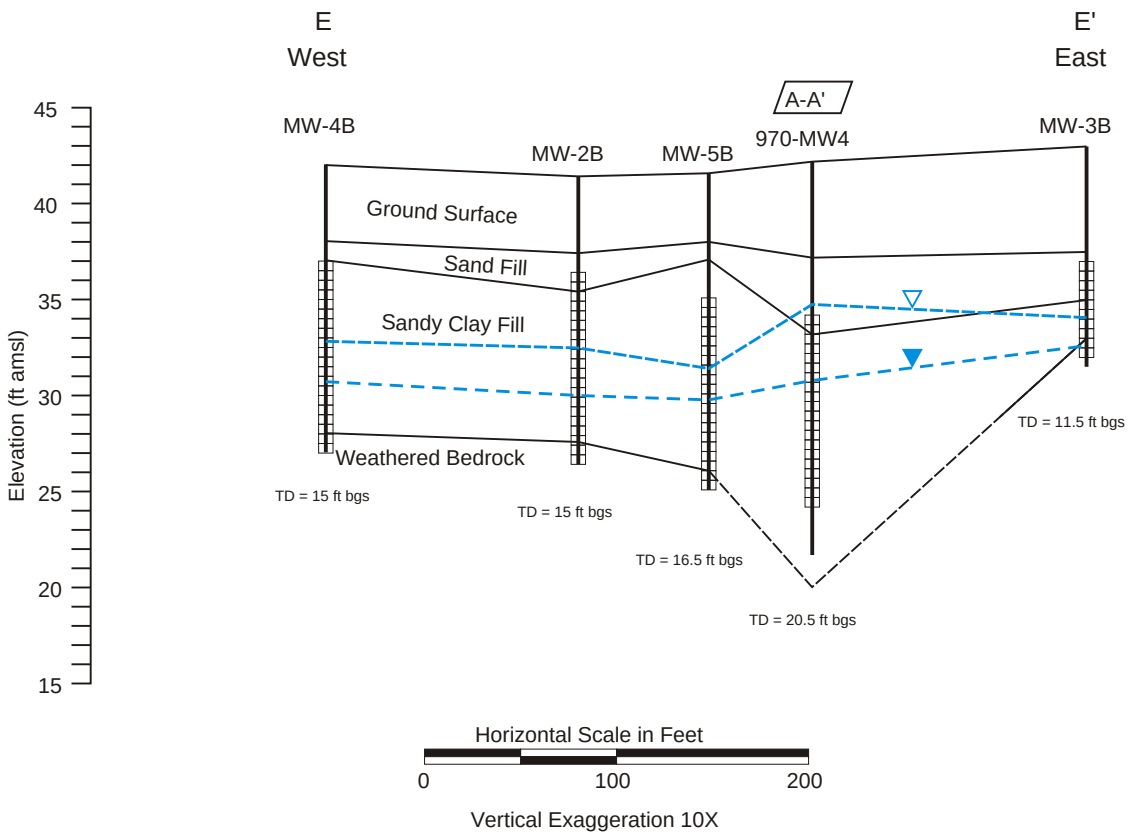
Explanation

- Maximum groundwater level (ft amsl), May 1998-Feb. 2000
- Minimum groundwater level (ft amsl), May 1998-Feb. 2000
- Screened interval
- A-A' Cross section intersection point

XS D-D' 4-00.CDR

DESIGNED BY JH	Battelle … Putting Technology To Work
DRAWN BY VS	Cross Section D-D'
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA
	PROJECT G337337-51 DATE 04/01

Cross Section E-E'
DoDHF Novato



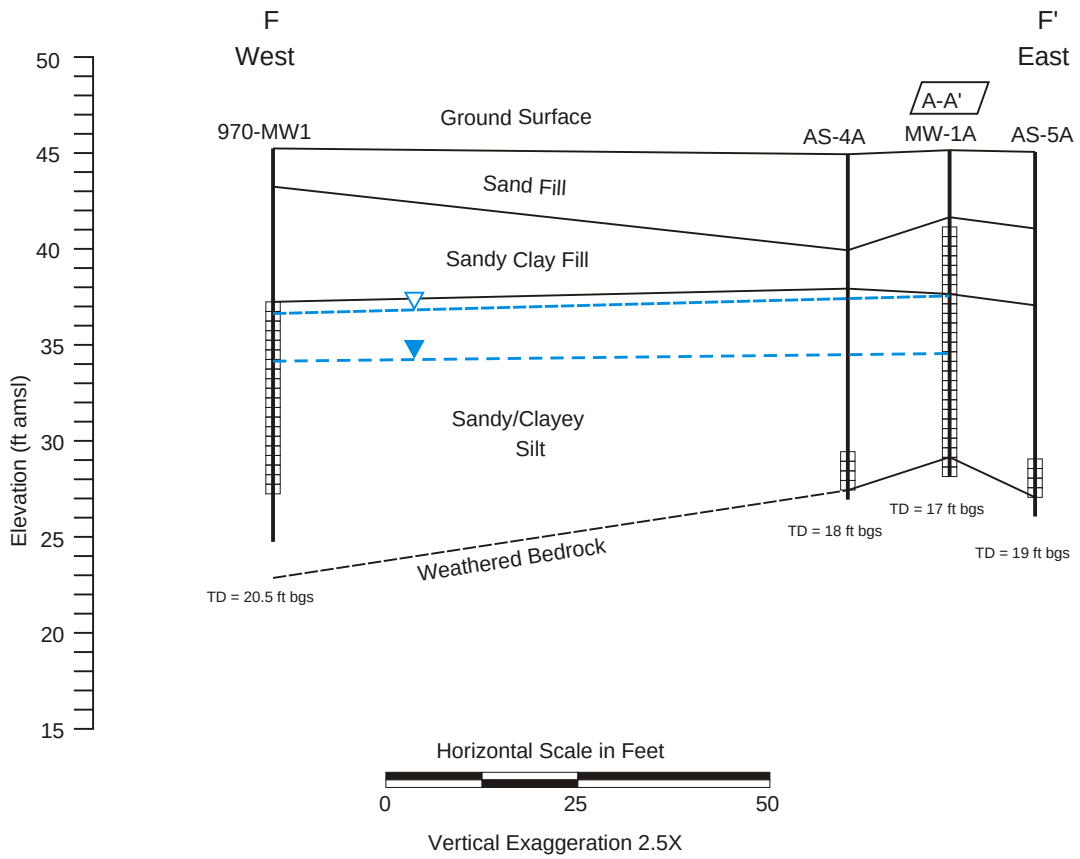
Explanation

- Maximum groundwater level (ft amsl), May 1998-Feb. 2000
- Minimum groundwater level (ft amsl), May 1998-Feb. 2000
- Screened interval
- A-A' Cross section intersection point

XS E-E' 4-00.CDR

DESIGNED BY SD	Battelle … Putting Technology To Work
DRAWN BY DS	Cross Section E-E'
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA
	PROJECT G337337-51 DATE 04/01

Cross Section F-F'
DoDHF Novato
(Southernmost Traverse)

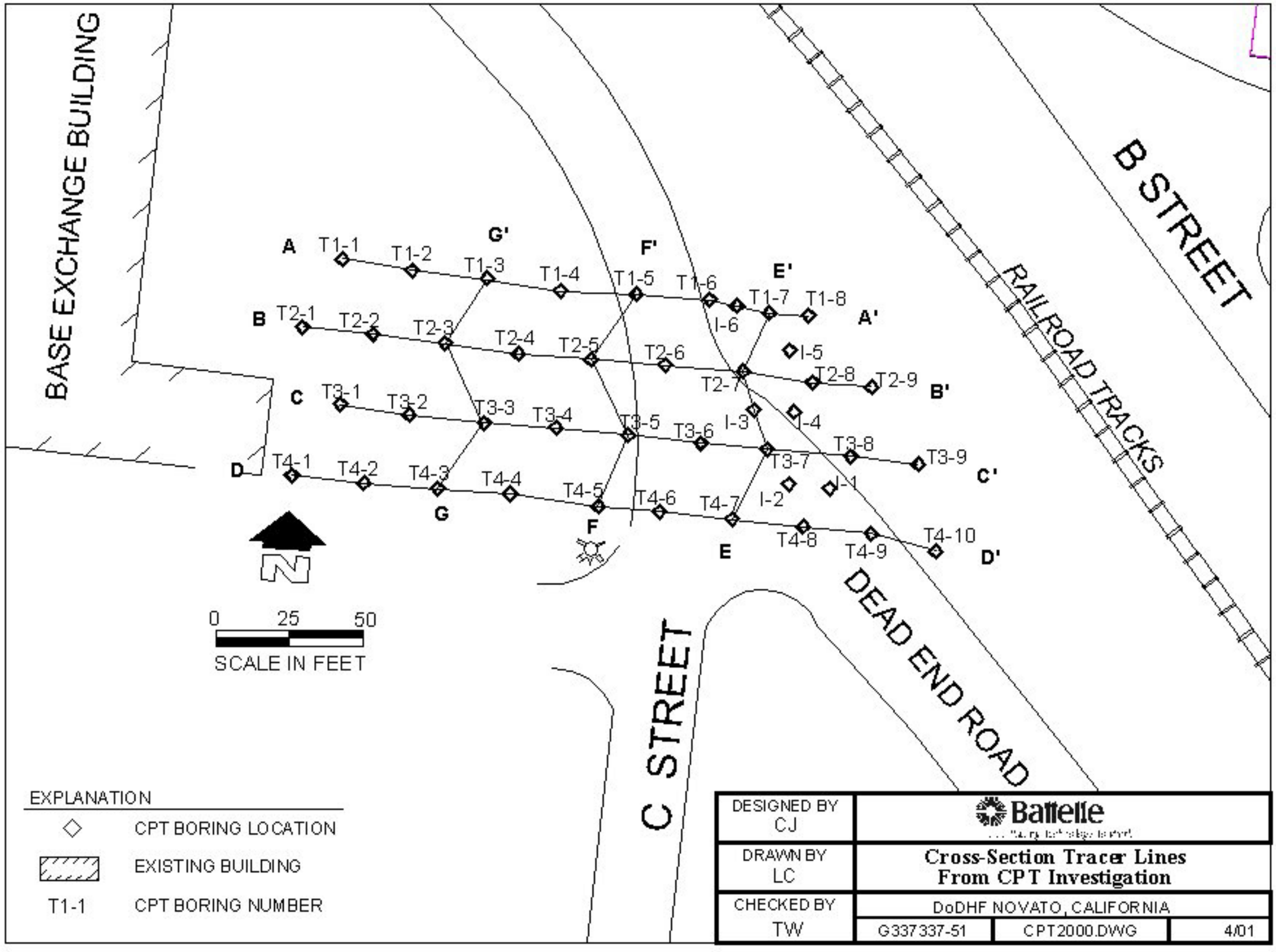


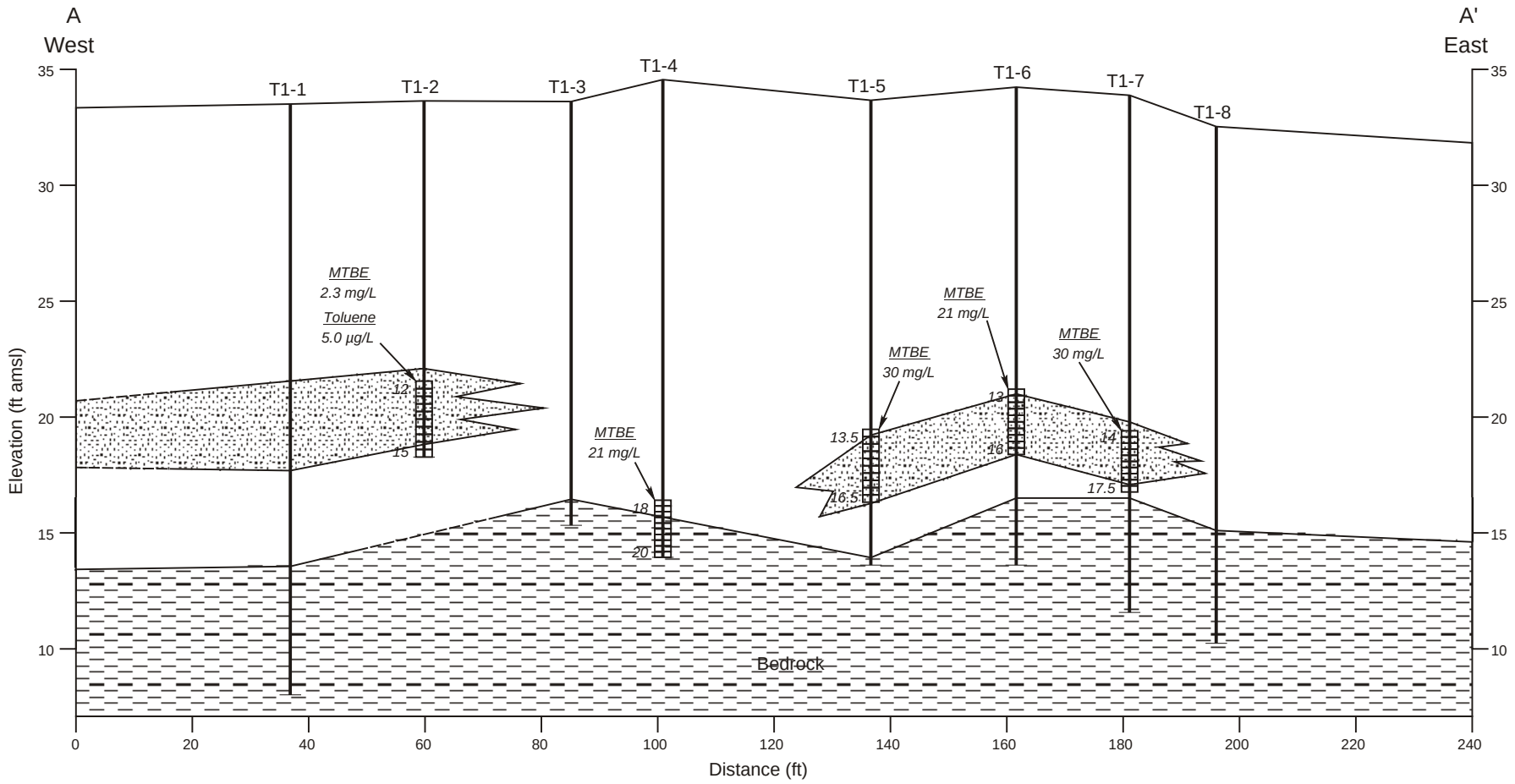
Explanation

- Maximum groundwater level (ft amsl), May 1998-Feb. 2000
- Minimum groundwater level (ft amsl), May 1998-Feb. 2000
- Screened interval
- A-A' Cross section intersection point

XS D-D' 4-00.CDR

DESIGNED BY JH	Battelle … Putting Technology To Work
DRAWN BY DS	Cross Section F-F'
CHECKED BY JG	DoD HOUSING FACILITY – NOVATO, CA
	PROJECT G337337-51 DATE 04/01


BASE EXCHANGE BUILDING
B STREET
RAILROAD TRACKS
C STREET
DEAD END ROAD
A
B
C
D
G'
F'
E'
A'
B'
C'
D'
G
F
E
T1-1
T1-2
T1-3
T1-4
T1-5
T1-6
T1-7
T1-8
T2-1
T2-2
T2-3
T2-4
T2-5
T2-6
T2-7
T2-8
T2-9
T3-1
T3-2
T3-3
T3-4
T3-5
T3-6
T3-7
T3-8
T3-9
T4-1
T4-2
T4-3
T4-4
T4-5
T4-6
T4-7
T4-8
T4-9
T4-10
I-1
I-2
I-3
I-4
I-5
I-6
N
0
25
50
SCALE IN FEET
EXPLANATION
CPT BORING LOCATION
EXISTING BUILDING
T1-1
CPT BORING NUMBER
DESIGNED BY
CJ
DRAWN BY
LC
CHECKED BY
TW
Battelle
Cross-Section Tracer Lines
From CPT Investigation
DoDHF NOVATO, CALIFORNIA
G337337-51
CPT2000.DWG
4/01

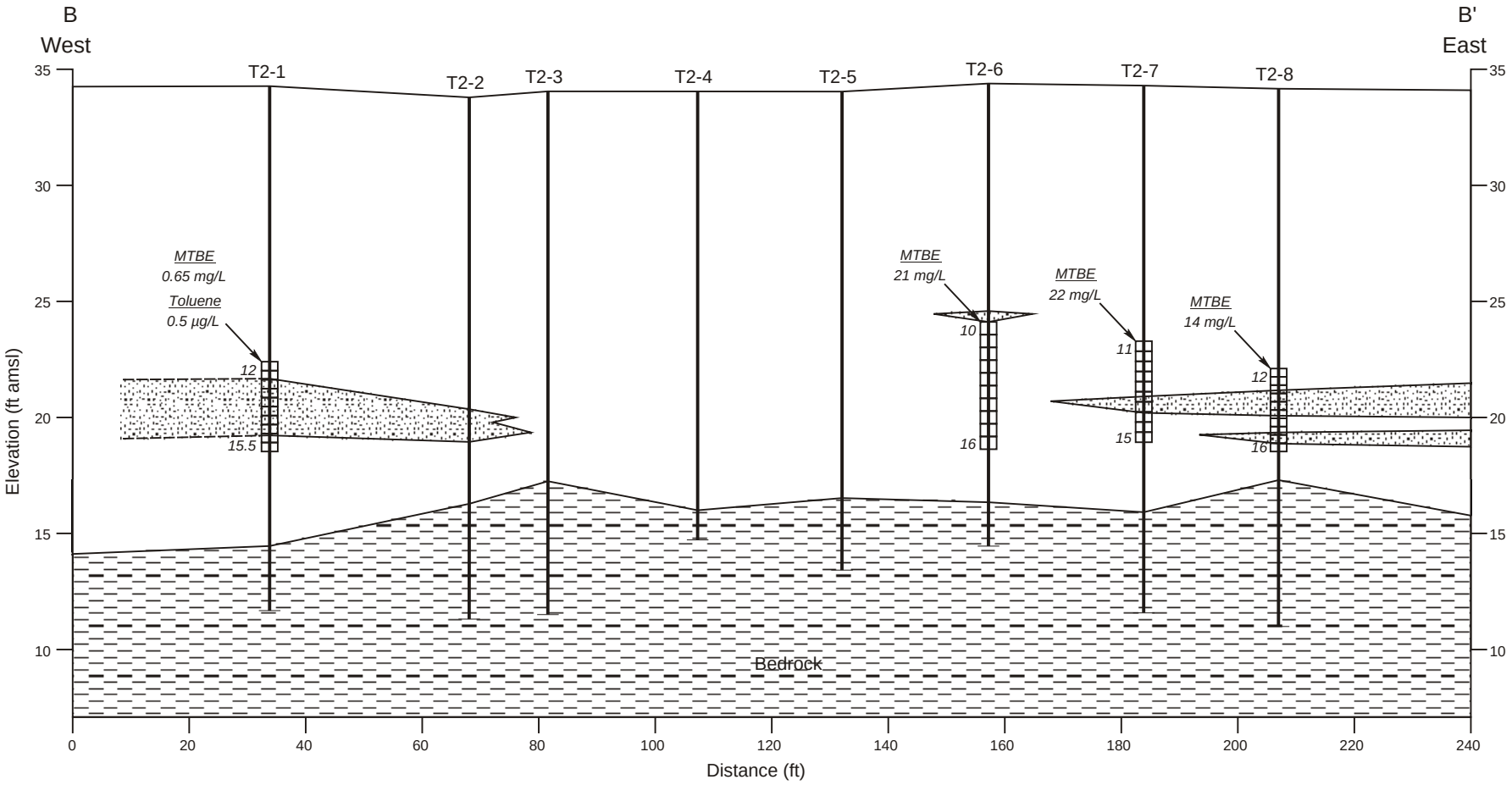


Mostly sand | Mostly silt and clay | Bedrock (shale) | Screened interval ft bgs ft bgs

Vertical Exaggeration = 4X

XSA-A'02.CDR

DESIGNED BY CP	Battelle . . . Putting Technology To Work
DRAWN BY VS	Cross Section A – A'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
PROJECT G337337-51	DATE 4/01

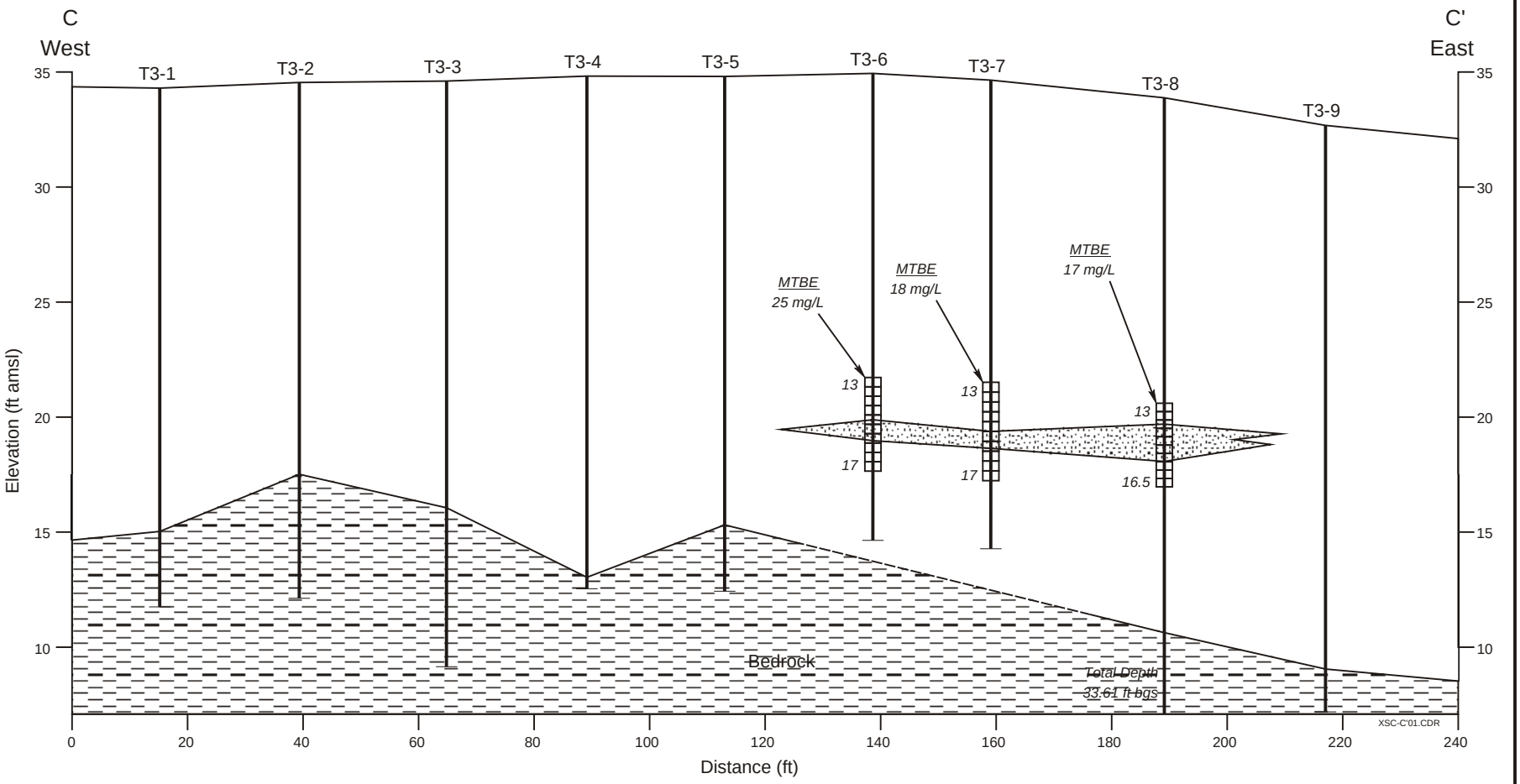


Mostly sand | Mostly silt and clay | Bedrock (shale) | Screened interval (ft bgs, ft bgs)

Vertical Exaggeration = 4X

XSB-B'02.CDR

DESIGNED BY CP	Battelle … Putting Technology To Work
DRAWN BY VS	Cross Section B – B'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
PROJECT G337337-51	DATE 4/01



Mostly sand

Mostly silt and clay

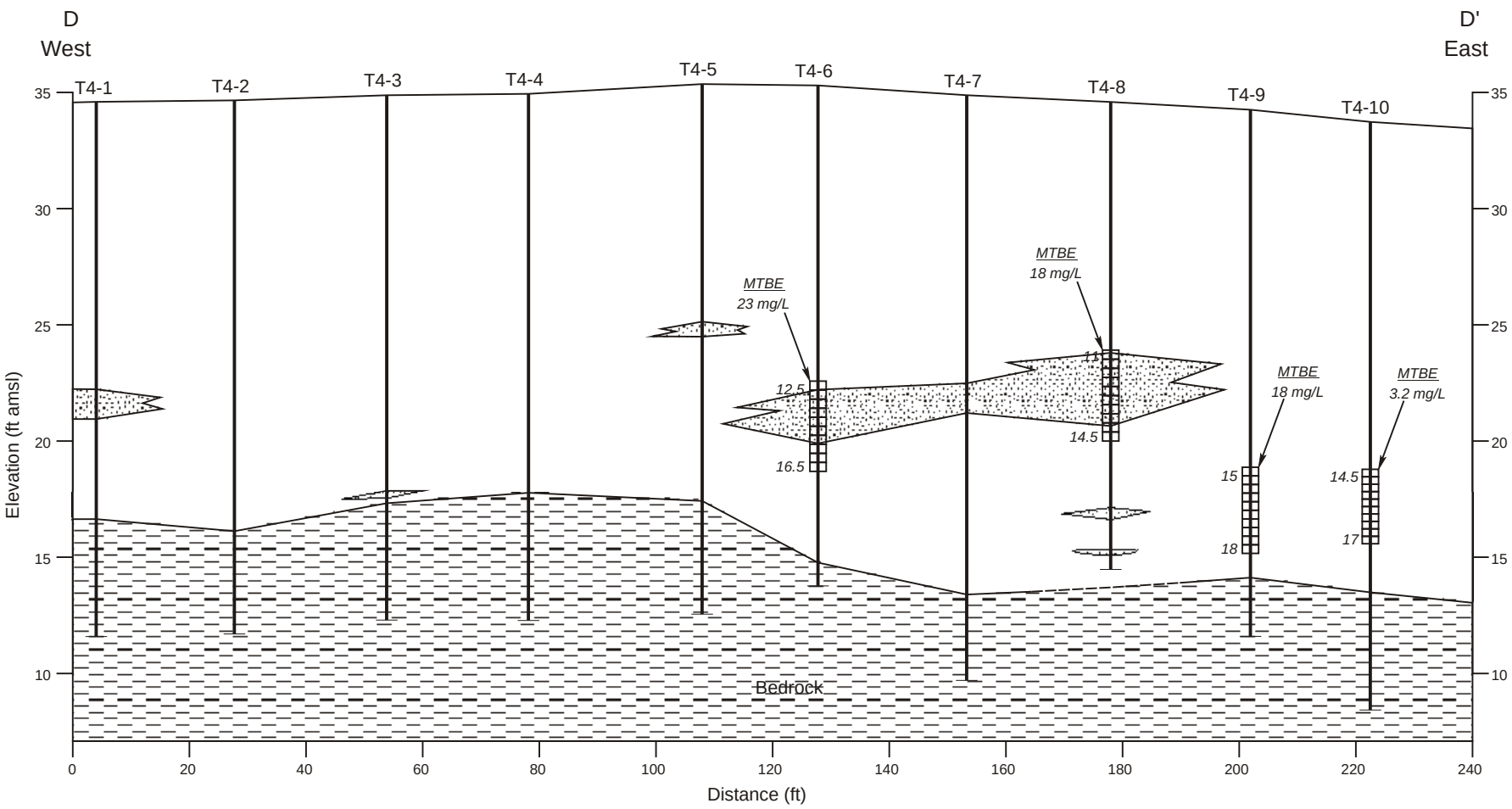
Bedrock (shale)

Screened interval
ft bgs
ft bgs

Vertical Exaggeration = 4X

XSC-C'02.CDR

DESIGNED BY CP	Battelle . . . Putting Technology To Work
DRAWN BY VS	Cross Section C – C'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
	PROJECT G337337-51 DATE 4/01

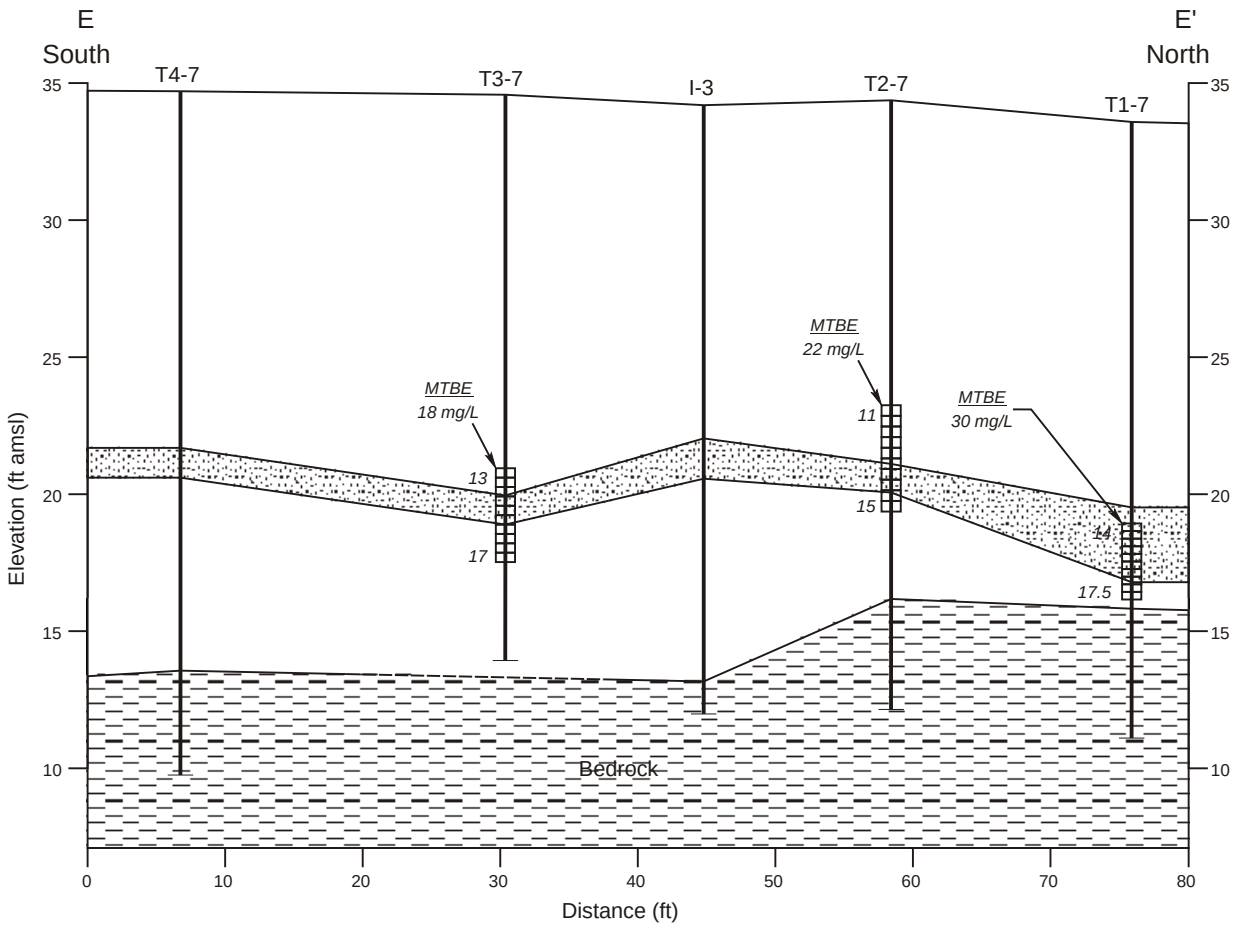


Mostly sand | Mostly silt and clay | Bedrock (shale) | Screened interval (ft bgs, ft bgs)

Vertical Exaggeration = 4X

XSD-D'02.CDR

DESIGNED BY CP	Battelle … Putting Technology To Work
DRAWN BY VS	Cross Section D – D'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
PROJECT G337337-51	DATE 4/01



Mostly sand

Mostly silt and clay

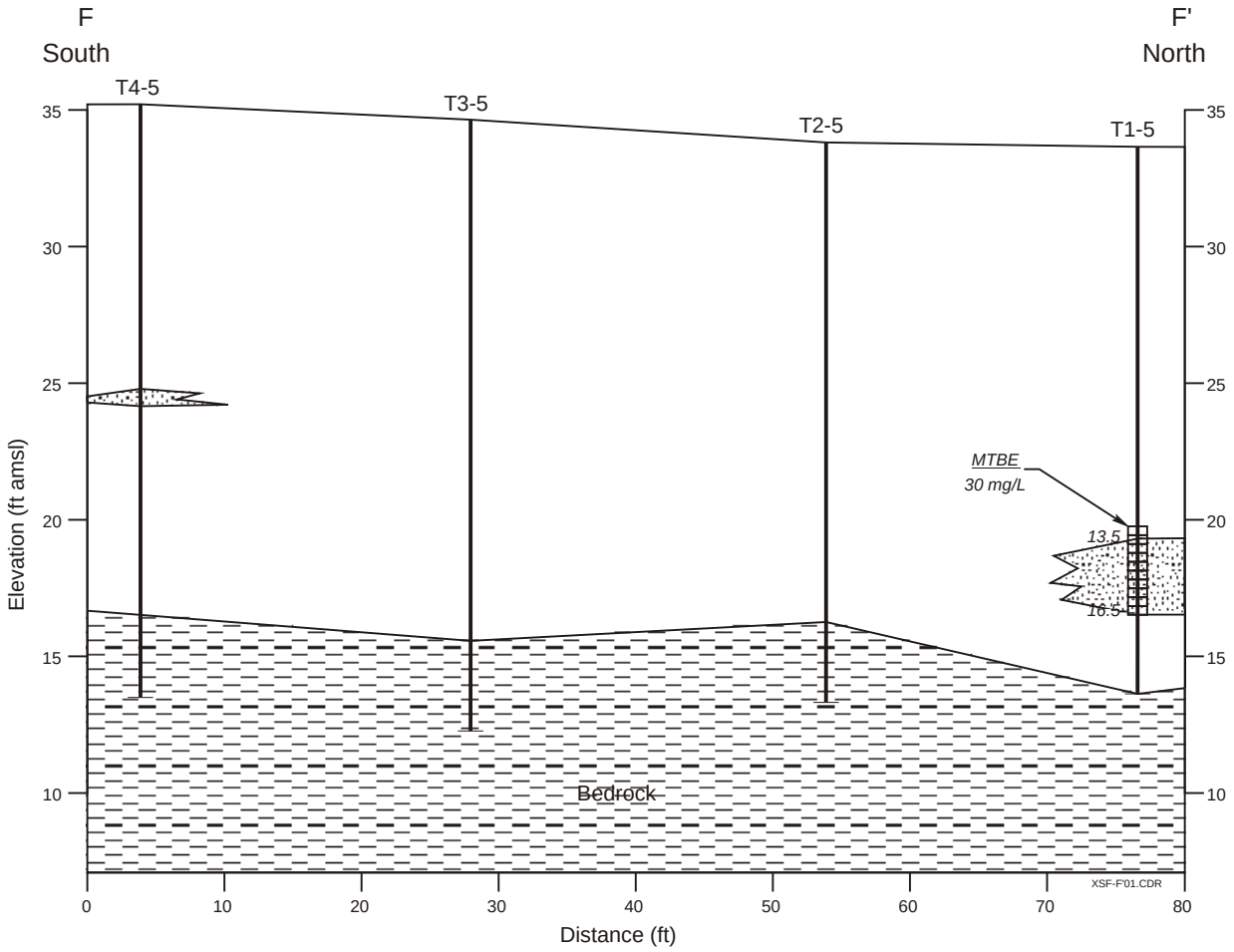
Bedrock (shale)

Screened interval
ft bgs
ft bgs

Vertical Exaggeration = 4X

XSE-E'02.CDR

DESIGNED BY CP	Battelle . . . Putting Technology To Work	
DRAWN BY VS	Cross Section E – E'	
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA	
	PROJECT G337337-51	DATE 4/01



Mostly sand

Mostly silt and clay

Bedrock (shale)

Screened interval

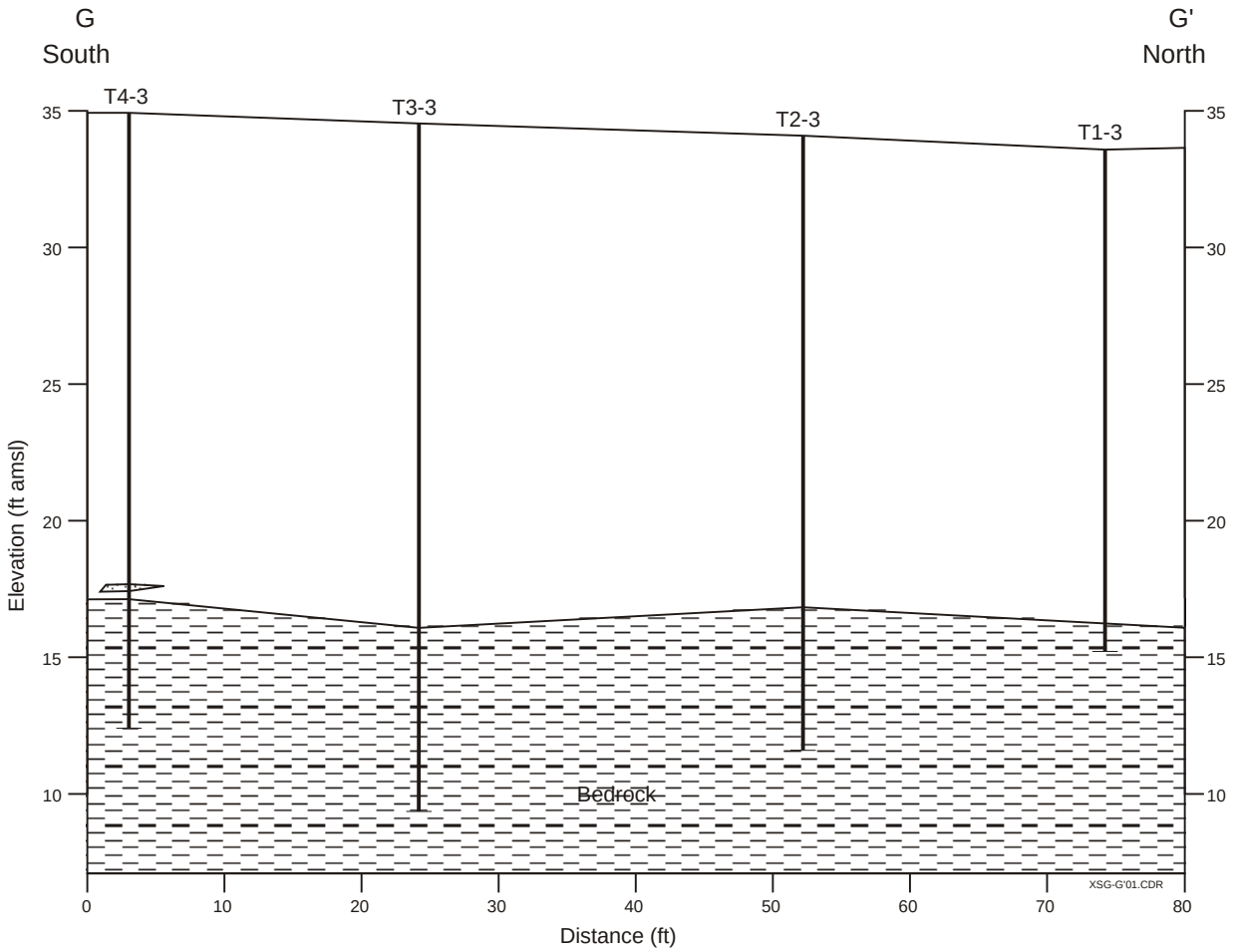
ft bgs

ft bgs

Vertical Exaggeration = 4X

XSF-F'02.CDR

DESIGNED BY CP	Battelle … Putting Technology To Work
DRAWN BY VS	Cross Section F – F'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
PROJECT G337337-51	DATE 4/01



Mostly sand

Mostly silt and clay

Bedrock (shale)

Vertical Exaggeration = 4X

XSG-G'02.CDR

DESIGNED BY CP	Battelle . . . Putting Technology To Work
DRAWN BY VS	Cross Section G – G'
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA
	PROJECT G337337-51 DATE 4/01

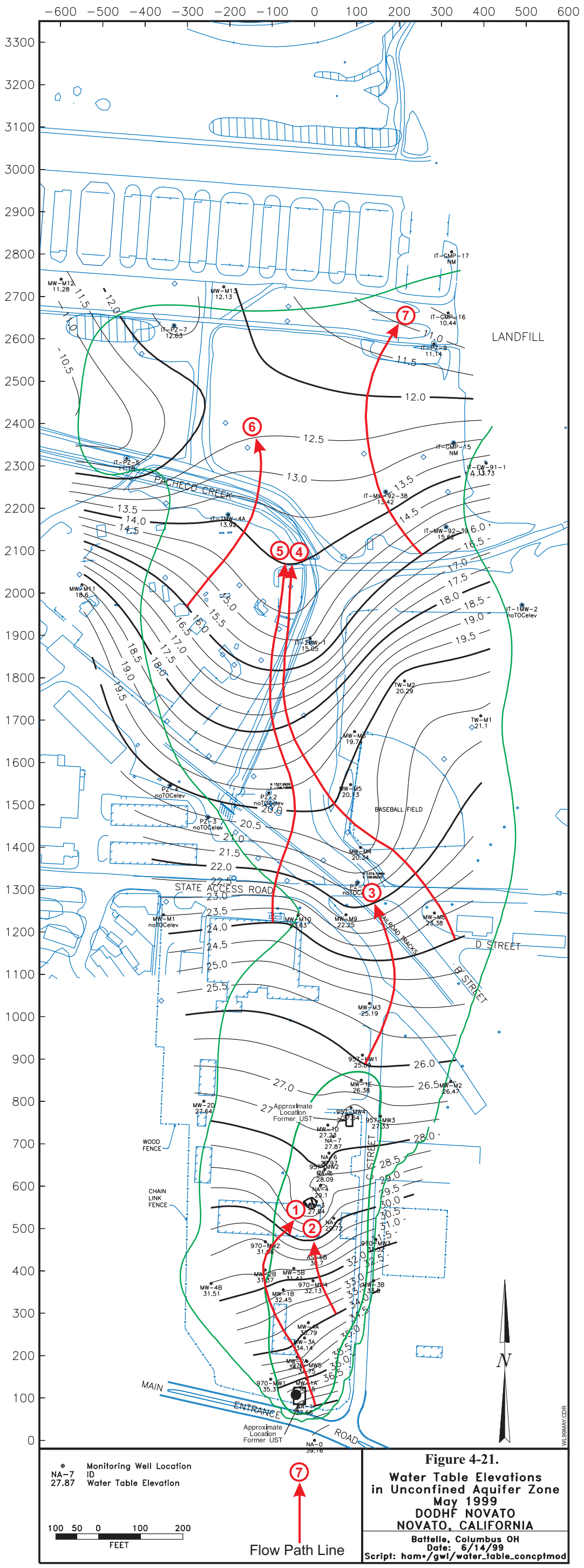


Figure 4-21.

Water Table Elevations in Unconfined Aquifer Zone May 1999 DODHF NOVATO NOVATO, CALIFORNIA

Battelle, Columbus OH
Date: 6/14/99
Script: ham+/gwi/water_table_concptmod

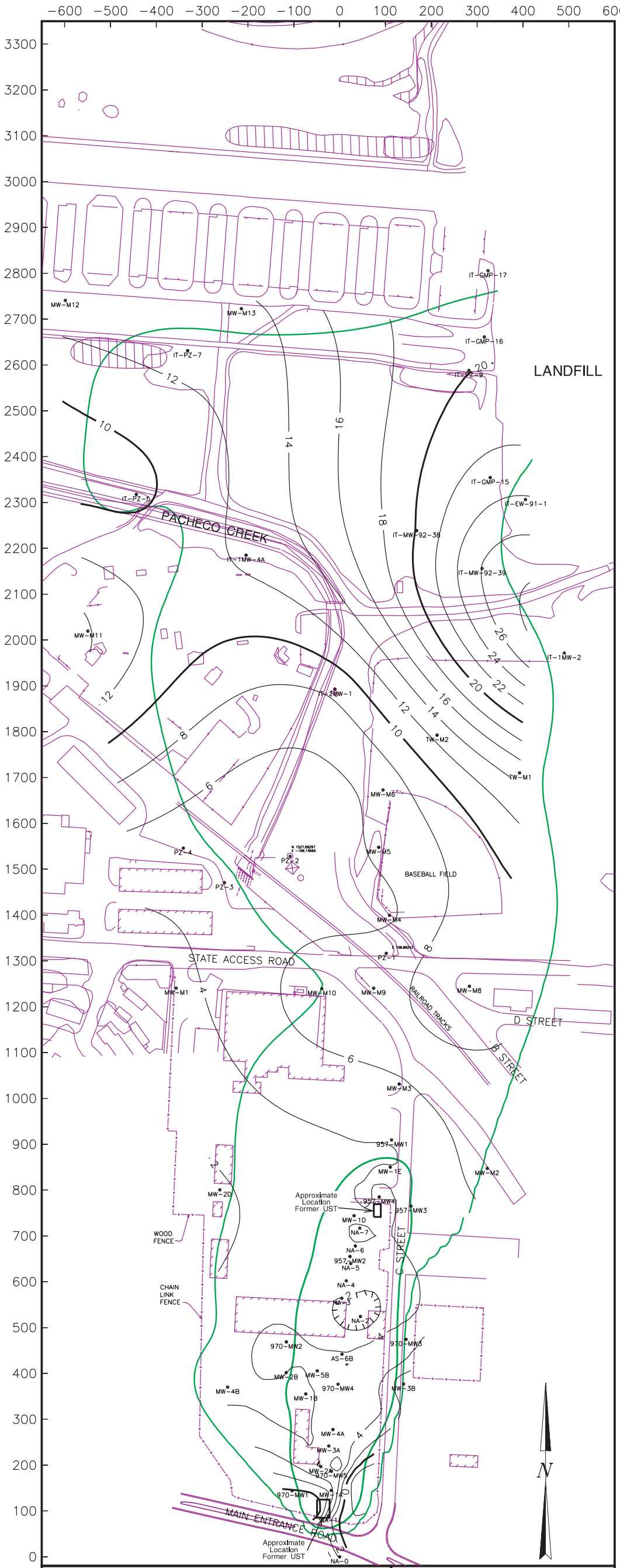
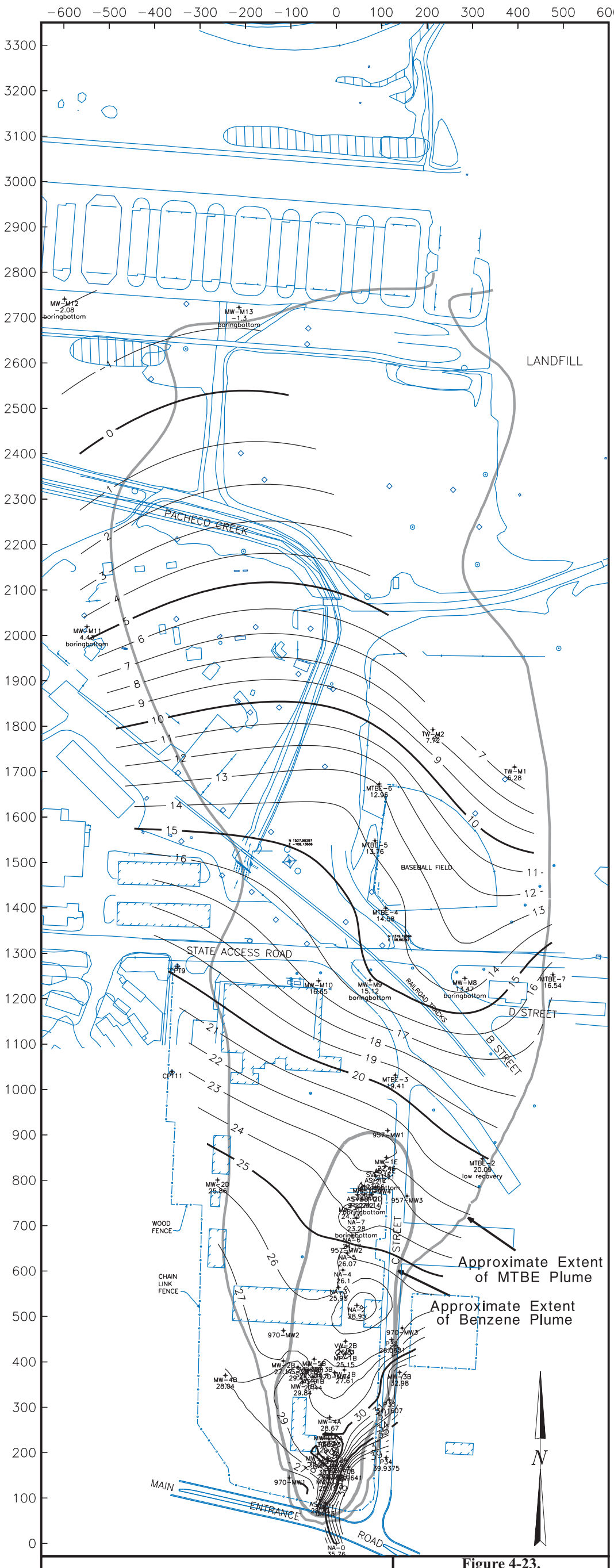


Figure 4-22

Saturated Thickness of Unconfined Aquifer May 1999 DODHF NOVATO NOVATO, CALIFORNIA

Battelle, Columbus OH
Date: 8/27/99
Script: */gwl/sat_thick.sh


LANDFILL
PACHECO CREEK
STATE ACCESS ROAD
BASEBALL FIELD
RAILROAD TRACKS
D STREET
B STREET
C STREET
WOOD FENCE
CHAIN LINK FENCE
MAIN ENTRANCE ROAD
Approximate Extent of MTBE Plume
Approximate Extent of Benzene Plume
N
Boring Location
NA-6 ID
24.17 Elevation of Top of Weathered Bedrock
100 50 0 100 200
FEET
Figure 4-23.
Elevation of Top of Weathered Bedrock Surface
DODHF NOVATO
NOVATO, CALIFORNIA
Battelle, Columbus OH
Date: 2/4/98
Script: /.../strat/modlayer.sh

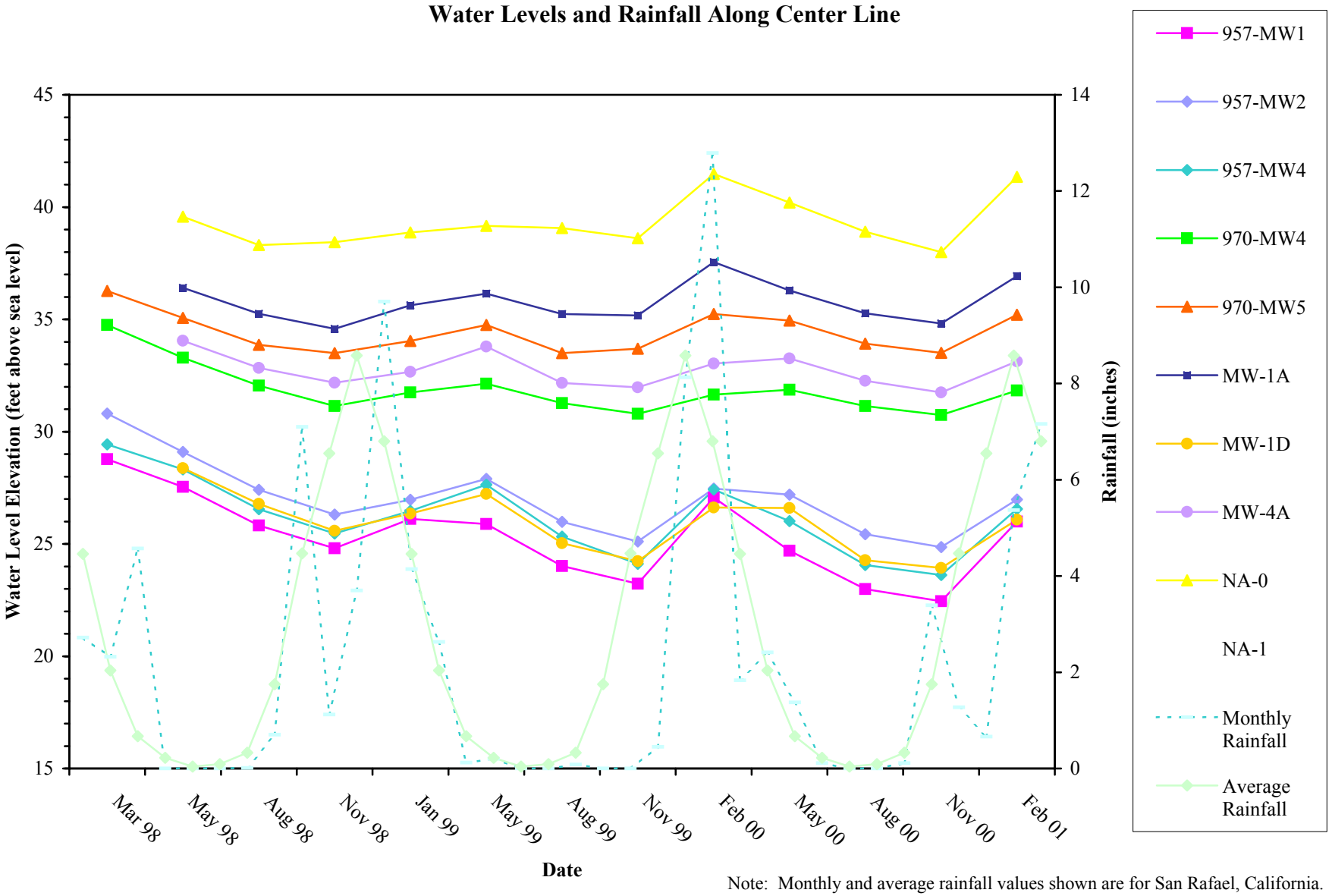
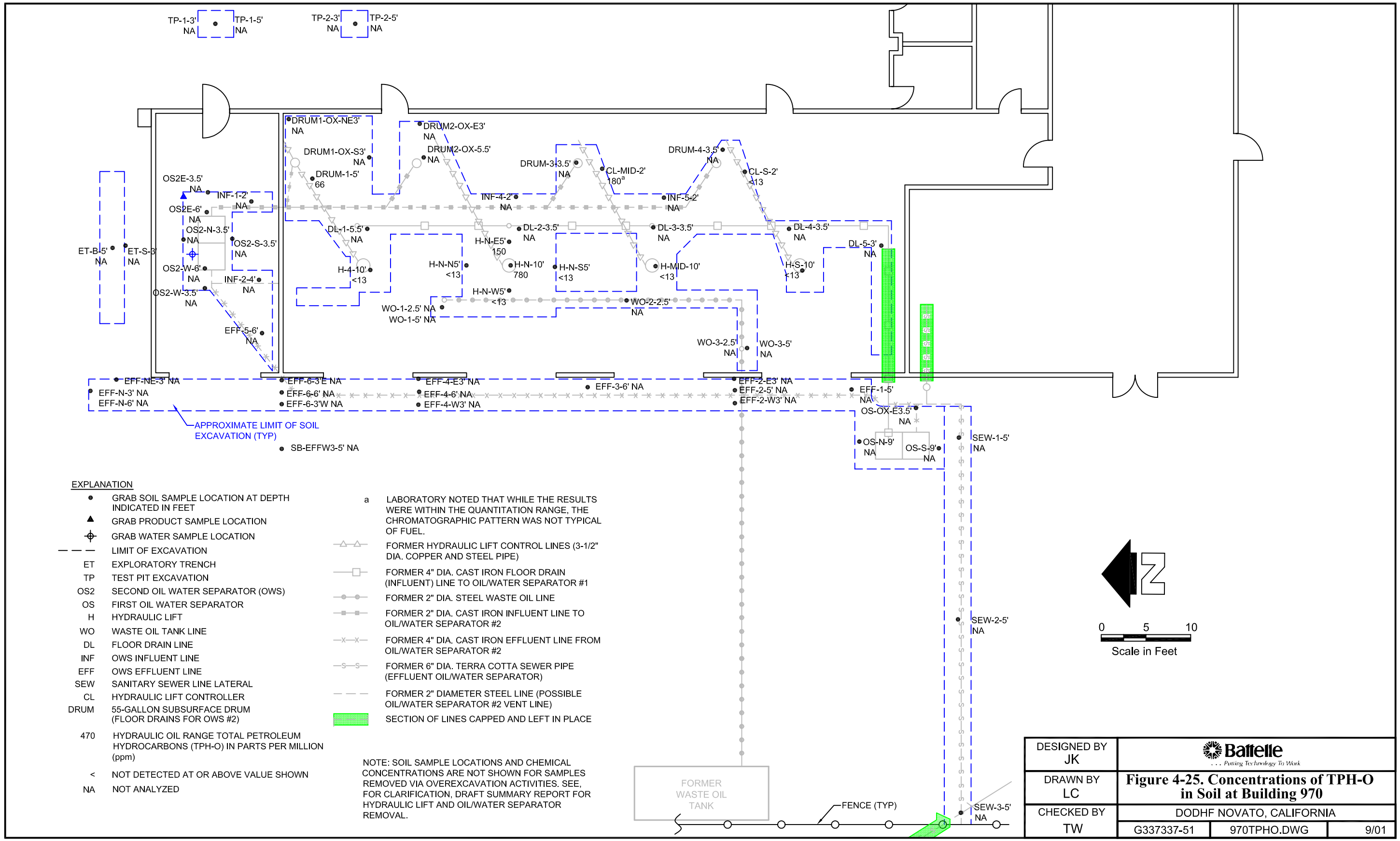


Figure 4-24. Water Levels and Rainfall Along Center Line



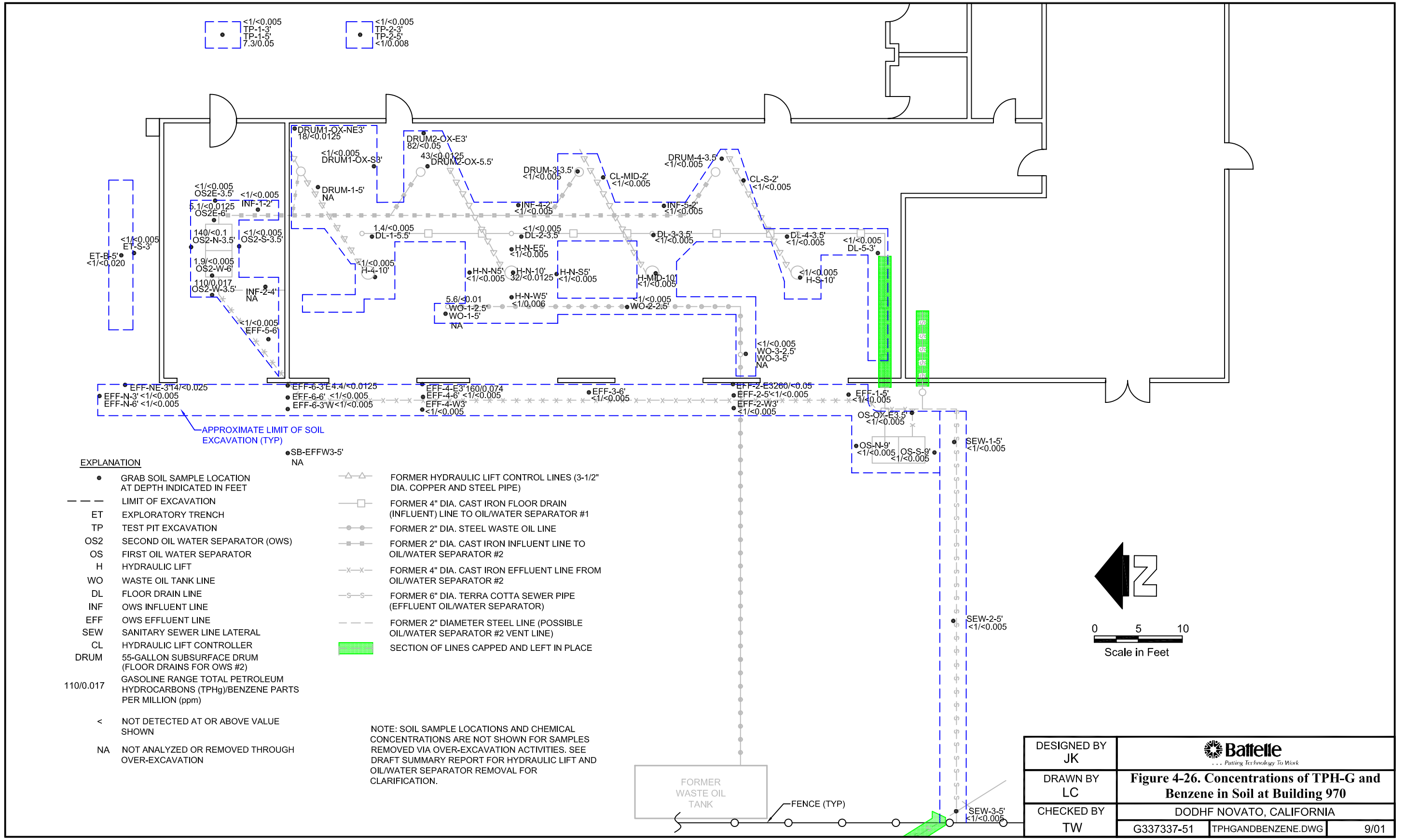
EXPLANATION

•	GRAB SOIL SAMPLE LOCATION AT DEPTH INDICATED IN FEET
▲	GRAB PRODUCT SAMPLE LOCATION
⊕	GRAB WATER SAMPLE LOCATION
— — —	LIMIT OF EXCAVATION
ET	EXPLORATORY TRENCH
TP	TEST PIT EXCAVATION
OS2	SECOND OIL WATER SEPARATOR (OWS)
OS	FIRST OIL WATER SEPARATOR
H	HYDRAULIC LIFT
WO	WASTE OIL TANK LINE
DL	FLOOR DRAIN LINE
INF	OWS INFLUENT LINE
EFF	OWS EFFLUENT LINE
SEW	SANITARY SEWER LINE LATERAL
CL	HYDRAULIC LIFT CONTROLLER
DRUM	55-GALLON SUBSURFACE DRUM (FLOOR DRAINS FOR OWS #2)
470	HYDRAULIC OIL RANGE TOTAL PETROLEUM HYDROCARBONS (TPH-O) IN PARTS PER MILLION (ppm)
<	NOT DETECTED AT OR ABOVE VALUE SHOWN
NA	NOT ANALYZED

a	LABORATORY NOTED THAT WHILE THE RESULTS WERE WITHIN THE QUANTITATION RANGE, THE CHROMATOGRAPHIC PATTERN WAS NOT TYPICAL OF FUEL.
	FORMER HYDRAULIC LIFT CONTROL LINES (3-1/2" DIA. COPPER AND STEEL PIPE)
	FORMER 4" DIA. CAST IRON FLOOR DRAIN (INFLUENT) LINE TO OIL/WATER SEPARATOR #1
	FORMER 2" DIA. STEEL WASTE OIL LINE
	FORMER 2" DIA. CAST IRON INFLUENT LINE TO OIL/WATER SEPARATOR #2
	FORMER 4" DIA. CAST IRON EFFLUENT LINE FROM OIL/WATER SEPARATOR #2
	FORMER 6" DIA. TERRA COTTA SEWER PIPE (EFFLUENT OIL/WATER SEPARATOR)
	FORMER 2" DIAMETER STEEL LINE (POSSIBLE OIL/WATER SEPARATOR #2 VENT LINE)
	SECTION OF LINES CAPPED AND LEFT IN PLACE

NOTE: SOIL SAMPLE LOCATIONS AND CHEMICAL CONCENTRATIONS ARE NOT SHOWN FOR SAMPLES REMOVED VIA OVEREXCAVATION ACTIVITIES. SEE, FOR CLARIFICATION, DRAFT SUMMARY REPORT FOR HYDRAULIC LIFT AND OIL/WATER SEPARATOR REMOVAL.

DESIGNED BY JK	Battelle — Putting Technology To Work		
DRAWN BY LC	**Figure 4-25. Concentrations of TPH-O in Soil at Building 970**		
CHECKED BY TW	DODHF NOVATO, CALIFORNIA		
	G337337-51	970TPHO.DWG	9/01



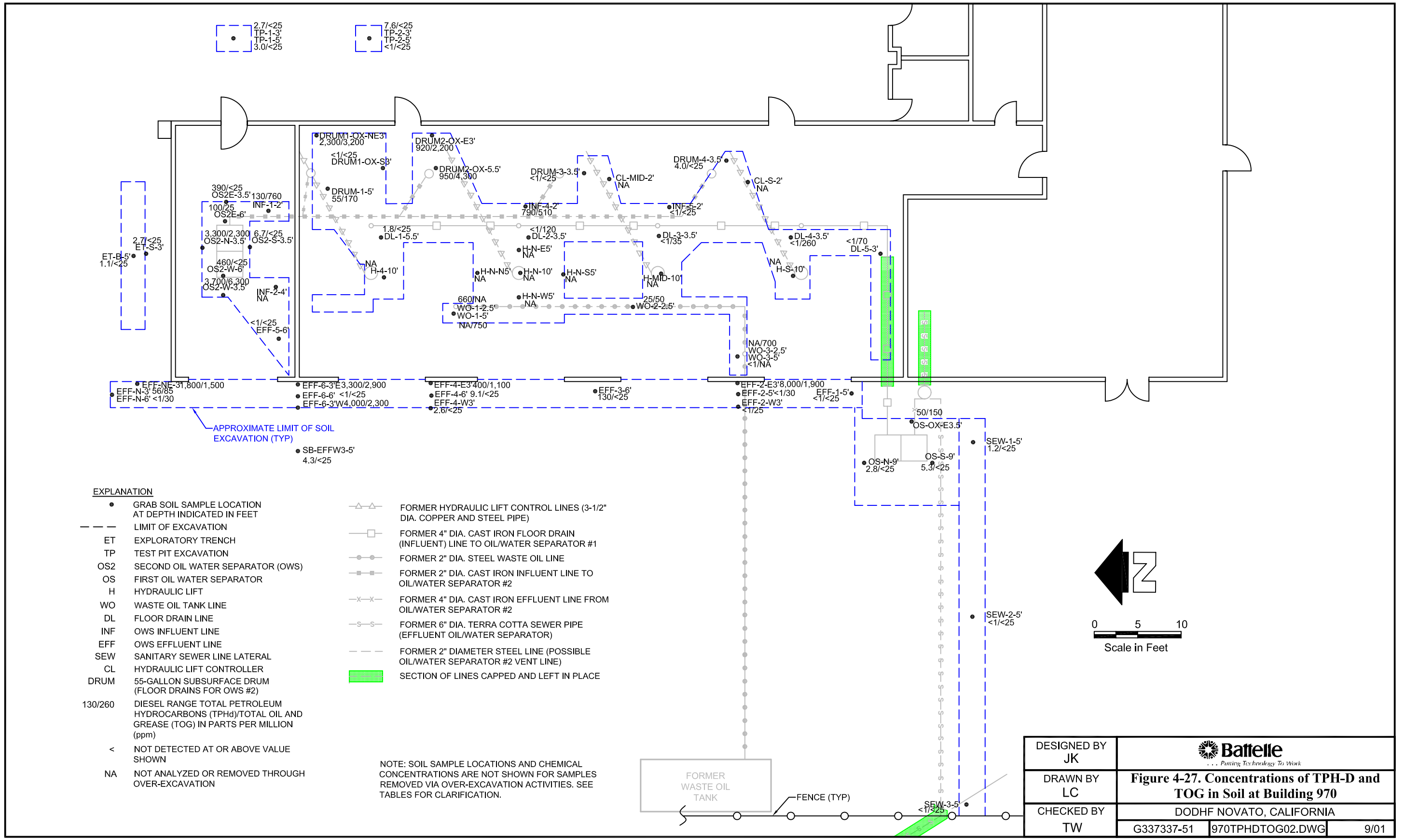
EXPLANATION

•	GRAB SOIL SAMPLE LOCATION AT DEPTH INDICATED IN FEET
— — —	LIMIT OF EXCAVATION
ET	EXPLORATORY TRENCH
TP	TEST PIT EXCAVATION
OS2	SECOND OIL WATER SEPARATOR (OWS)
OS	FIRST OIL WATER SEPARATOR
H	HYDRAULIC LIFT
WO	WASTE OIL TANK LINE
DL	FLOOR DRAIN LINE
INF	OWS INFLUENT LINE
EFF	OWS EFFLUENT LINE
SEW	SANITARY SEWER LINE LATERAL
CL	HYDRAULIC LIFT CONTROLLER
DRUM	55-GALLON SUBSURFACE DRUM (FLOOR DRAINS FOR OWS #2)
110/0.017	GASOLINE RANGE TOTAL PETROLEUM HYDROCARBONS (TPHg)/BENZENE PARTS PER MILLION (ppm)
<	NOT DETECTED AT OR ABOVE VALUE SHOWN
NA	NOT ANALYZED OR REMOVED THROUGH OVER-EXCAVATION

	FORMER HYDRAULIC LIFT CONTROL LINES (3-1/2" DIA. COPPER AND STEEL PIPE)
	FORMER 4" DIA. CAST IRON FLOOR DRAIN (INFLUENT) LINE TO OIL/WATER SEPARATOR #1
	FORMER 2" DIA. STEEL WASTE OIL LINE
	FORMER 2" DIA. CAST IRON INFLUENT LINE TO OIL/WATER SEPARATOR #2
	FORMER 4" DIA. CAST IRON EFFLUENT LINE FROM OIL/WATER SEPARATOR #2
	FORMER 6" DIA. TERRA COTTA SEWER PIPE (EFFLUENT OIL/WATER SEPARATOR)
	FORMER 2" DIAMETER STEEL LINE (POSSIBLE OIL/WATER SEPARATOR #2 VENT LINE)
	SECTION OF LINES CAPPED AND LEFT IN PLACE

NOTE: SOIL SAMPLE LOCATIONS AND CHEMICAL CONCENTRATIONS ARE NOT SHOWN FOR SAMPLES REMOVED VIA OVER-EXCAVATION ACTIVITIES. SEE DRAFT SUMMARY REPORT FOR HYDRAULIC LIFT AND OIL/WATER SEPARATOR REMOVAL FOR CLARIFICATION.

DESIGNED BY JK	Battelle … Putting Technology To Work	
DRAWN BY LC	**Figure 4-26. Concentrations of TPH-G and Benzene in Soil at Building 970**	
CHECKED BY TW	DODHF NOVATO, CALIFORNIA	
	G337337-51	TPHGANDBENZENE.DWG 9/01



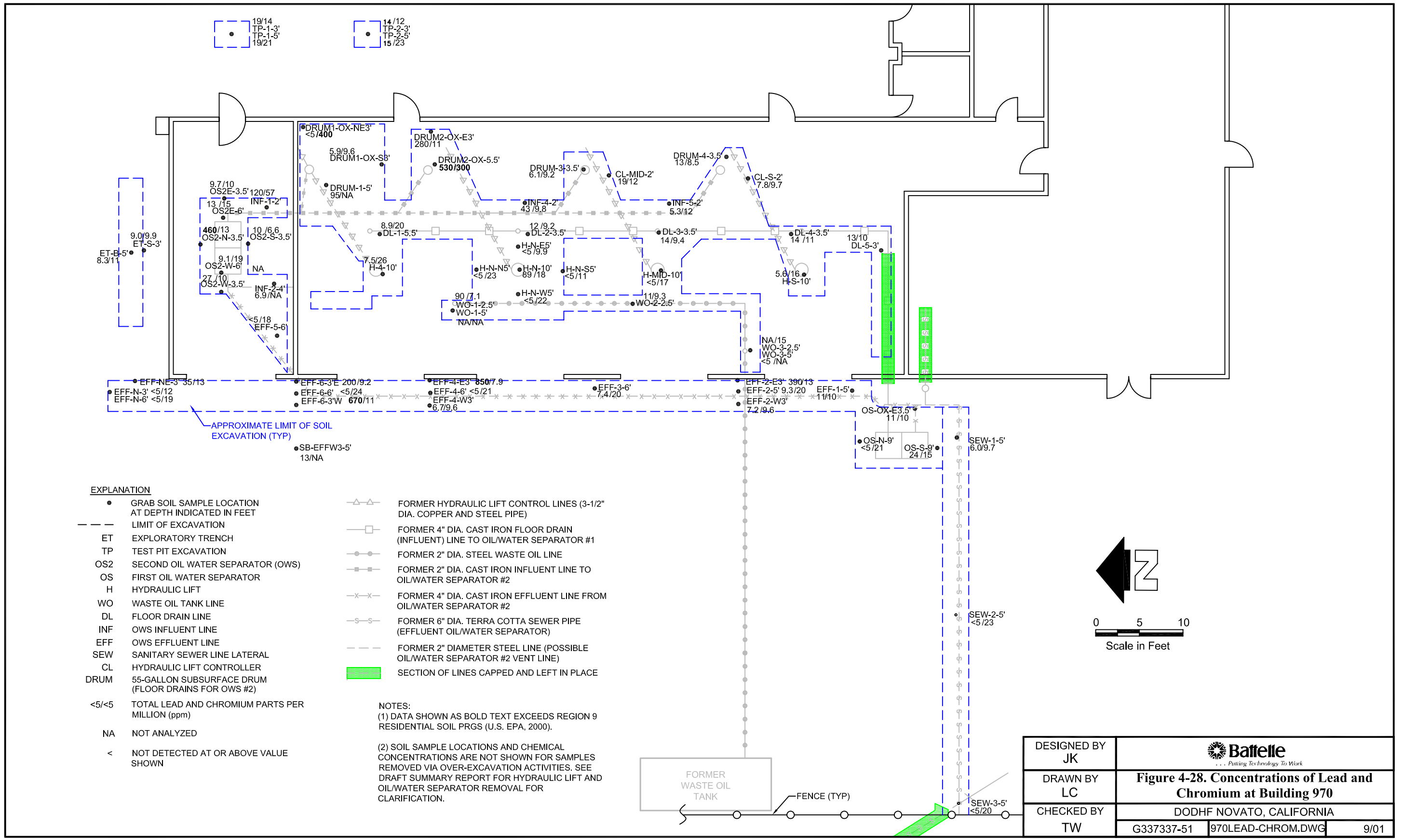
EXPLANATION

•	GRAB SOIL SAMPLE LOCATION AT DEPTH INDICATED IN FEET
— — —	LIMIT OF EXCAVATION
ET	EXPLORATORY TRENCH
TP	TEST PIT EXCAVATION
OS2	SECOND OIL WATER SEPARATOR (OWS)
OS	FIRST OIL WATER SEPARATOR
H	HYDRAULIC LIFT
WO	WASTE OIL TANK LINE
DL	FLOOR DRAIN LINE
INF	OWS INFLUENT LINE
EFF	OWS EFFLUENT LINE
SEW	SANITARY SEWER LINE LATERAL
CL	HYDRAULIC LIFT CONTROLLER
DRUM	55-GALLON SUBSURFACE DRUM (FLOOR DRAINS FOR OWS #2)
130/260	DIESEL RANGE TOTAL PETROLEUM HYDROCARBONS (TPHd)/TOTAL OIL AND GREASE (TOG) IN PARTS PER MILLION (ppm)
<	NOT DETECTED AT OR ABOVE VALUE SHOWN
NA	NOT ANALYZED OR REMOVED THROUGH OVER-EXCAVATION

- FORMER HYDRAULIC LIFT CONTROL LINES (3-1/2" DIA. COPPER AND STEEL PIPE)
- FORMER 4" DIA. CAST IRON FLOOR DRAIN (INFLUENT) LINE TO OIL/WATER SEPARATOR #1
- FORMER 2" DIA. STEEL WASTE OIL LINE
- FORMER 2" DIA. CAST IRON INFLUENT LINE TO OIL/WATER SEPARATOR #2
- FORMER 4" DIA. CAST IRON EFFLUENT LINE FROM OIL/WATER SEPARATOR #2
- FORMER 6" DIA. TERRA COTTA SEWER PIPE (EFFLUENT OIL/WATER SEPARATOR)
- FORMER 2" DIAMETER STEEL LINE (POSSIBLE OIL/WATER SEPARATOR #2 VENT LINE)
- SECTION OF LINES CAPPED AND LEFT IN PLACE

NOTE: SOIL SAMPLE LOCATIONS AND CHEMICAL CONCENTRATIONS ARE NOT SHOWN FOR SAMPLES REMOVED VIA OVER-EXCAVATION ACTIVITIES. SEE TABLES FOR CLARIFICATION.

DESIGNED BY JK	Battelle … Putting Technology To Work		
DRAWN BY LC	**Figure 4-27. Concentrations of TPH-D and TOG in Soil at Building 970**		
CHECKED BY TW	DODHF NOVATO, CALIFORNIA		
	G337337-51	970TPHDTOG02.DWG	9/01



EXPLANATION

•	GRAB SOIL SAMPLE LOCATION AT DEPTH INDICATED IN FEET
— — —	LIMIT OF EXCAVATION
ET	EXPLORATORY TRENCH
TP	TEST PIT EXCAVATION
OS2	SECOND OIL WATER SEPARATOR (OWS)
OS	FIRST OIL WATER SEPARATOR
H	HYDRAULIC LIFT
WO	WASTE OIL TANK LINE
DL	FLOOR DRAIN LINE
INF	OWS INFLUENT LINE
EFF	OWS EFFLUENT LINE
SEW	SANITARY SEWER LINE LATERAL
CL	HYDRAULIC LIFT CONTROLLER
DRUM	55-GALLON SUBSURFACE DRUM (FLOOR DRAINS FOR OWS #2)
<5/<5	TOTAL LEAD AND CHROMIUM PARTS PER MILLION (ppm)
NA	NOT ANALYZED
<	NOT DETECTED AT OR ABOVE VALUE SHOWN

△—△—	FORMER HYDRAULIC LIFT CONTROL LINES (3-1/2" DIA. COPPER AND STEEL PIPE)
—□—	FORMER 4" DIA. CAST IRON FLOOR DRAIN (INFLUENT) LINE TO OIL/WATER SEPARATOR #1
—●—●	FORMER 2" DIA. STEEL WASTE OIL LINE
—■—■	FORMER 2" DIA. CAST IRON INFLUENT LINE TO OIL/WATER SEPARATOR #2
—X—X—	FORMER 4" DIA. CAST IRON EFFLUENT LINE FROM OIL/WATER SEPARATOR #2
—S—S—	FORMER 6" DIA. TERRA COTTA SEWER PIPE (EFFLUENT OIL/WATER SEPARATOR)
— — —	FORMER 2" DIAMETER STEEL LINE (POSSIBLE OIL/WATER SEPARATOR #2 VENT LINE)
▒▒▒	SECTION OF LINES CAPPED AND LEFT IN PLACE

NOTES:
(1) DATA SHOWN AS BOLD TEXT EXCEEDS REGION 9 RESIDENTIAL SOIL PRGS (U.S. EPA, 2000).

(2) SOIL SAMPLE LOCATIONS AND CHEMICAL CONCENTRATIONS ARE NOT SHOWN FOR SAMPLES REMOVED VIA OVER-EXCAVATION ACTIVITIES. SEE DRAFT SUMMARY REPORT FOR HYDRAULIC LIFT AND OIL/WATER SEPARATOR REMOVAL FOR CLARIFICATION.

DESIGNED BY JK	Battelle … Putting Technology To Work	
DRAWN BY LC	**Figure 4-28. Concentrations of Lead and Chromium at Building 970**	
CHECKED BY TW	DODHF NOVATO, CALIFORNIA	
	G337337-51	970LEAD-CHROM.DWG 9/01

TP-1-3'
TP-1-5'
TP-2-3'
TP-2-5'
DRUM1-OX-NE3'
DRUM2-OX-E3'
DRUM1-OX-S8'
DRUM2-OX-5.5'
DRUM-1-5'
DRUM-3-3.5'
CL-MID-2'
DRUM-4-3.5'
CL-S-2'
OS2E-3.5'
INF-1-2'
INF-4-2'
INF-5-2'
OS2E-6'
DL-1-5.5'
DL-2-3.5'
DL-3-3.5'
DL-4-3.5'
ET-B-5'
ET-S-3'
OS2-N-3.5'
OS2-S-3.5'
H-N-E5'
DL-5-3'
OS2-W-6'
H-4-10'
H-N-N5'
H-N-10'
H-N-S5'
H-MID-10'
H-S-10'
OS2-W-3.5'
INF-2-4'
H-N-W5'
WO-1-2.5'
WO-1-5'
WO-2-2.5'
EFF-5-6'
WO-3-2.5'
WO-3-5'
EFF-NE-3'
EFF-6-3'E
EFF-4-E3'
EFF-3-6'
EFF-2-E3'
EFF-1-5'
EFF-N-3'
EFF-N-6'
EFF-6-6'
EFF-4-6'
EFF-2-5'
EFF-6-3'W
EFF-4-W3'
EFF-2-W3'
OS-OX-E3.5'
APPROXIMATE LIMIT OF SOIL EXCAVATION (TYP)
OS-N-9'
OS-S-9'
SEW-1-5'
SB-EFFW3-5'
NA
SEW-2-5'
FORMER WASTE OIL TANK
FENCE (TYP)
SEW-3-5'

EXPLANATION

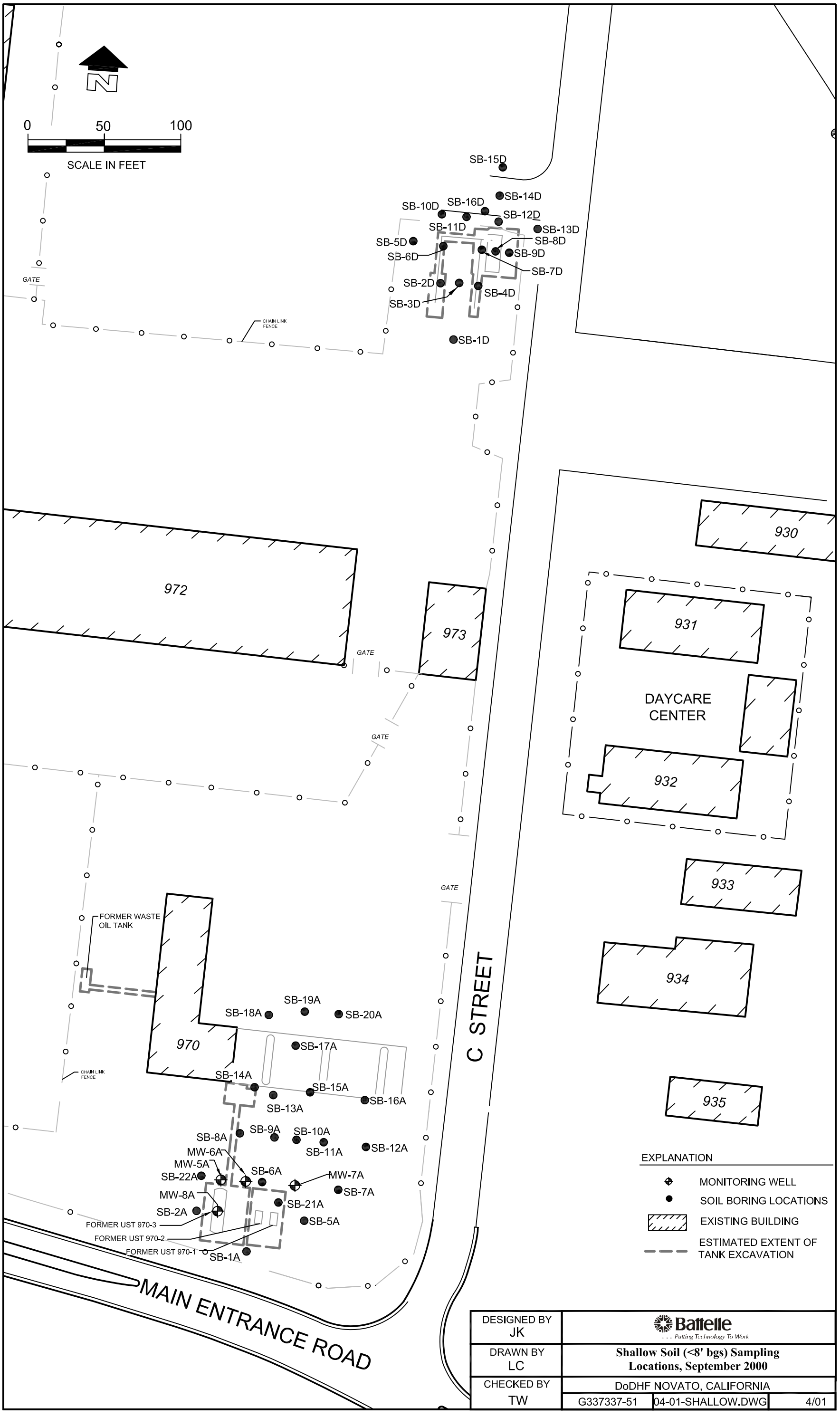
- GRAB SOIL SAMPLE LOCATION AT DEPTH INDICATED IN FEET
- LIMIT OF EXCAVATION
- ET EXPLORATORY TRENCH
- TP TEST PIT EXCAVATION
- OS2 SECOND OIL WATER SEPARATOR (OWS)
- OS FIRST OIL WATER SEPARATOR
- H HYDRAULIC LIFT
- WO WASTE OIL TANK LINE
- DL FLOOR DRAIN LINE
- INF OWS INFLUENT LINE
- EFF OWS EFFLUENT LINE
- SEW SANITARY SEWER LINE LATERAL
- CL HYDRAULIC LIFT CONTROLLER
- DRUM 55-GALLON SUBSURFACE DRUM (FLOOR DRAINS FOR OWS #2)
- APPROXIMATE AREA OF REMAINING HYDROCARBON-AFFECTED SOIL
- ? QUERIED WHERE EXTENT OF HYDROCARBON-AFFECTED SOIL UNCERTAIN

- FORMER HYDRAULIC LIFT CONTROL LINES (3-1/2" DIA. COPPER AND STEEL PIPE)
- FORMER 4" DIA. CAST IRON FLOOR DRAIN (INFLUENT) LINE TO OIL/WATER SEPARATOR #1
- FORMER 2" DIA. STEEL WASTE OIL LINE
- FORMER 2" DIA. CAST IRON INFLUENT LINE TO OIL/WATER SEPARATOR #2
- FORMER 4" DIA. CAST IRON EFFLUENT LINE FROM OIL/WATER SEPARATOR #2
- FORMER 6" DIA. TERRA COTTA SEWER PIPE (EFFLUENT OIL/WATER SEPARATOR)
- FORMER 2" DIAMETER STEEL LINE (POSSIBLE OIL/WATER SEPARATOR #2 VENT LINE)
- SECTION OF LINES CAPPED AND LEFT IN PLACE

N

0 5 10
Scale in Feet

DESIGNED BY JK	Battelle … Putting Technology To Work		
DRAWN BY LC	**Figure 4-29. Conceptual Extent of Residual Petroleum Hydrocarbons in Soil at Building 970**		
CHECKED BY TW	DODHF NOVATO, CALIFORNIA		
	G337337-51	970EXTENT.DWG	9/01


N
0
50
100
SCALE IN FEET
SB-15D
SB-14D
SB-10D
SB-16D
SB-12D
SB-11D
SB-13D
SB-5D
SB-8D
SB-6D
SB-9D
SB-7D
SB-2D
SB-4D
SB-3D
GATE
CHAIN LINK FENCE
SB-1D
972
973
930
931
DAYCARE CENTER
932
933
934
935
GATE
GATE
GATE
FORMER WASTE OIL TANK
CHAIN LINK FENCE
970
SB-19A
SB-18A
SB-20A
SB-17A
SB-14A
SB-15A
SB-16A
SB-13A
SB-9A
SB-10A
SB-8A
SB-11A
SB-12A
MW-6A
MW-5A
SB-22A
SB-6A
MW-7A
SB-7A
MW-8A
SB-21A
SB-2A
SB-5A
FORMER UST 970-3
FORMER UST 970-2
FORMER UST 970-1
SB-1A
C STREET
MAIN ENTRANCE ROAD
EXPLANATION
MONITORING WELL
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED EXTENT OF TANK EXCAVATION
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
. . . Putting Technology To Work
Shallow Soil (<8' bgs) Sampling Locations, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01

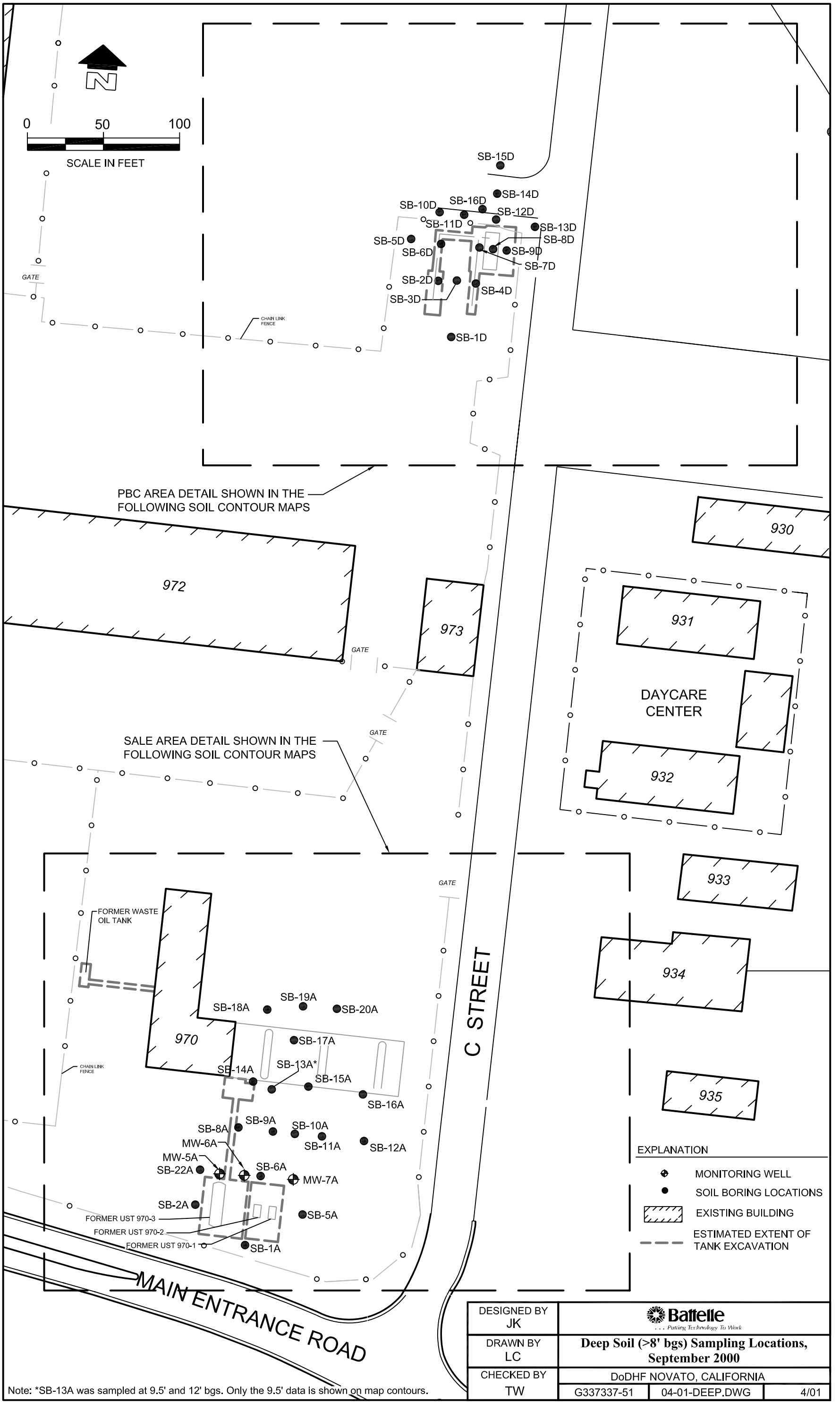
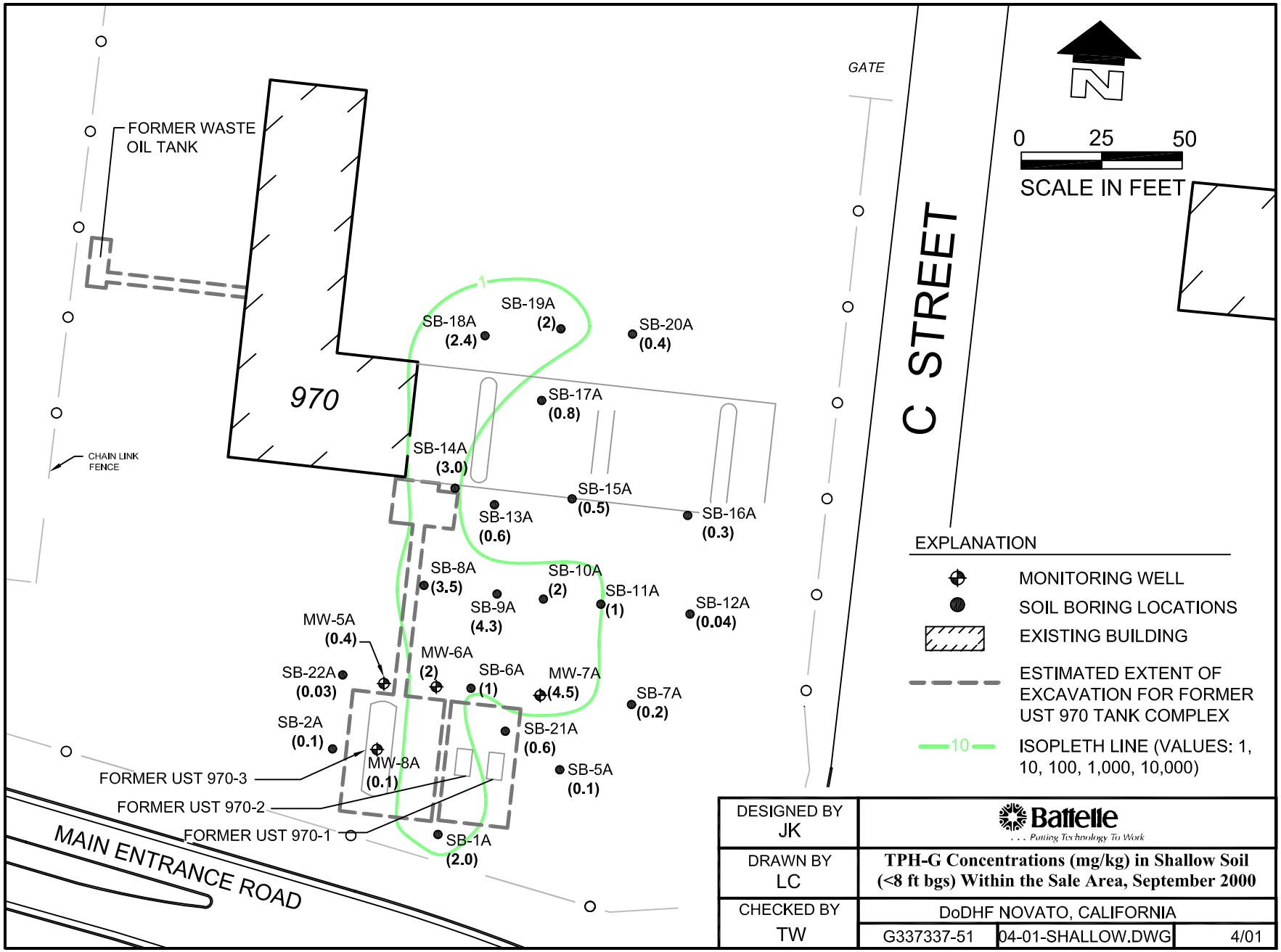
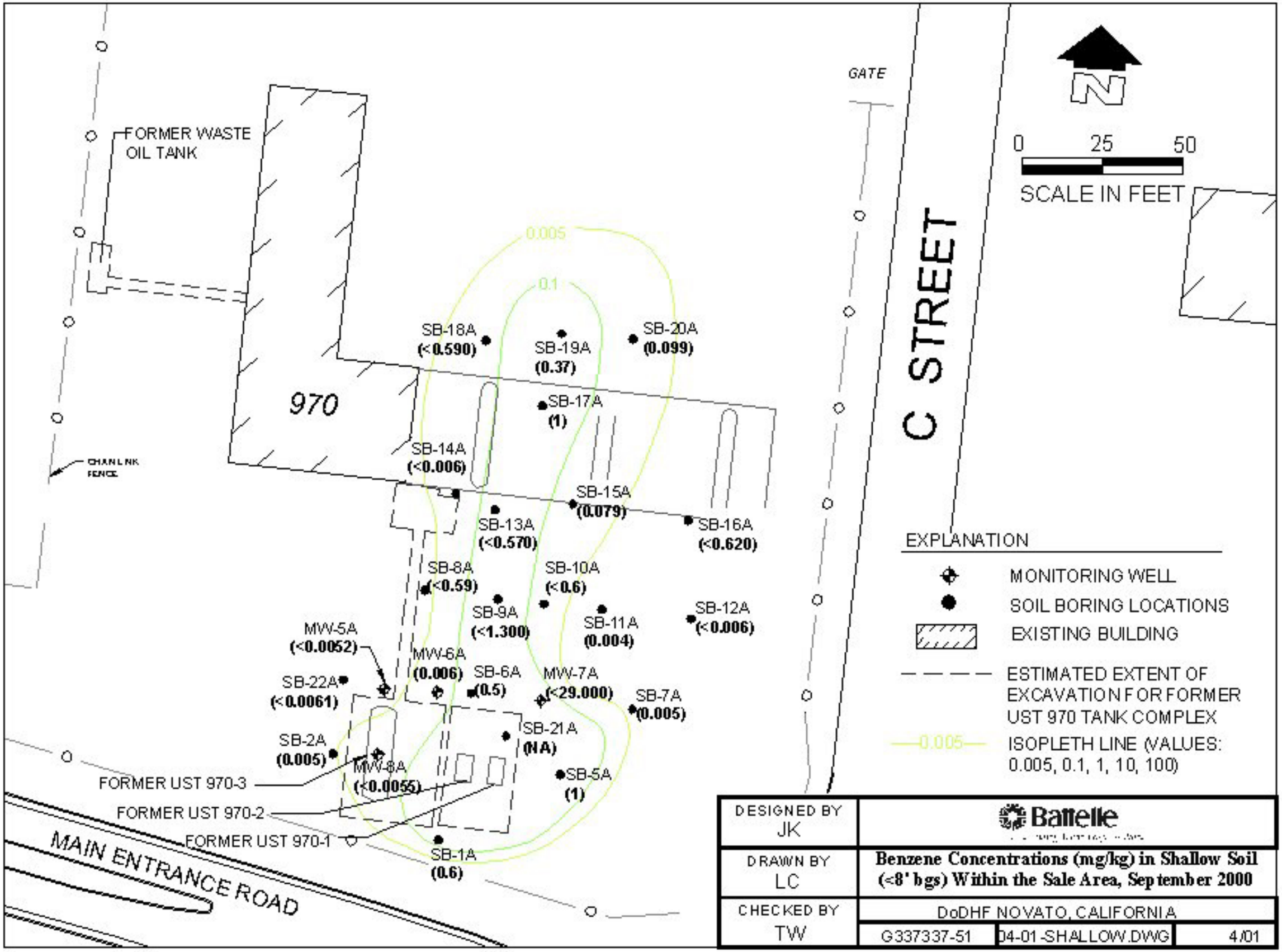
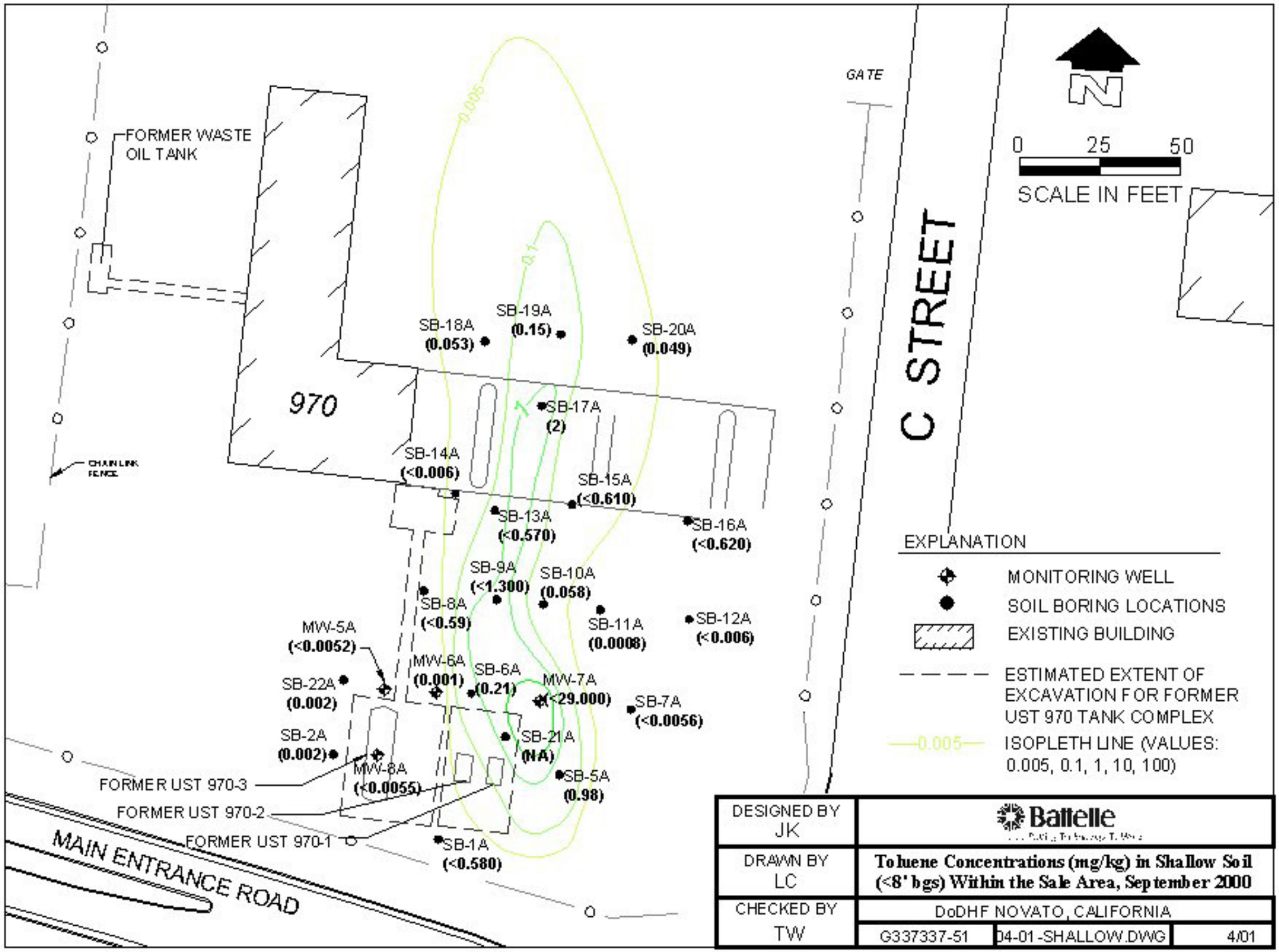


Figure 4-31. Deep Soil (<8' bgs) Sampling Locations, September 2000

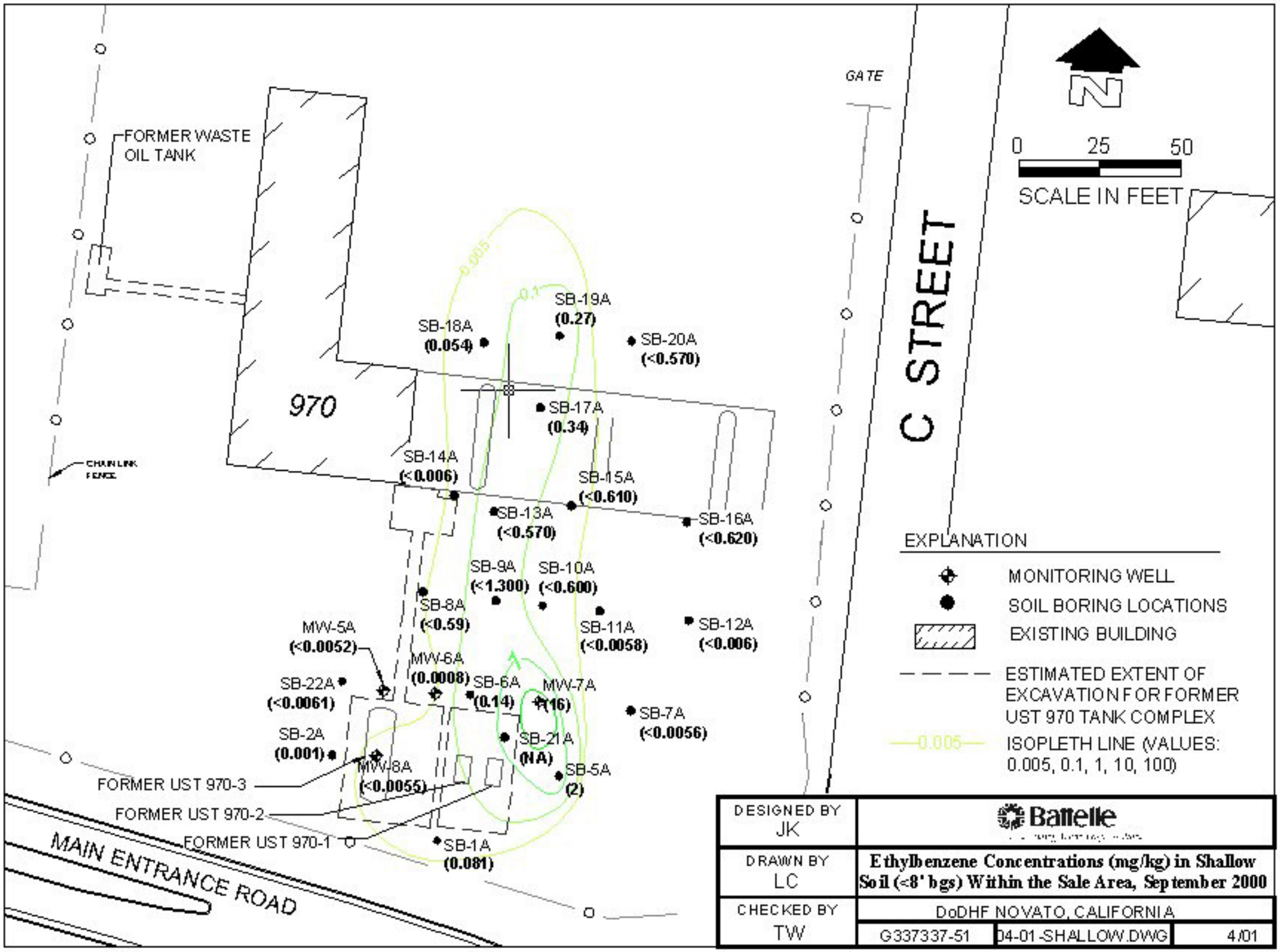

GATE
C STREET
N
0 25 50
SCALE IN FEET
FORMER WASTE OIL TANK
970
CHAIN LINK FENCE
SB-18A (2.4)
SB-19A (2)
SB-20A (0.4)
SB-17A (0.8)
SB-14A (3.0)
SB-15A (0.5)
SB-16A (0.3)
SB-13A (0.6)
SB-8A (3.5)
SB-10A (2)
SB-11A (1)
SB-12A (0.04)
SB-9A (4.3)
MW-5A (0.4)
MW-6A (2)
SB-22A (0.03)
SB-6A (1)
MW-7A (4.5)
SB-7A (0.2)
SB-2A (0.1)
SB-21A (0.6)
MW-8A (0.1)
SB-5A (0.1)
FORMER UST 970-3
FORMER UST 970-2
FORMER UST 970-1
SB-1A (2.0)
MAIN ENTRANCE ROAD
EXPLANATION
MONITORING WELL
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED EXTENT OF EXCAVATION FOR FORMER UST 970 TANK COMPLEX
10
ISOPLETH LINE (VALUES: 1, 10, 100, 1,000, 10,000)
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
Putting Technology To Work
TPH-G Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the Sale Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01



DESIGNED BY JK	Battelle		
DRAWN BY LC	**Benzene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01



DESIGNED BY JK	Battelle		
DRAWN BY LC	**Toluene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01



DESIGNED BY JK	Battelle		
DRAWN BY LC	**Ethylbenzene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01

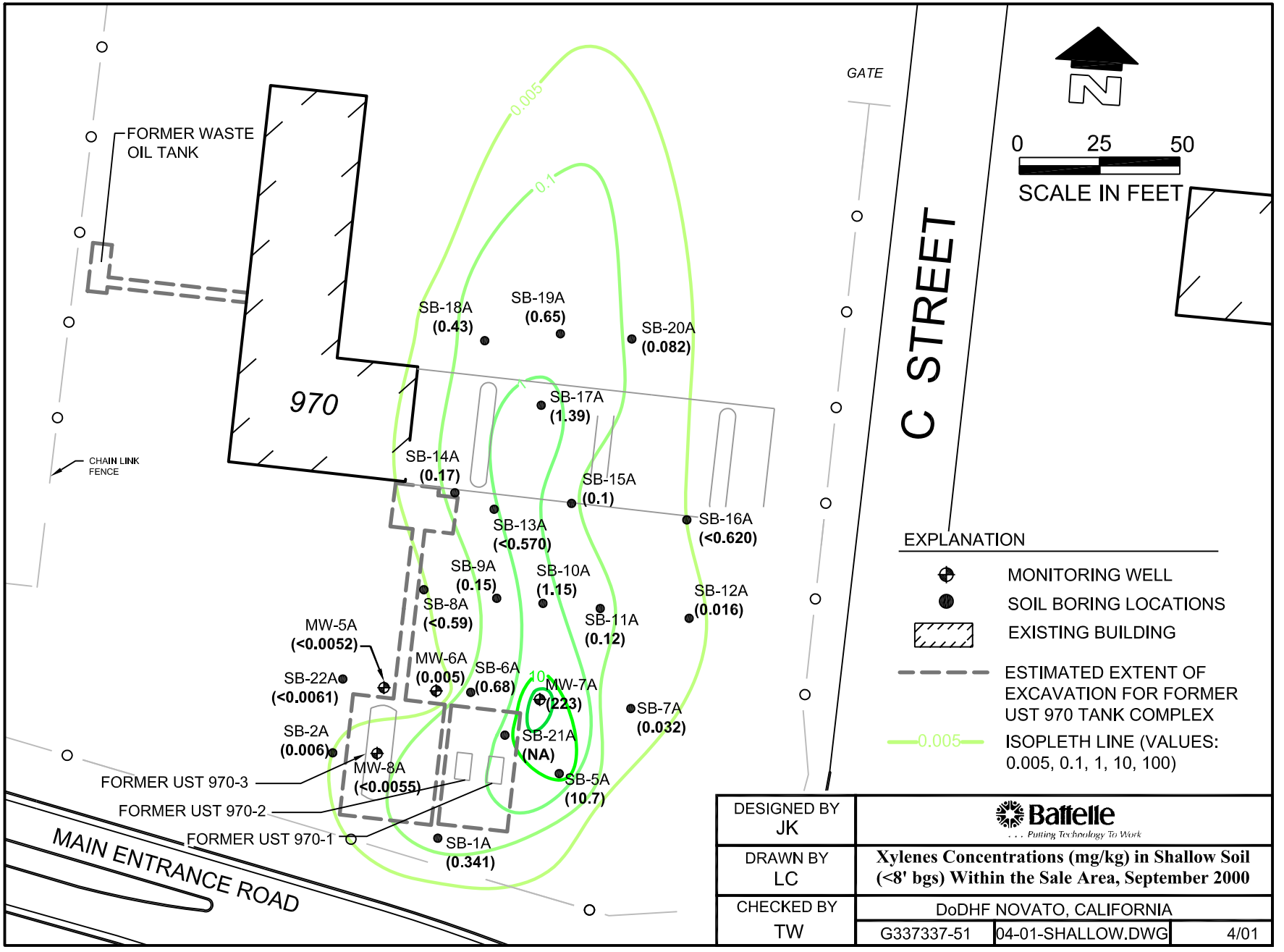
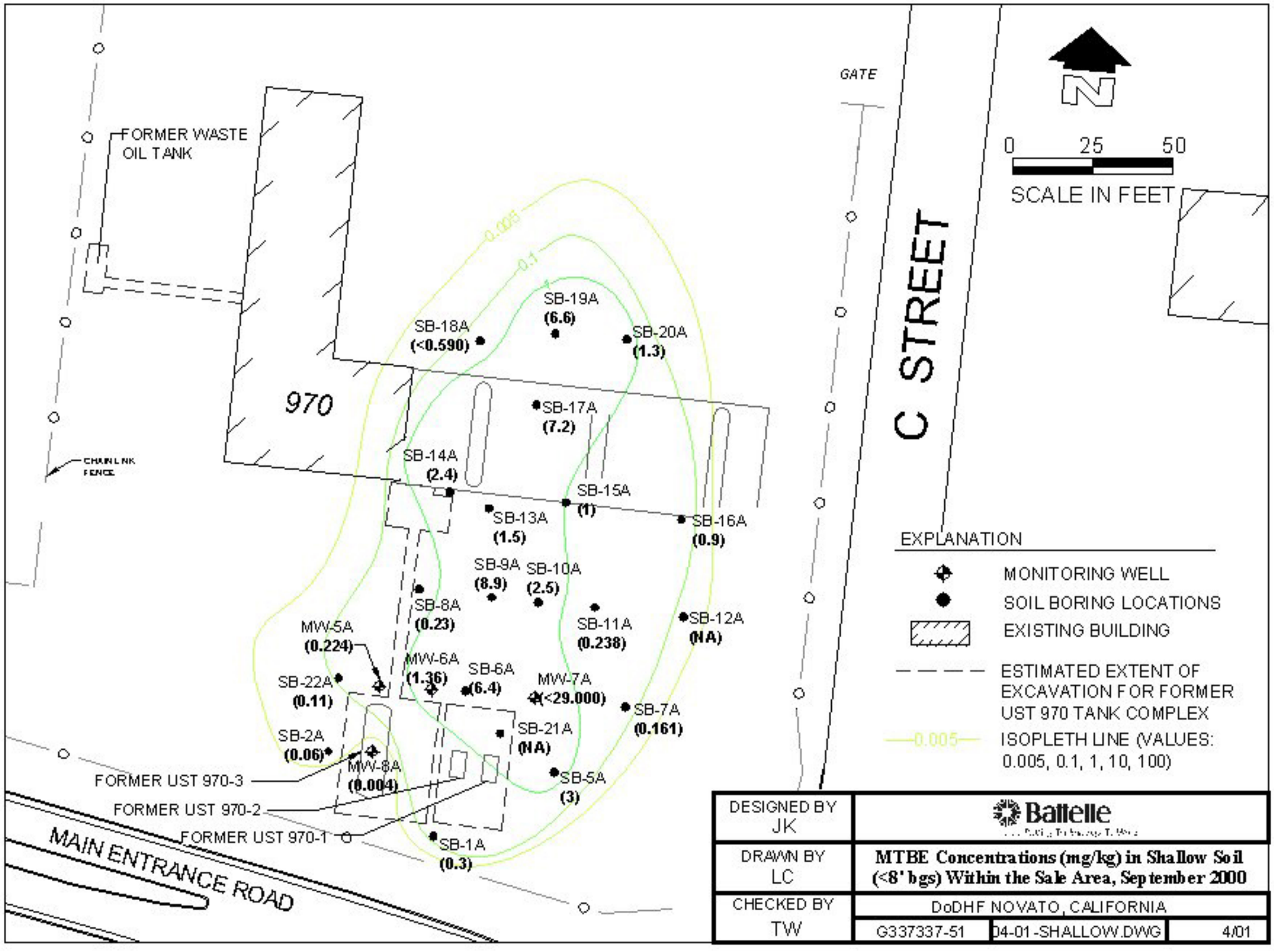
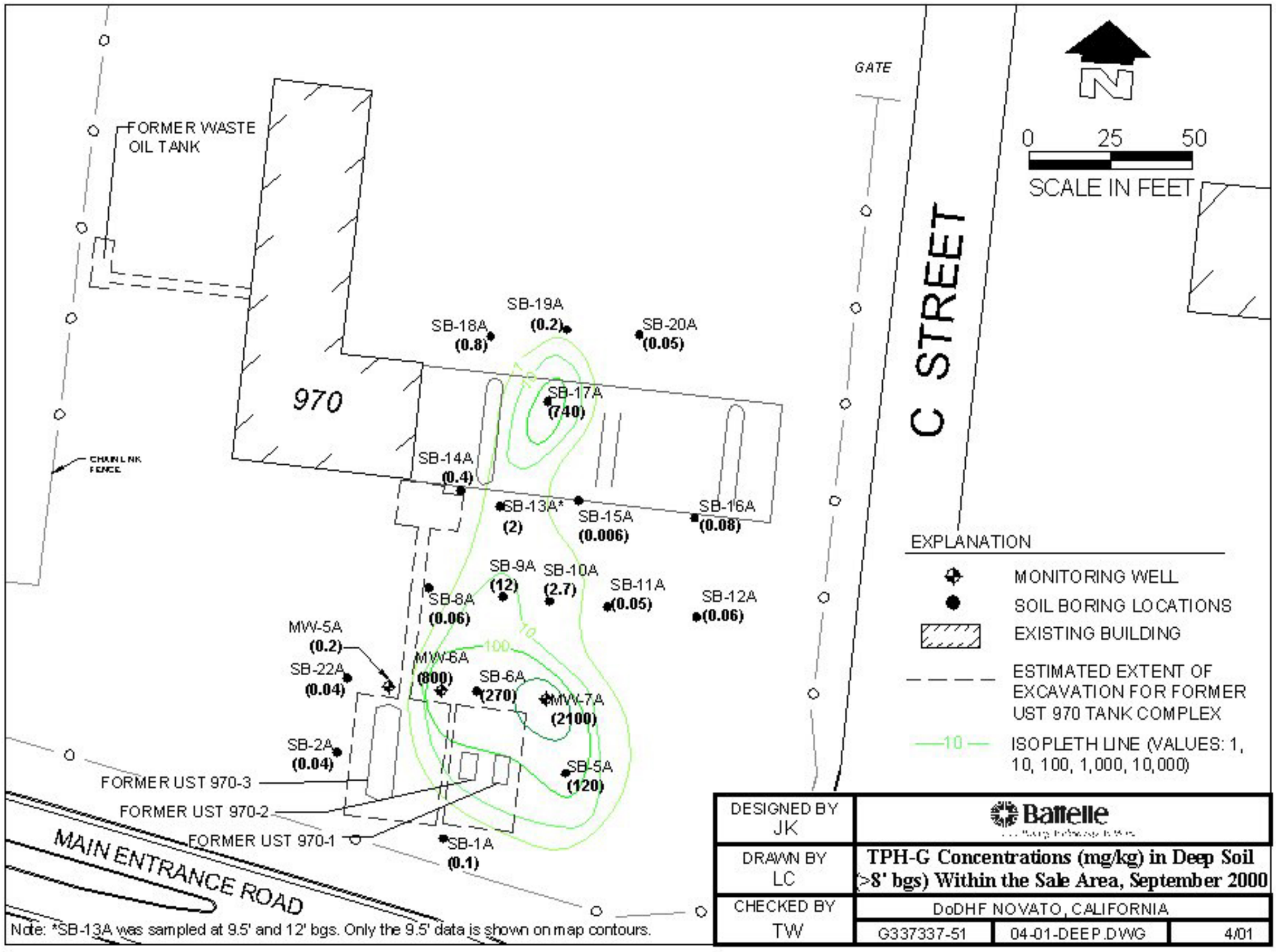


Figure 4-36. Xylenes Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the Sale Area, September 2000

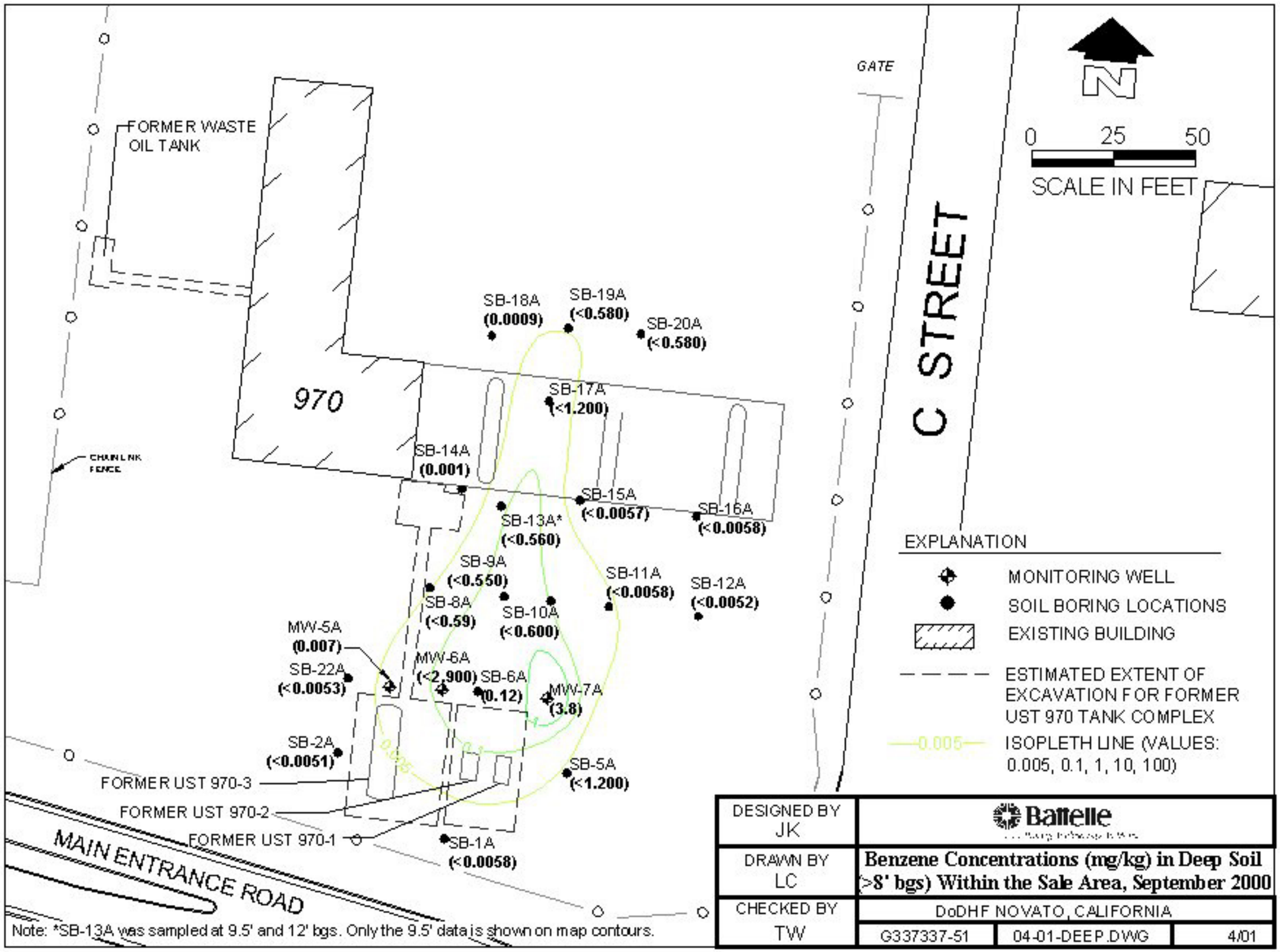


DESIGNED BY JK	Battelle		
DRAWN BY LC	**MTBE Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01



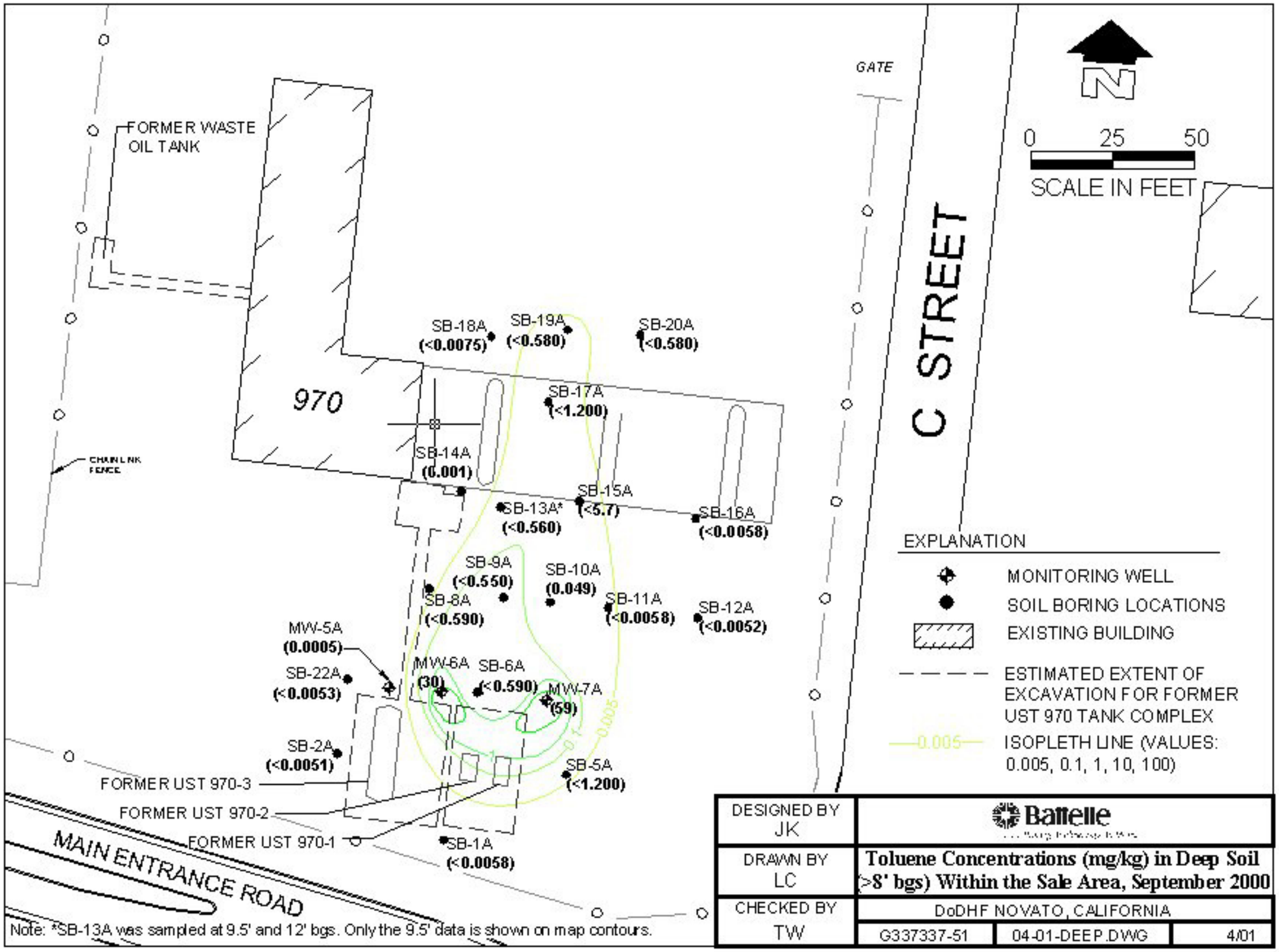
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

DESIGNED BY JK	Battelle		
DRAWN BY LC	**TPH-G Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



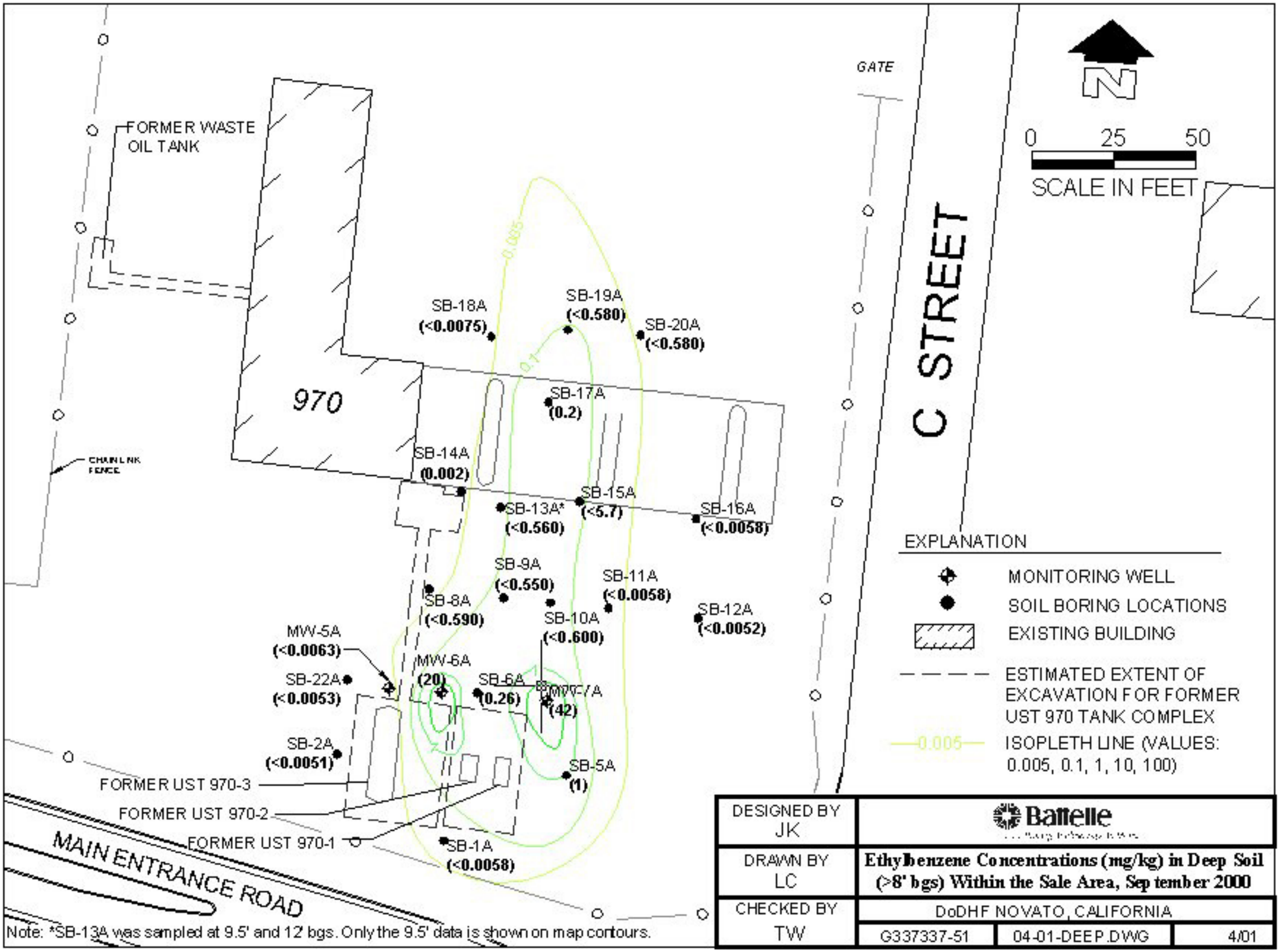
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

DESIGNED BY JK	Battelle		
DRAWN BY LC	**Benzene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



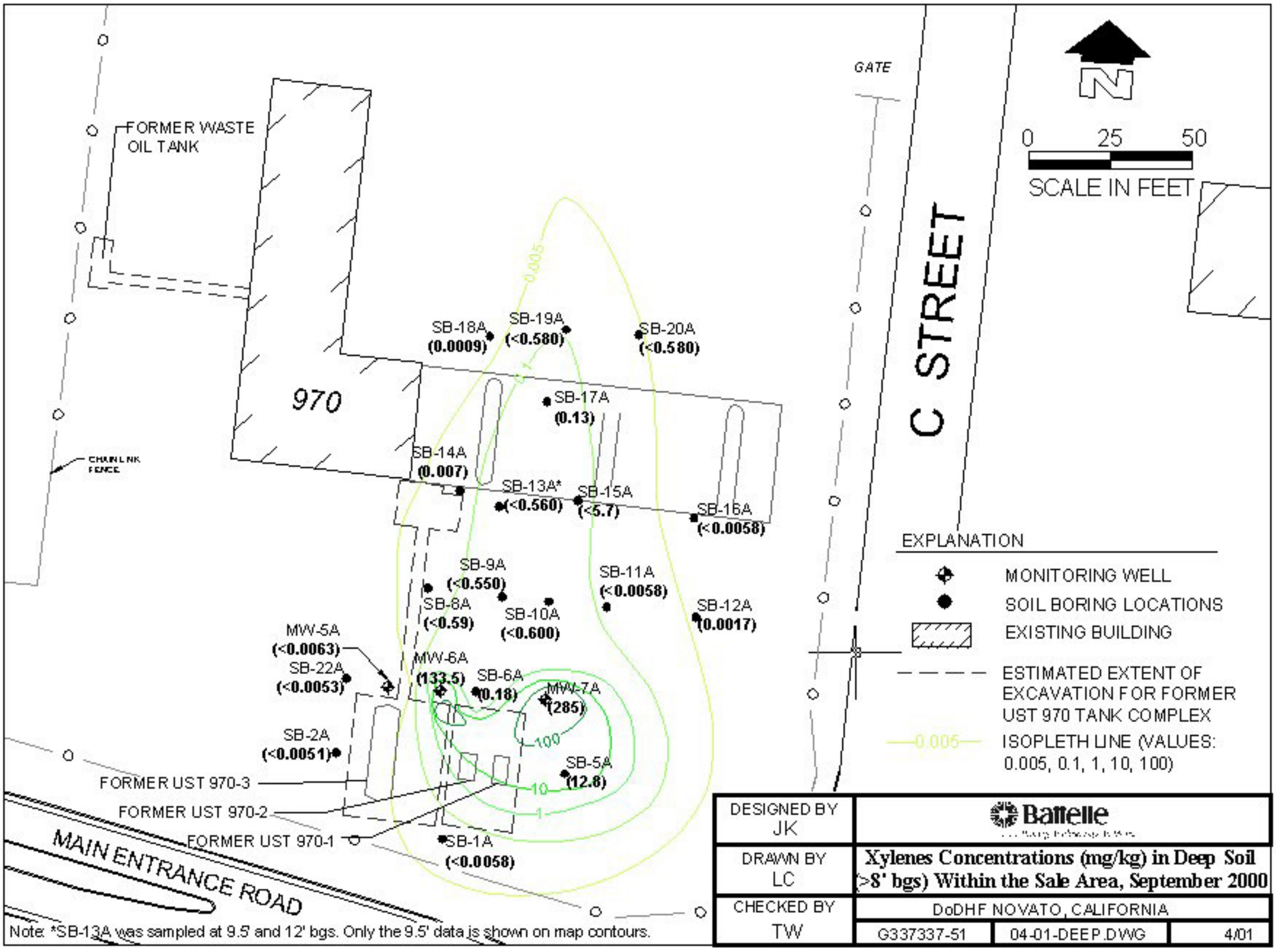
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

DESIGNED BY JK	Battelle		
DRAWN BY LC	**Toluene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



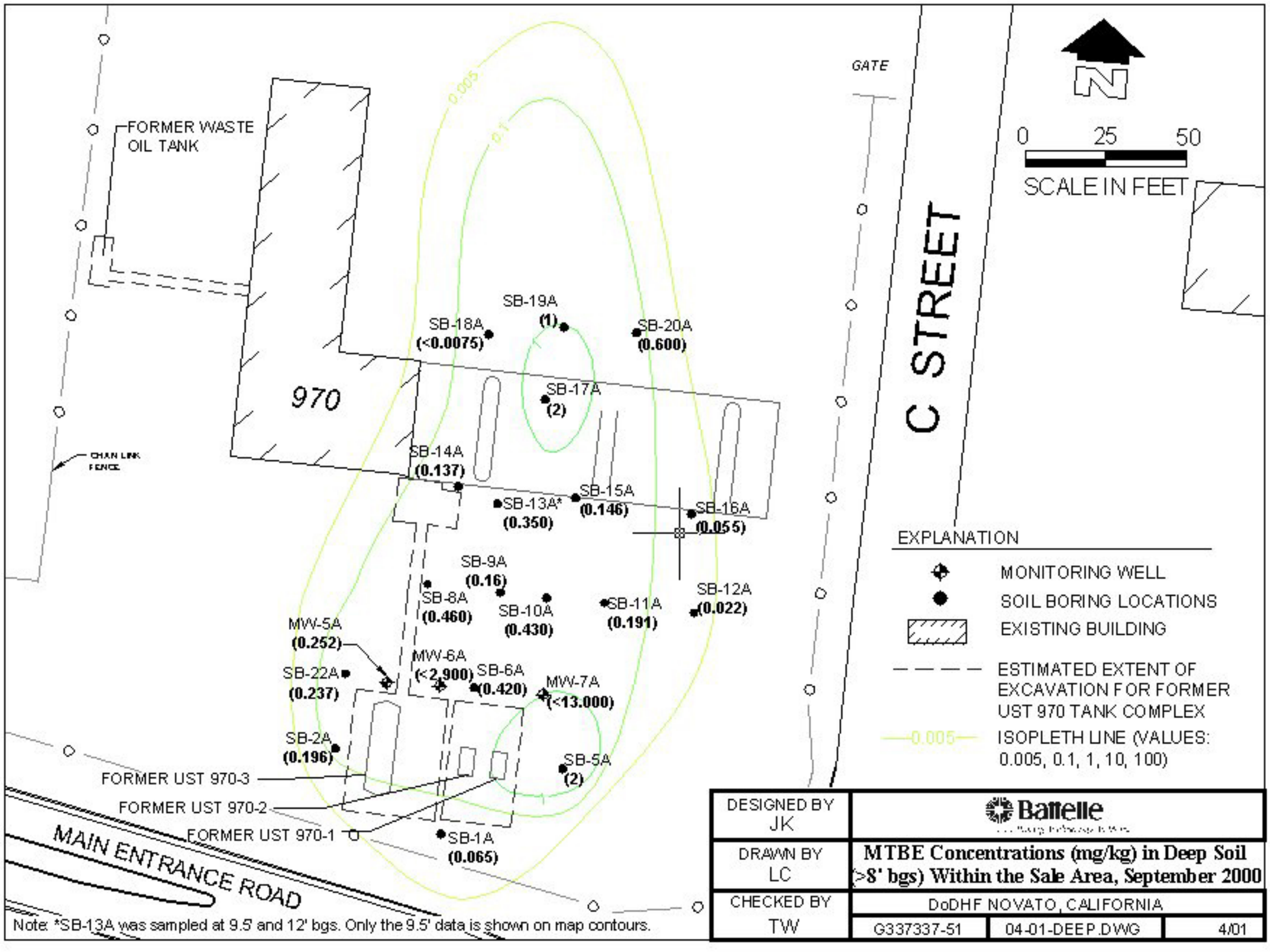
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

DESIGNED BY JK	Battelle		
DRAWN BY LC	**Ethylbenzene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



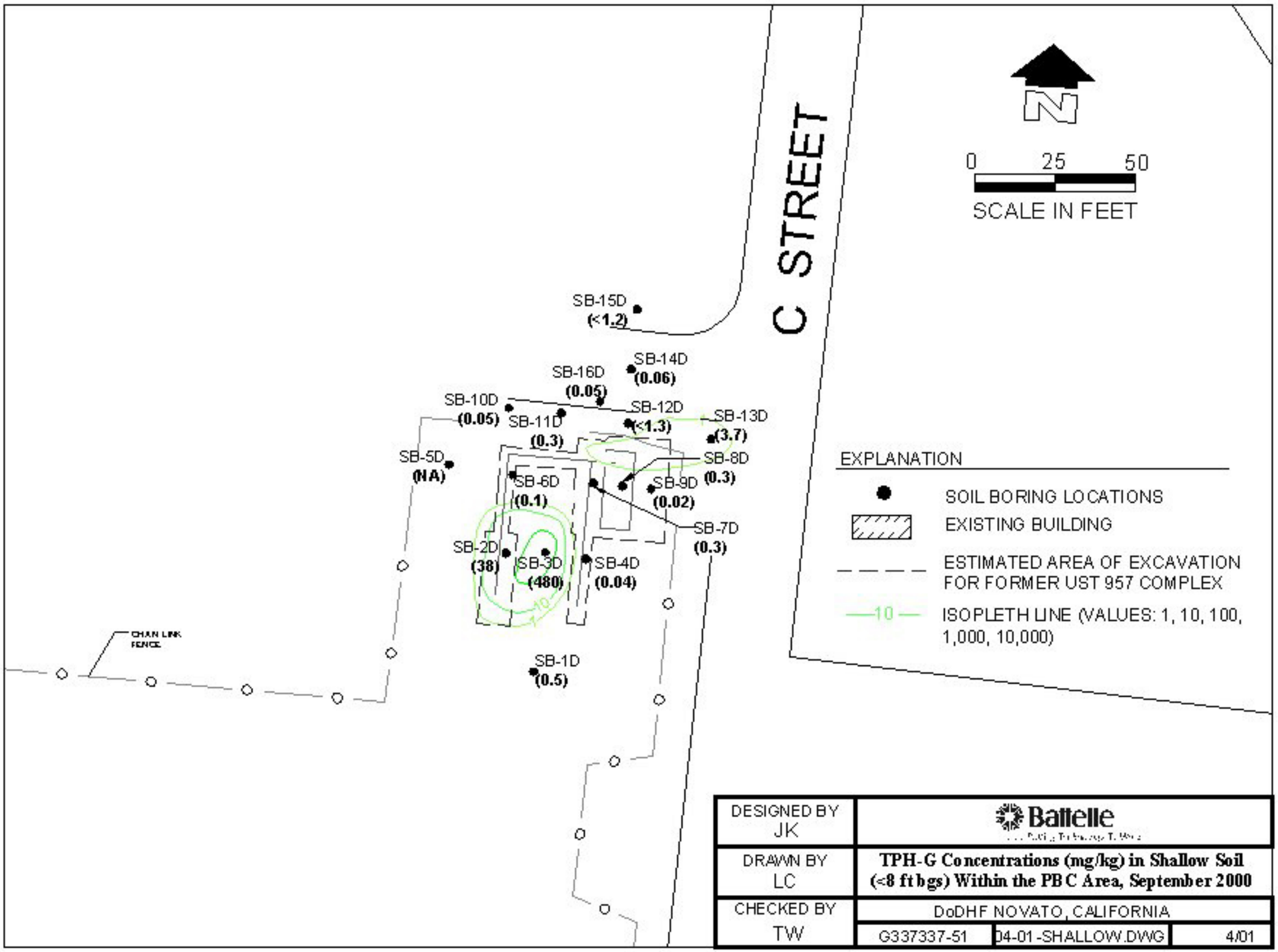
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

DESIGNED BY JK	Battelle		
DRAWN BY LC	**Xylenes Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01

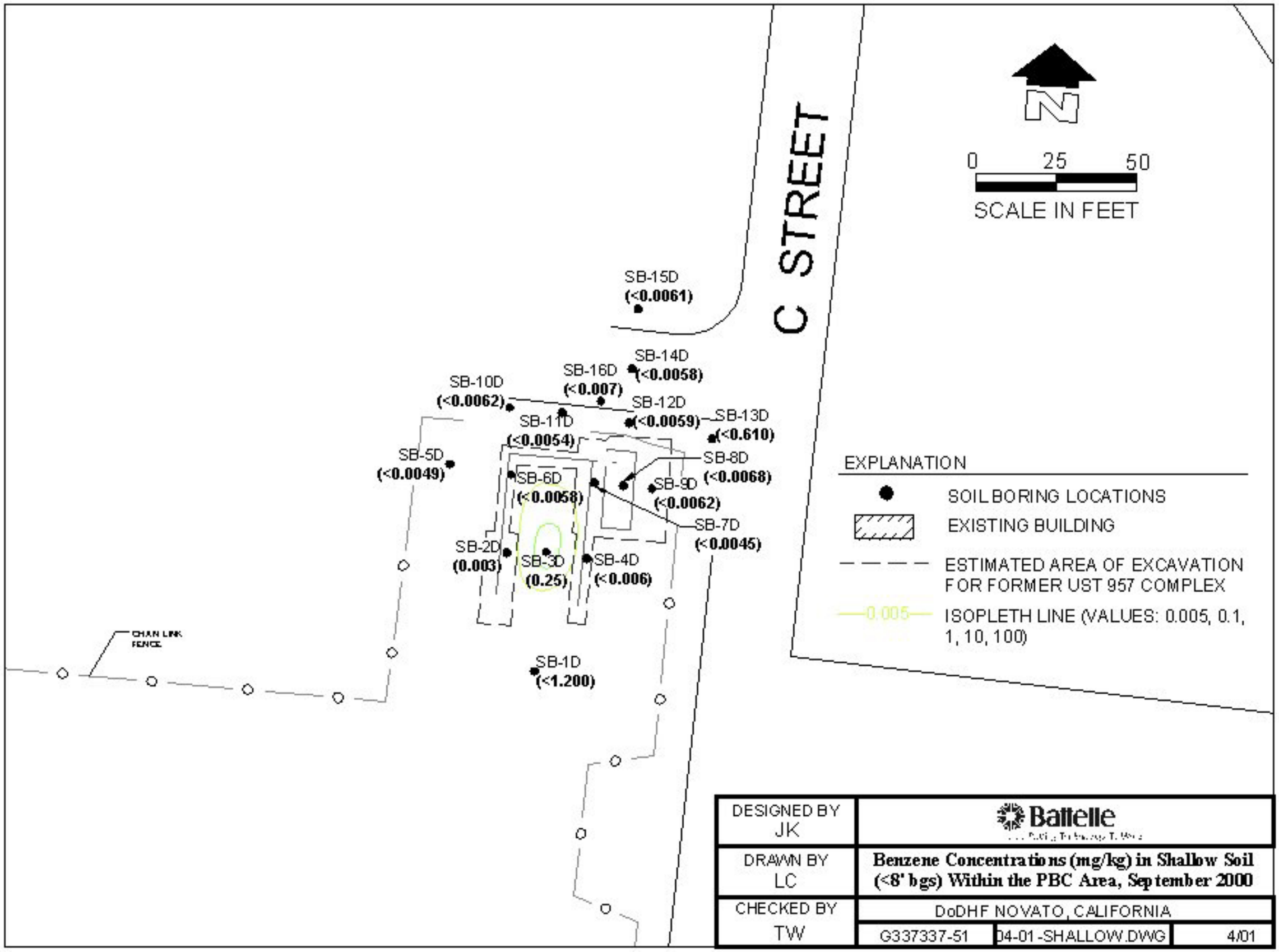


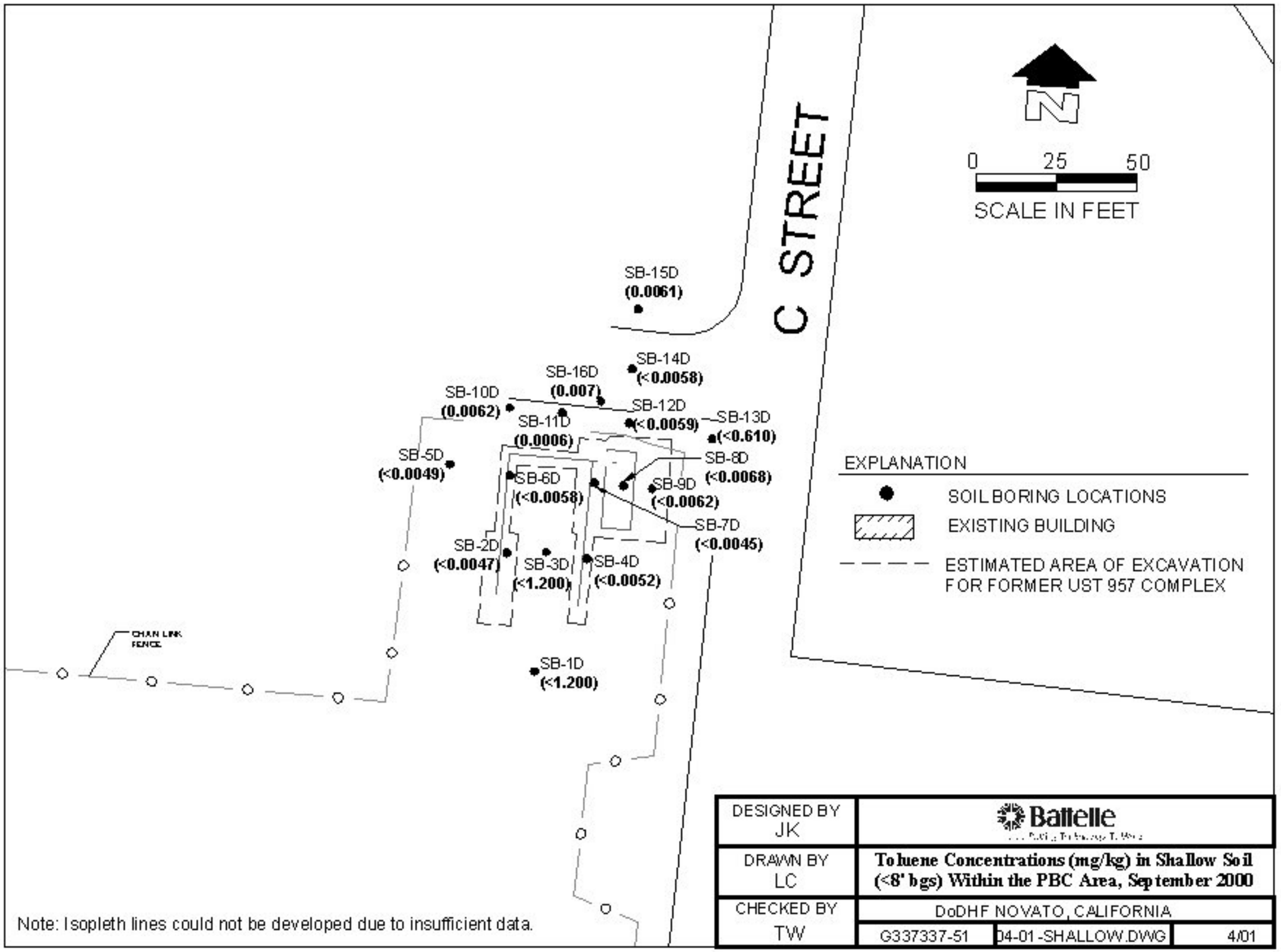
Note: *SB-13A was sampled at 9.5' and 12' bgs. Only the 9.5' data is shown on map contours.

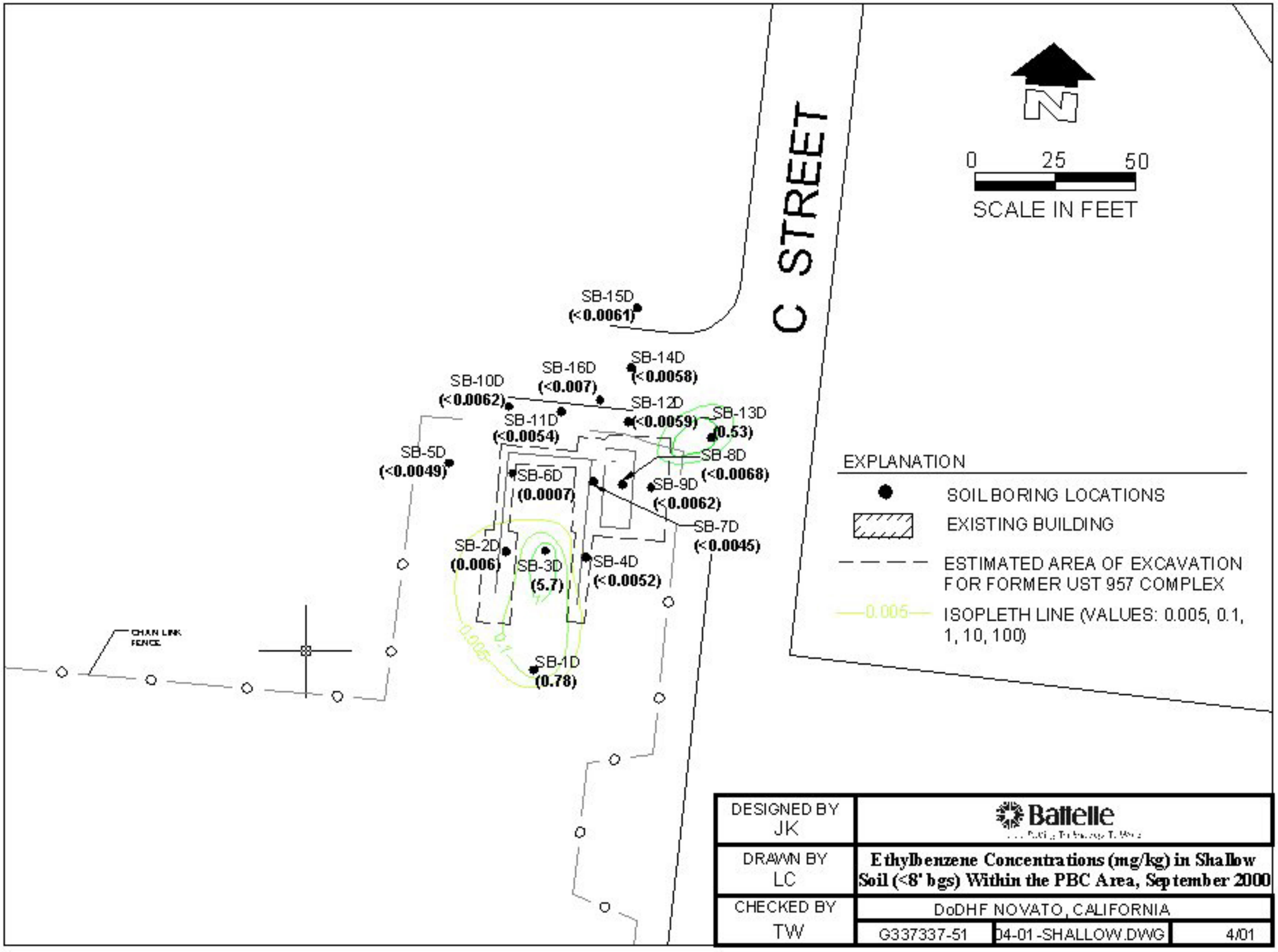
DESIGNED BY JK	Battelle		
DRAWN BY LC	**MTBE Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the Sale Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



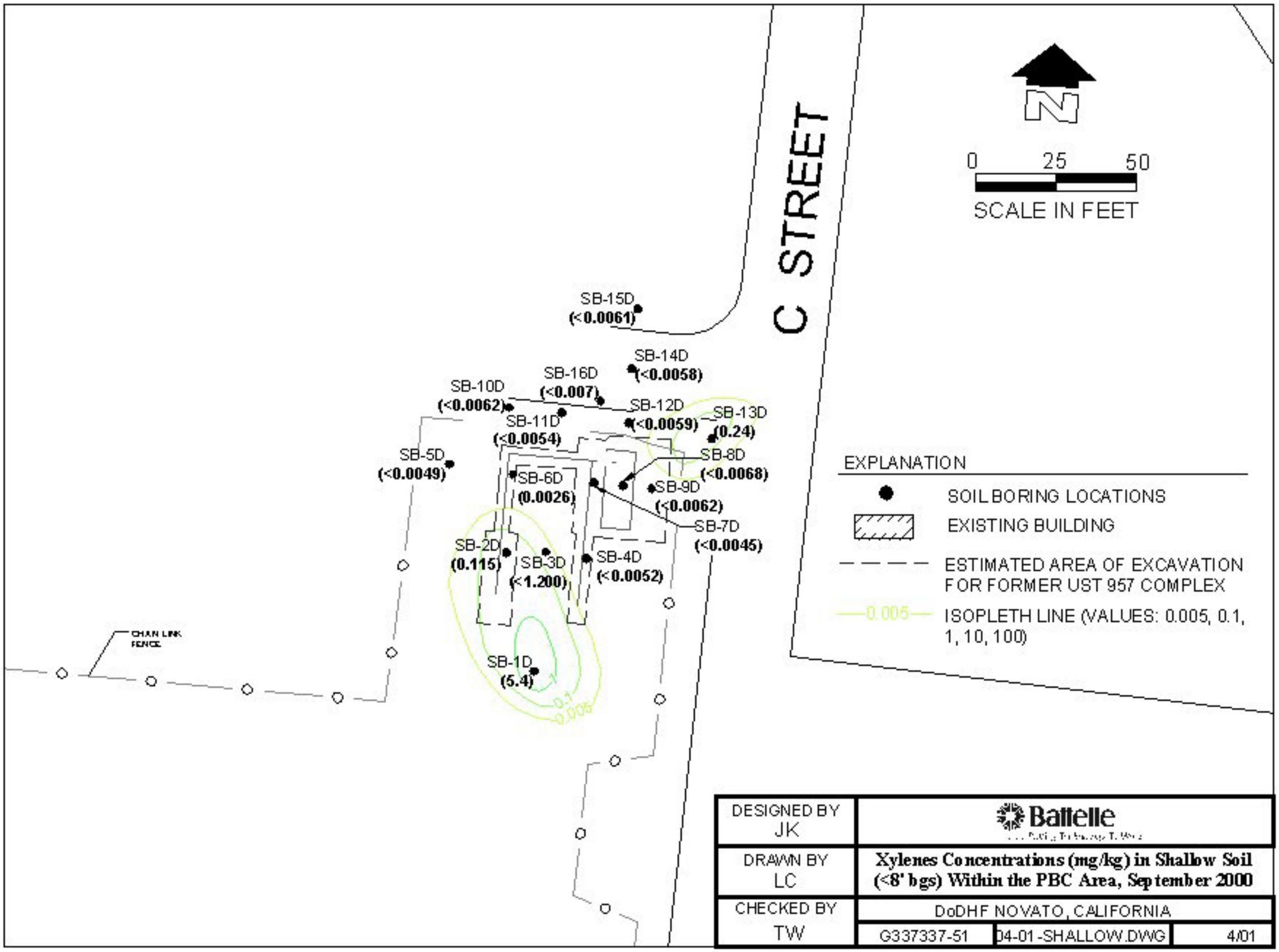
DESIGNED BY JK	Battelle		
DRAWN BY LC	**TPH-G Concentrations (mg/kg) in Shallow Soil (<8 ft bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01

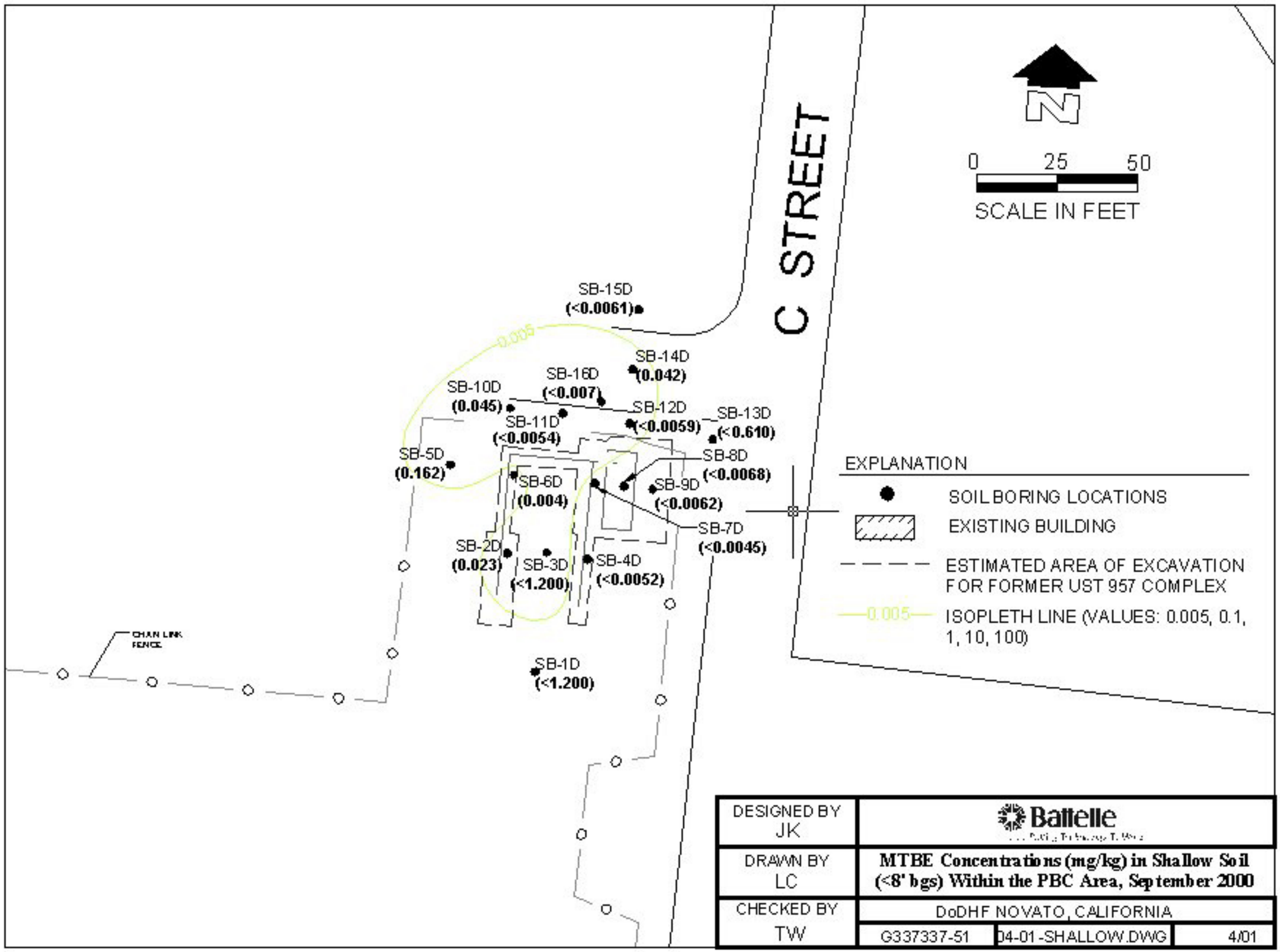

C STREET
N
0 25 50
SCALE IN FEET
SB-15D
(<0.0061)
SB-14D
(<0.0058)
SB-16D
(<0.007)
SB-10D
(<0.0062)
SB-12D
(<0.0059)
SB-13D
(<0.610)
SB-11D
(<0.0054)
SB-5D
(<0.0049)
SB-8D
(<0.0068)
SB-6D
(<0.0058)
SB-9D
(<0.0062)
SB-7D
(<0.0045)
SB-2D
(0.003)
SB-3D
(0.25)
SB-4D
(<0.006)
SB-1D
(<1.200)
CHAIN LINK FENCE
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
0.005
ISOPLETH LINE (VALUES: 0.005, 0.1, 1, 10, 100)
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
Benzene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01

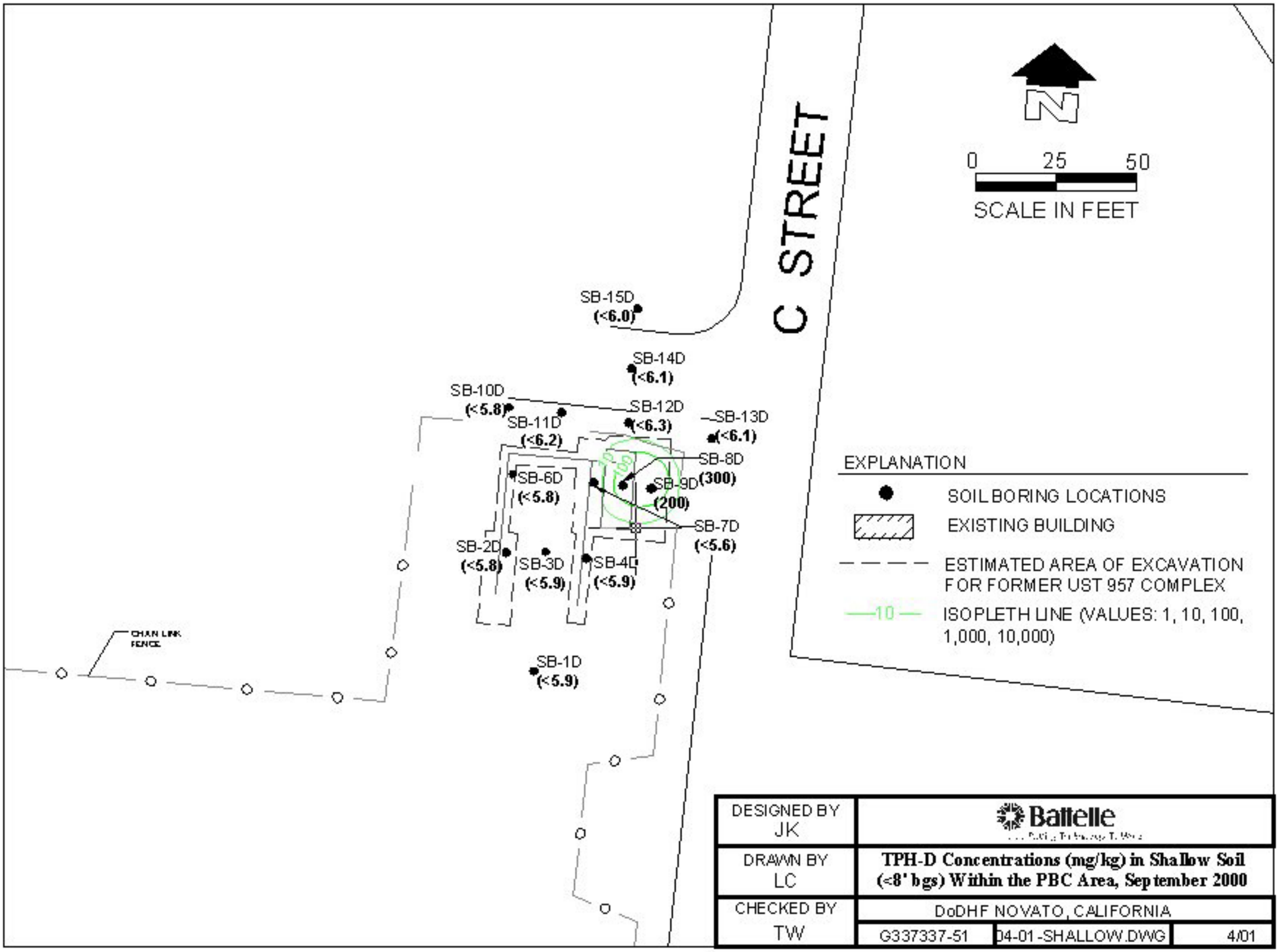

C STREET
N
0 25 50
SCALE IN FEET
SB-15D
(0.0061)
SB-14D
(<0.0058)
SB-16D
(0.007)
SB-10D
(0.0062)
SB-12D
(<0.0059)
SB-13D
(<0.610)
SB-11D
(0.0006)
SB-5D
(<0.0049)
SB-8D
(<0.0068)
SB-6D
(<0.0058)
SB-9D
(<0.0062)
SB-7D
(<0.0045)
SB-2D
(<0.0047)
SB-3D
(<1.200)
SB-4D
(<0.0052)
CHAN LINK FENCE
SB-1D
(<1.200)
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
Note: Isopleth lines could not be developed due to insufficient data.
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
Toluene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01



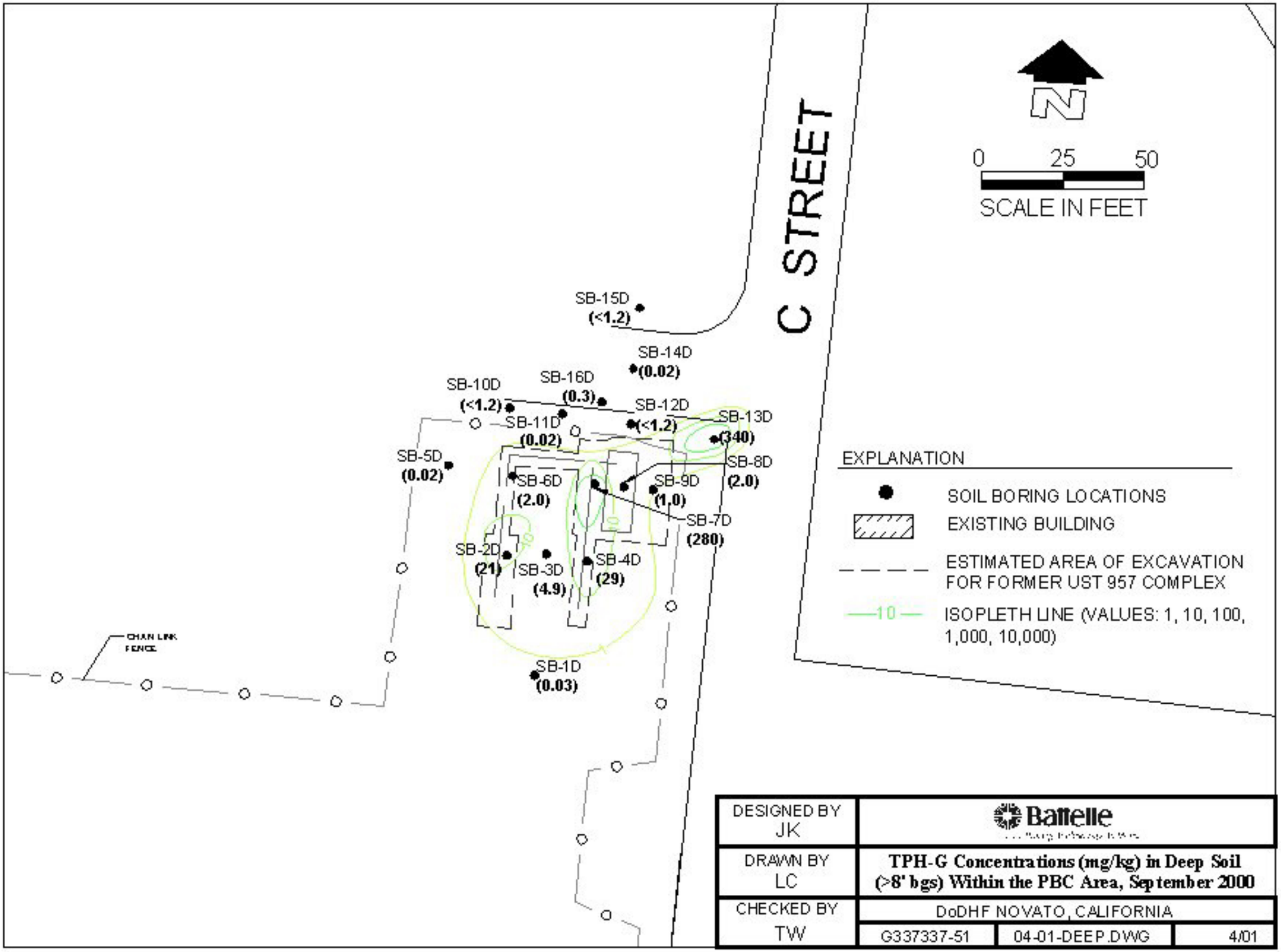
DESIGNED BY JK	Battelle		
DRAWN BY LC	**Ethylbenzene Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01


C STREET
N
0 25 50
SCALE IN FEET
SB-15D
(<0.0061)
SB-14D
(<0.0058)
SB-16D
(<0.007)
SB-10D
(<0.0062)
SB-12D
(<0.0059)
SB-13D
(0.24)
SB-11D
(<0.0054)
SB-5D
(<0.0049)
SB-8D
(<0.0068)
SB-6D
(0.0026)
SB-9D
(<0.0062)
SB-7D
(<0.0045)
SB-2D
(0.115)
SB-3D
(<1.200)
SB-4D
(<0.0052)
SB-1D
(5.4)
0.1
0.005
CHAIN LINK FENCE
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
0.005 ISOPLETH LINE (VALUES: 0.005, 0.1, 1, 10, 100)
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
Xylenes Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01

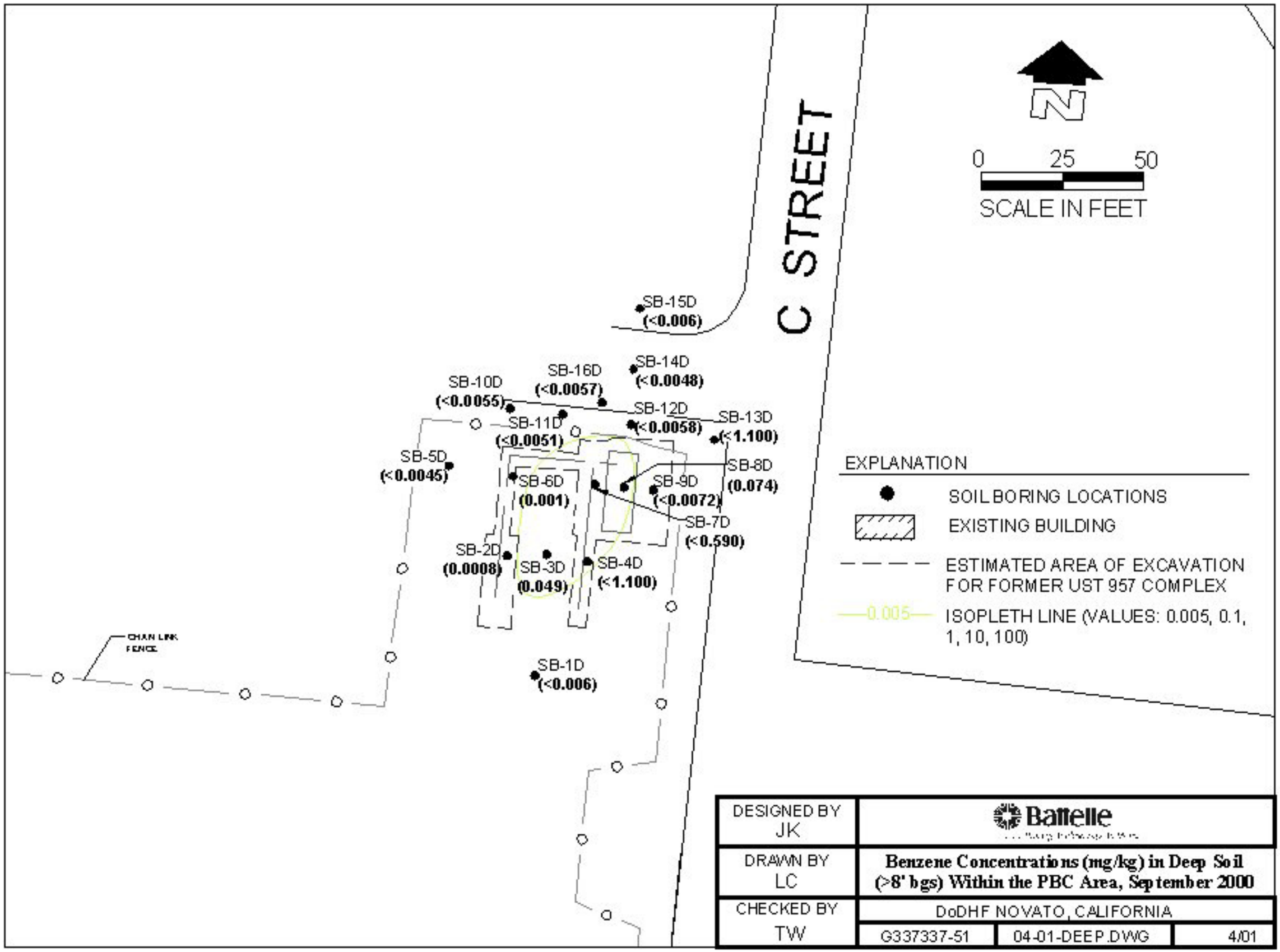

C STREET
N
0 25 50
SCALE IN FEET
SB-15D
(<0.0061)
0.005
SB-14D
(0.042)
SB-16D
(<0.007)
SB-10D
(0.045)
SB-12D
(<0.0059)
SB-13D
(<0.610)
SB-11D
(<0.0054)
SB-5D
(0.162)
SB-8D
(<0.0068)
SB-6D
(0.004)
SB-9D
(<0.0062)
SB-7D
(<0.0045)
SB-2D
(0.023)
SB-3D
(<1.200)
SB-4D
(<0.0052)
CHAN LINK FENCE
SB-1D
(<1.200)
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
0.005 ISOPLETH LINE (VALUES: 0.005, 0.1, 1, 10, 100)
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
MTBE Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-SHALLOW.DWG
4/01



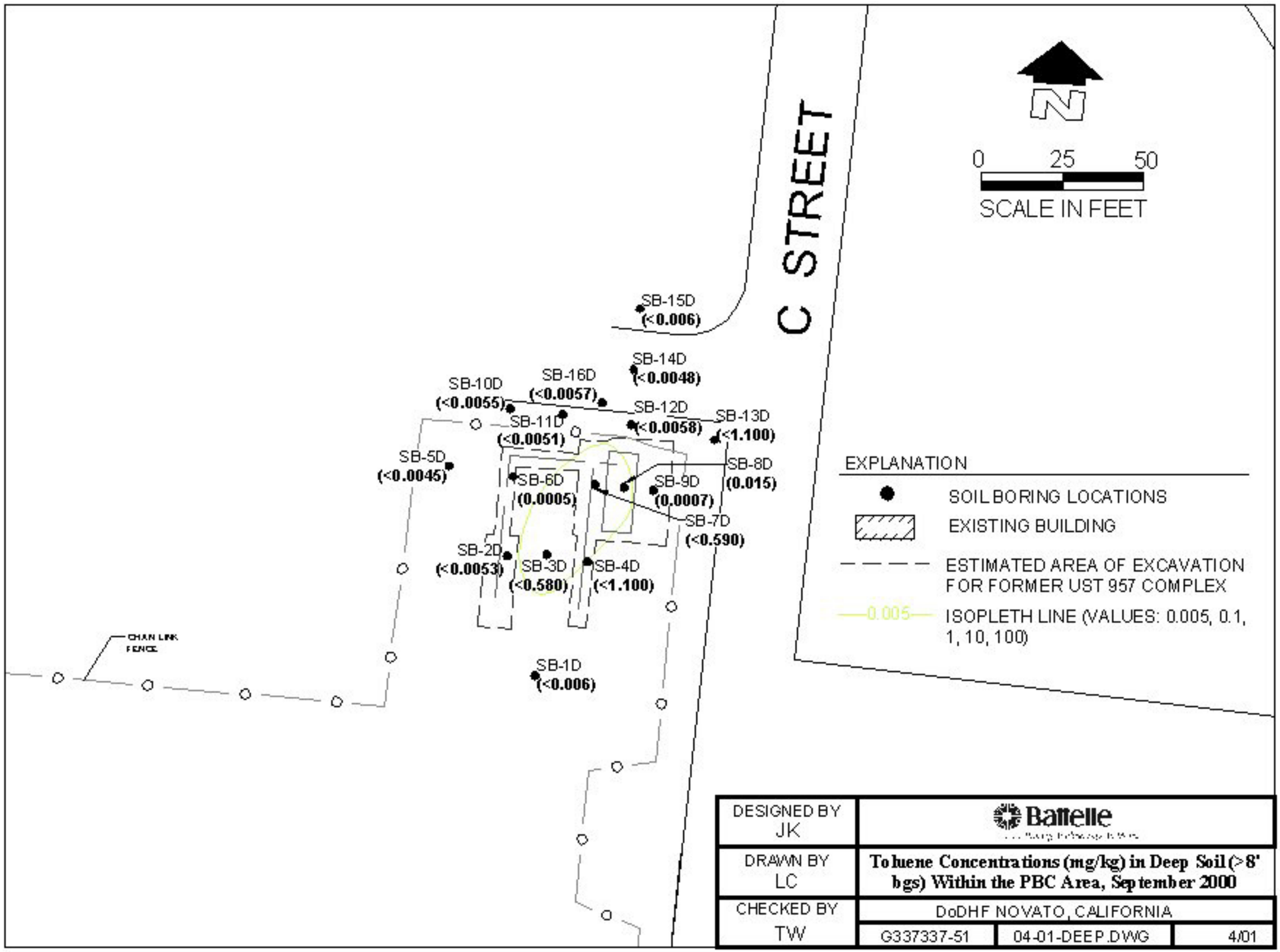
DESIGNED BY JK	Battelle		
DRAWN BY LC	**TPH-D Concentrations (mg/kg) in Shallow Soil (<8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-SHALLOW.DWG	4/01



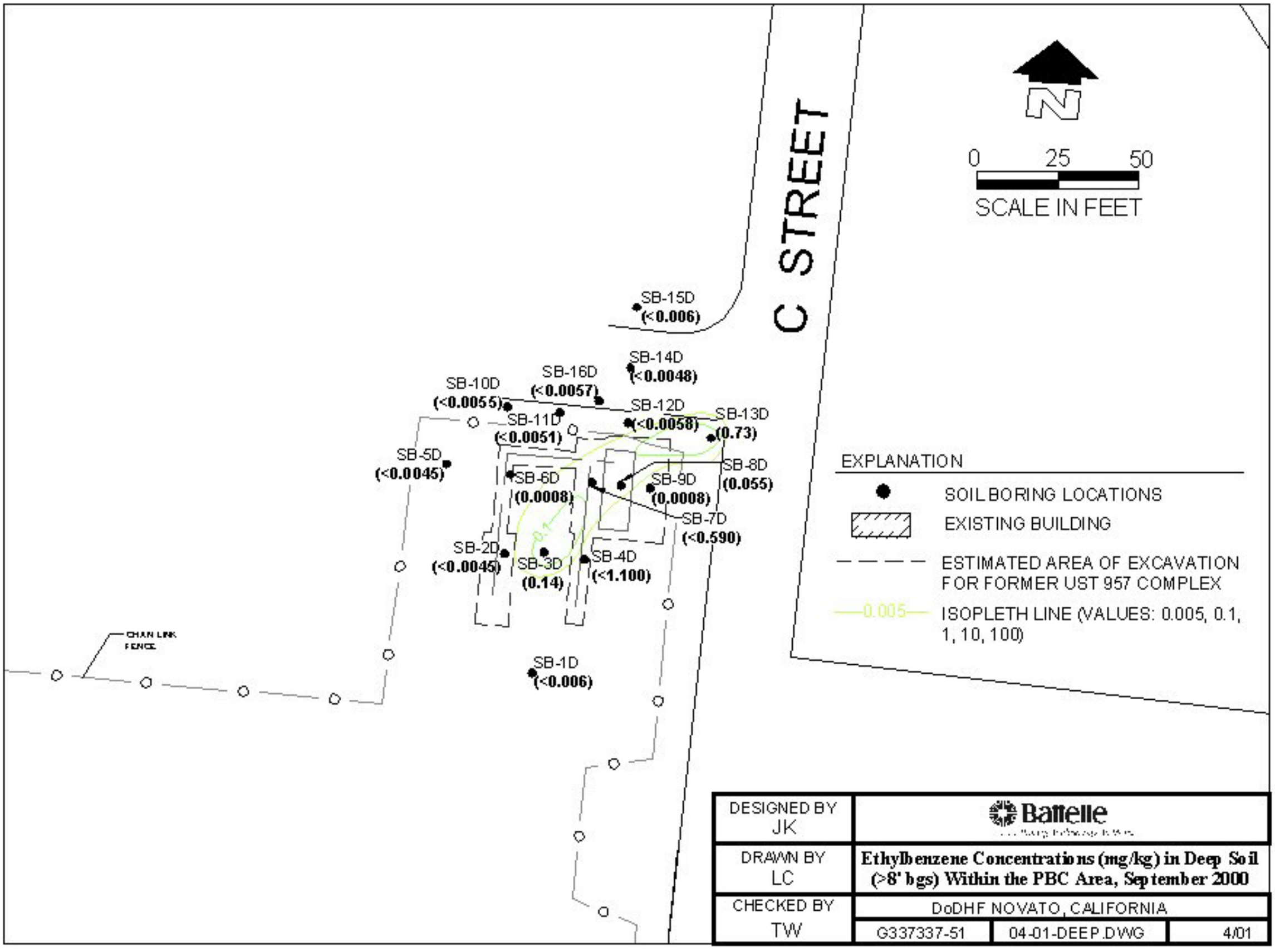
DESIGNED BY JK	Battelle		
DRAWN BY LC	**TPH-G Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



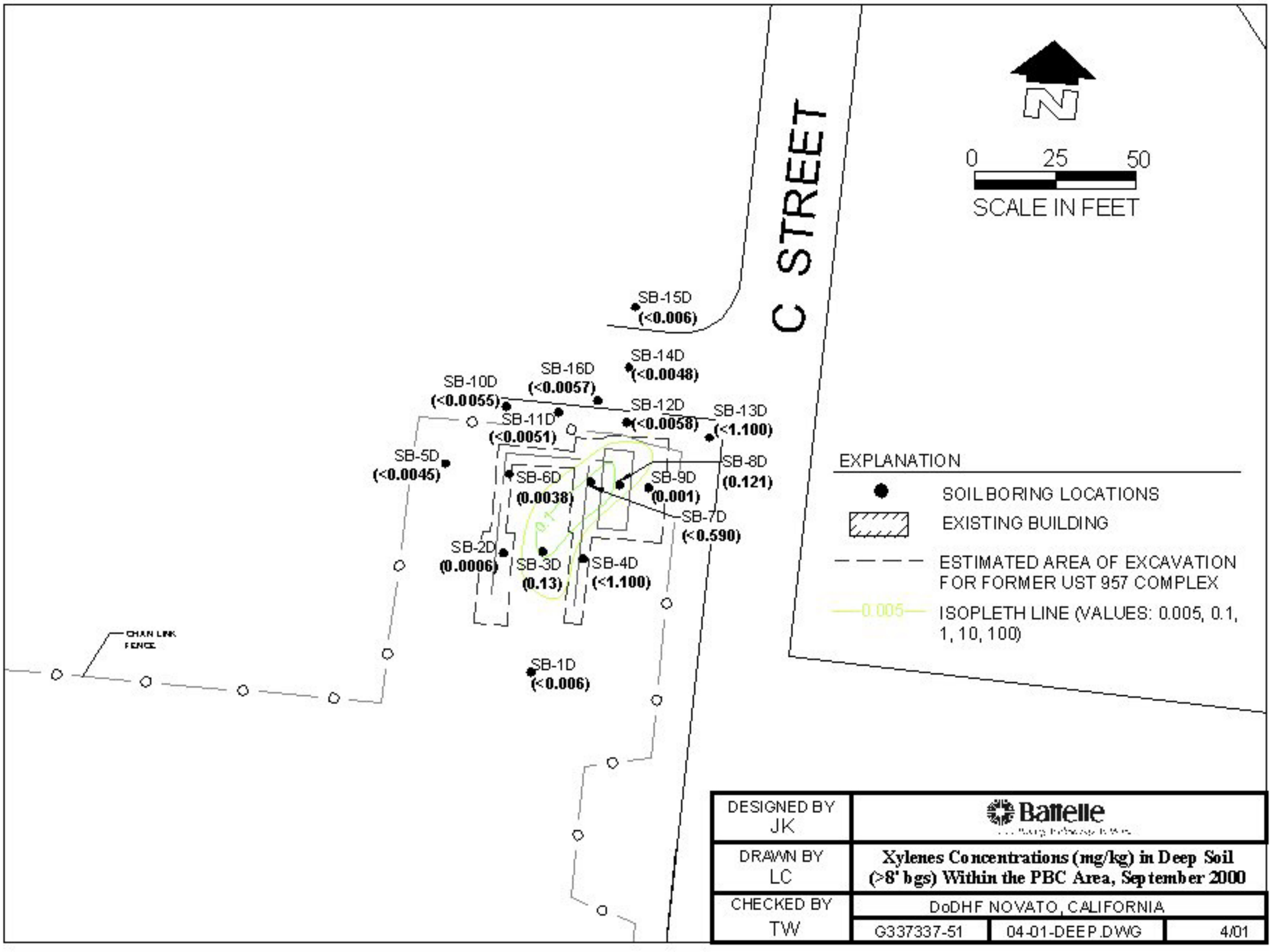
DESIGNED BY JK	Battelle		
DRAWN BY LC	**Benzene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01

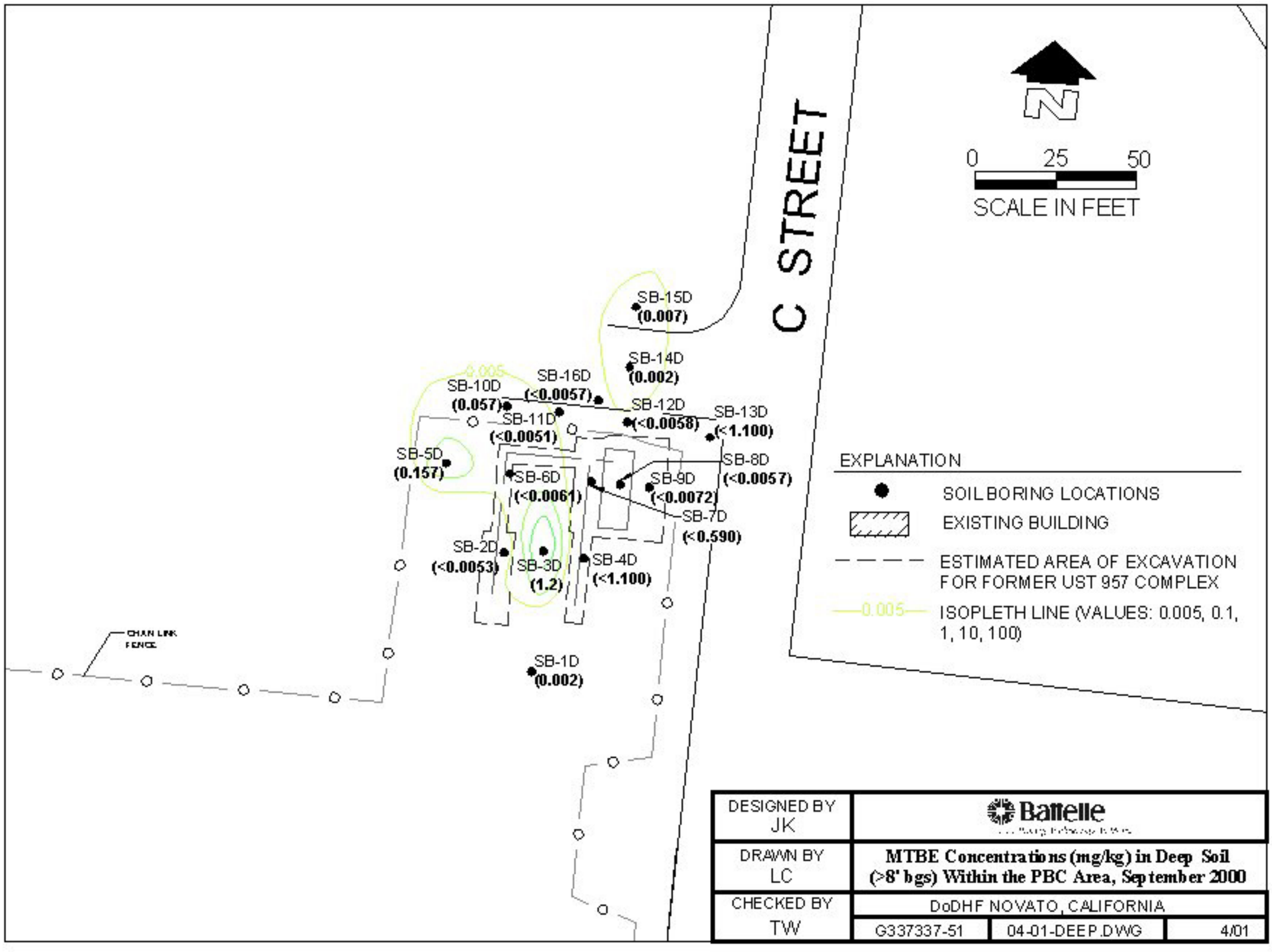


DESIGNED BY JK	Battelle		
DRAWN BY LC	**Toluene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01



DESIGNED BY JK	Battelle		
DRAWN BY LC	**Ethylbenzene Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01


C STREET
N
0 25 50
SCALE IN FEET
SB-15D
(<0.006)
SB-14D
(<0.0048)
SB-16D
(<0.0057)
SB-10D
(<0.0055)
SB-12D
(<0.0058)
SB-13D
(<1.100)
SB-11D
(<0.0051)
SB-5D
(<0.0045)
SB-8D
(0.121)
SB-6D
(0.0038)
SB-9D
(0.001)
SB-7D
(<0.590)
SB-2D
(0.0006)
SB-3D
(0.13)
SB-4D
(<1.100)
CHAIN LINK FENCE
SB-1D
(<0.006)
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
0.005
ISOPLETH LINE (VALUES: 0.005, 0.1, 1, 10, 100)
DESIGNED BY JK
DRAWN BY LC
CHECKED BY TW
Battelle
Xylenes Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-DEEP.DWG
4/01



DESIGNED BY JK	Battelle		
DRAWN BY LC	**MTBE Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	G337337-51	04-01-DEEP.DWG	4/01

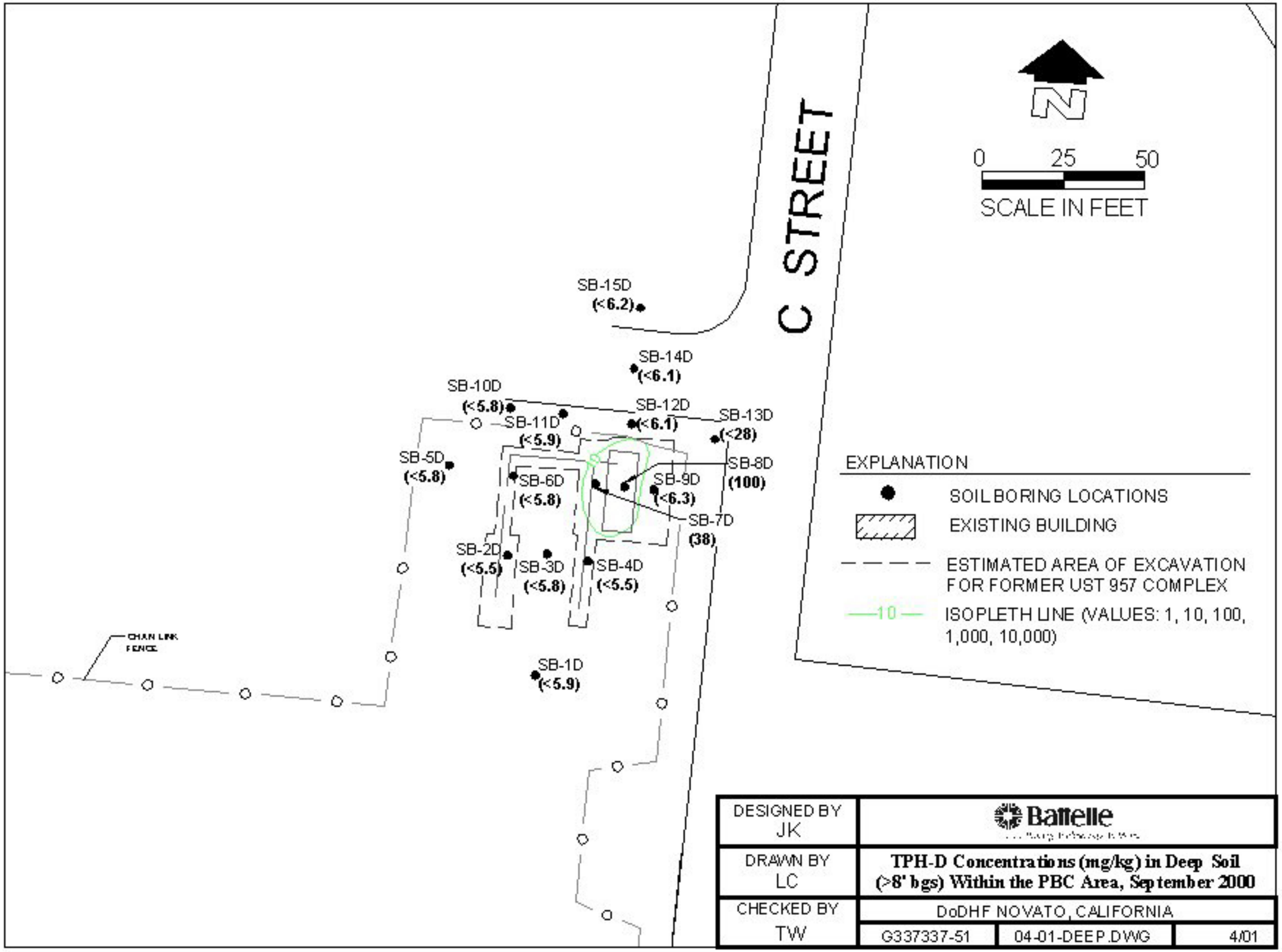

C STREET
N
0
25
50
SCALE IN FEET
SB-15D
(<6.2)
SB-14D
(<6.1)
SB-10D
(<5.8)
SB-11D
(<5.9)
SB-12D
(<6.1)
SB-13D
(<28)
SB-5D
(<5.8)
SB-6D
(<5.8)
SB-9D
(<6.3)
SB-8D
(100)
SB-7D
(38)
SB-2D
(<5.5)
SB-3D
(<5.8)
SB-4D
(<5.5)
SB-1D
(<5.9)
CHAIN LINK FENCE
EXPLANATION
SOIL BORING LOCATIONS
EXISTING BUILDING
ESTIMATED AREA OF EXCAVATION FOR FORMER UST 957 COMPLEX
10
ISOPLETH LINE (VALUES: 1, 10, 100, 1,000, 10,000)
DESIGNED BY
JK
Battelle
DRAWN BY
LC
TPH-D Concentrations (mg/kg) in Deep Soil (>8' bgs) Within the PBC Area, September 2000
CHECKED BY
TW
DoDHF NOVATO, CALIFORNIA
G337337-51
04-01-DEEP.DWG
4/01

Figure 4-58. February 2001 Contour Maps at Former UST Site 957/970 DoDHF Novato

Table 4-1. Depth to Primary Soil Layers

Well ID	NAD 27 Easting	NAD 27 Northing	Ground Surface Elevation (ft amsl)	Depth (in ft) to:		
				Bottom of Sand Fill	Bottom of Sandy Clay Fill	Top of Weathered Bedrock
NA-1	1416818.19	572822.62	45.73	3	8	11.5
MW-1A	1416827.61	572877.5	45.15	3.5	7.5	16
MW-2A	1416808.4	572930.79	44.28	4	8.5	14
MW-3A	1416828.46	572974.62	44.09	4.5	8	14
MW-4A	1416839.91	573009.86	43.67	6	8	15
AS-1A	1416813.54	572929.69	44.25	6	10	15.5
AS-2A	1416849.77	572924.91	44.4	3.5	10.5	16.5
AS-3A	1416835.14	572962.32	44.13	6	6	15
MP-1A	1416829.21	572912.99	44.66	5.5	7.5	14
MP-2A	1416841.98	572973.9	44.13	8	8	14
MW-1B	1416785.55	573091.1	42.84	3.5	8.5	13
MW-2B	1416745.8	573140.3	41.67	4	6	14.5
MW-3B	1416999.72	573099.5	43.07	5.5	8	10
MW-4B	1416616.45	573116.62	42.04	4	5	14
MW-5B	1416813.74	573139.85	41.58	3.5	4.5	15.5
AS-1B	1416809.38	573100.82	42.44	6	7	15
AS-2B	1416777.26	573124.48	41.95	6	8	12.5
AS-3B	1416829.3	573126.1	41.8	2	8	14.5
MP-1B	1416883.17	57147.21	41.65	2	5	16.5
SVE-1B	1416798.92	573116.08	41.99	8	10	14.5
SVE-2B	1416800.9	573128.14	41.73	3	7	14.5
VW-1B	1416878.44	573112.15	44.84	1.5	6	14.5
VW-2B	1416885.16	573174.94	44.25	4	5.5	14.5
NA-2	1416915.21	573252.21	40.45	4	6.5	11.5
NA-3	1416877.13	573294.45	39.95	2	5	14
NA-4	1416889.32	573331.82	39.6	3.5	6	13.5
NA-5	1416901.43	573368.82	39.07	3	6.5	13
NA-6	1416913.85	573406.4	38.67	4	6	14.5
NA-7	1416925.99	573444.7	38.28	2.5	7	15[(a)]
MW-1D	1416915.28	573472.47	37.83	3.5	5	13.5
MW-2D	1416626.41	573547.3	36.36	4	5.5	10.5
AS-1D	1416931.74	573495.52	37.57	3.5	5	13.5
AS-2D	1416962	573493.87	37.64	3	5	13.5
MP-1D	1416948.07	573513.27	37.41	4	6	14.5
SVE-1D	1416946.6	57394.57	37.62	2	5	15[(a)]
MW-1E	1417000.66	573573.32	37.46	5	7	15
AS-1E	1416973.61	573534.1	37.66	3	10.5	14
AS-2E	1416996.12	573553.68	37.71	4	10	16
SVE-1E	1416981.74	573546.05	37.7	6	8.5	15[(a)]
MW-M2	1417211.6	573557.14	34.09	9.5	N/A[(b)]	14
MW-M3	1417031.55	573752.98	35.41	4	5.5	16
MW-M4	1417033.56	574121.67	29.58	4	6.5	15
MW-M5	1417019.45	574271.21	28.26	4.5	8	14.5

Table 4-1. Depth to Primary Soil Layers (Continued)

Well ID	NAD 27 Easting	NAD 27 Northing	Ground Surface Elevation (ft amsl)	Depth (in ft) to:		
				Bottom of Sand Fill	Bottom of Sandy Clay Fill	Top of Weathered Bedrock
MW-M6	1417036.75	574395.48	26.46	4	5.5	13.5
MW-M7	1417391.96	573952.06	30.04	5.5	8	13.5
MW-10A	573012.33	1416665.36	43.39	3	6.5	15
MW-2E	573740.12	1416691.62	34.48	4.5	N/A	17
MW-3D	573507.63	1416970.21	N/A	N/A	4	19.5
MW-5A	572871.82	1416797.30	45.3	3	6.5	12.5
MW-6A	572870.81	1416813.58	45.21	3.5	6	13.5
MW-6B	573306.95	1416610.00	39.6	2.5	7.25	14
MW-7A	572868.13	1416845.86	45.36	2	5	16.25
MW-8A	572851.31	1416795.2	45.59	10[(c)]	N/A	13.5
MW-M14	575407.27	1417202.05	16.55	2.5	9.5	20.5
MW-M16	573936.76	1417373.94	30.34	3.5	7.5	13.5
MW-M17	574266.4	1416836.84	30.85	4.5	7	15
MW-M18	574419.6	1416856.94	29.28	4	10	14.75
MW-M19	574515.78	1416561.9	29.13	4	8.5	18.5
MW-M20	574119.74	1417082.91	30.27	4.5	7.75	13.5
MW-M21	574302.84	1417111.64	27.68	3.75	5.25	14
MW-M22	574387.44	1417095.23	26.85	4	7	12.5
MW-M23	574545.36	1417168.12	25.7	4.5	7.75	14
MW-M24	574348	1417429.28	27.96	4	5[(d)]	13.75
MW-M25	574755.53	1417460.79	29.28	4	N/A	N/A
MW-M26	575110.19	1417009.92	22.11	3	11.5	19.5
MW-M27	575312.5	1416529.32	19.12	1.5	5	20
SB-1A	572824.89	1416814.01	45.69	4	7	N/A
SB-2A	572851.50	1416781.32	45.65	2	6	N/A
SB-3A	572847.44	1416826.38	45.31	No recovery		
SB-4A	572845.65	1416838.77	45.32	No recovery		
SB-5A	572845.02	1416851.93	45.31	3	7	N/A
SB-6A	572870.36	1416824.34	45.16	4	7	N/A
SB-7A	572865.30	1416874.24	45.20	3.75	5	N/A
SB-8A	572902.34	1416809.73	44.64	2.5	7.5	N/A
SB-9A	572899.67	1416832.45	44.76	3.5	7	N/A
SB-10A	572898.08	1416846.86	44.82	4	7	N/A
SB-11A	572896.49	1416864.72	44.89	4	7	N/A
SB-12A	572893.43	1416892.43	44.83	2.75	4.5	N/A
SB-13A	572927.42	1416831.64	44.25	4	6.5	N/A
SB-14A	572932.55	1416819.40	44.11	Limited recovery		
SB-15A	572929.24	1416855.78	44.36	4	6.5	N/A
SB-16A	572924.10	1416891.70	44.61	4	7.5	N/A
SB-17A	572959.83	1416846.32	44.14	4.5	7	N/A
SB-18A	572979.96	1416828.71	43.96	1	7	N/A
SB-19A	572982.11	1416852.29	44.04	4.5	7.5	N/A
SB-20A	572980.48	1416874.56	44.12	6	8.5	N/A
SB-1D	573422.82	1416949.84	38.44	6	7.5	N/A
SB-2D	573459.78	1416941.32	38.03	3.5	7	N/A

Table 4-1. Depth to Primary Soil Layers (Continued)

Well ID	NAD 27 Easting	NAD 27 Northing	Ground Surface Elevation (ft amsl)	Depth (in ft) to:		
				Bottom of Sand Fill	Bottom of Sandy Clay Fill	Top of Weathered Bedrock
SB-3D	573459.96	1416953.58	38.01	3.5	8	N/A
SB-4D	573458.01	1416966.06	38.21	5	8	N/A
SB-5D	573487.35	1416923.46	37.58	3.5	6.5	N/A
SB-6D	573484.10	1416943.17	37.72	4.5	7.5	N/A
SB-7D	573481.74	1416968.44	37.75	Former tank	Fill to 9	N/A
SB-8D	573480.63	1416977.44	37.79	Former tank	Fill to 9.75	N/A
SB-9D	573479.76	1416986.37	37.81	Former tank	Fill to 9.5	N/A
SB-10D	573504.97	1416942.23	37.38	3.5	6	N/A
SB-11D	573503.27	1416958.39	37.55	4	7	N/A
SB-12D	573500.14	1416979.41	37.60	4.5	8	N/A
SB-13D	573495.35	1417005.01	37.92	3.75	6	N/A
SB-14D	573517.19	1416980.16	37.58	4.5	7.5	N/A
SB-15D	573535.80	1416982.17	37.70	4.5	6.5	N/A
T1-1	573840.71	1416938.64	33.41	6	11	20
T1-2	573836.73	1416962.67	33.52	6	10	19?
T1-3	573833.72	1416987.76	33.57	5	7.5	17
T1-4	573829.00	1417012.89	33.46	4	8	19
T1-5	573828.85	1417038.85	33.65	6.5	10	16
T1-6	573827.71	1417063.77	34.10	7.5	12	17
T1-7	573821.24	1417083.98	33.82	7	13	19
T1-8	573821.34	1417097.51	32.38	7	12	17.5
T2-1	573817.42	1416925.05	34.07	6	10	20
T2-2	573814.72	1416949.38	33.82	7	11	17.5
T2-3	573811.79	1416973.43	34.02	7	12	17.5
T2-4	573808.24	1416998.67	33.99	7	12	18
T2-5	573805.98	1417023.44	33.97	7	12.5	17.5
T2-6	573804.78	1417048.62	34.34	7.5	12.5	18
T2-7	573803.46	1417075.12	34.23	6	11.5	18
T2-8	573798.70	1417098.61	34.07	7	12	17
T3-1	573791.26	1416937.49	34.04	7	11	18
T3-2	573786.63	1416961.81	34.39	6.5	12	17
T3-3	573784.11	1416986.88	34.50	7	12	18
T3-4	573782.56	1417011.25	34.58	7	12.5	20
T3-5	573780.74	1417035.90	34.61	5	12	19
T3-6	573777.81	1417060.91	34.81	4	12	18[(e)]
T3-7	573775.84	1417082.88	34.46	5	11	21[(e)]
T3-8	573773.23	1417111.50	33.74	4.5	12	22[(e)]
T3-9	573770.59	1417134.93	32.58	4	10	23
T4-1	573767.10	1416921.45	34.68	5	9	18
T4-10	573740.02	1417140.21	33.65	4.5	10	20
T4-2	573764.27	1416946.33	34.65	7	10	18
T4-3	573762.95	1416971.31	34.98	4.5	10	18
T4-4	573761.20	1416995.80	34.95	4.5	10	17
T4-5	573756.24	1417025.72	35.32	5	10	18
T4-6	573754.69	1417046.30	35.19	4	9	20

Table 4-1. Depth to Primary Soil Layers (Continued)

Well ID	NAD 27 Easting	NAD 27 Northing	Ground Surface Elevation (ft amsl)	Depth (in ft) to:		
				Bottom of Sand Fill	Bottom of Sandy Clay Fill	Top of Weathered Bedrock
T4-7	573752.03	1417071.02	34.93	4.5	9.5	21
T4-8	573749.48	1417095.61	34.52	4.5	10	19.5[e]
T4-9	573747.48	1417118.48	34.10	5	12	20
I-1	573762.43	1417104.24	34.30	4.5	10	20
I-2	573763.61	1417090.32	34.41	4	11	22
I-3	573789.37	1417079.24	34.12	4.5	12	21
I-4	573788.41	1417092.21	34.17	4	12	22
I-5	573809.40	1417090.96	33.95	4.5	11	21
I-6	573824.77	1417072.81	33.94	4.5	11	20.5

(a) Depth indicates bottom of borehole.
(b) Sandy clay not encountered.
(c) No recovery from 8.5 to 10 ft.
(d) No recovery from 5.5 to 6.0 ft.
(e) CPT data lacks display of a clear weathered bedrock top.
N/A = Not available.

Table 4-2. Grain-Size Distribution

Sample ID	Depth of Sample Collection (ft)	Date of Collection	Clay (%)	Silt (%)	Sand (%)
SVE-2A-5.5-6	5.5-6.0	10/21/98	23	32	45
AS-5B-4-5	4.0-5.0	10/21/98	18	35	47
AS-5B-7.5-8	7.5-8.0	10/21/98	10	14	76
AS-5B-12-13	12.0-13.0	10/21/98	15	11	74
AS-5B-18-19	18.0-19.0	10/21/98	11	6	83
AS-3D-2.5-3	2.5-3.0	10/21/98	15	24	61
AS-3D-5.5-6	5.5-6.0	10/21/98	22	26	52
AS-3D-7.5-8	7.5-8.0	10/21/98	18	25	57
AS-3D-9.5-10	9.5-10.0	10/21/98	6	10	72
AS-3D-13.5-14	13.5-14.0	10/21/98	12	18	70
AS-3D-16.5-17	16.5-17.0	10/21/98	13	19	68
MW-M10-9-10	9.0-10.0	12/07/98	17	31	52
MW-M8-12-13	12.0-13.0	12/07/98	5	9	86
MW-M8-15-16	15.0-16.0	12/07/98	20	41	39
TW-M2-10-11	10.0-11.0	12/07/98	10	15	75
MW-M13-8-9	8.0-9.0	12/08/98	13	21	66
MW-M13-10-11	10-11	12/08/98	14	20	66

Table 4-3. Hydraulic Gradients and Groundwater Flow Velocities at Former UST Site 957/970

Path No.	h1 (ft)	h2 (ft)	Distance (ft)	Hydraulic Gradient	Velocities (ft/day) in Unconfined Aquifer								
					K=1			K=11			K=22		
					ne=30 (%)	ne=40 (%)	ne=50 (%)	ne=30 (%)	ne=40 (%)	ne=50 (%)	ne=30 (%)	ne=40 (%)	ne=50 (%)
1	38	29	490	0.0184	0.06	0.05	0.04	0.67	0.51	0.40	1.35	1.01	0.81
2	34	30	200	0.0200	0.07	0.05	0.04	0.73	0.55	0.44	1.47	1.10	0.88
3	26	22	295	0.0136	0.05	0.03	0.03	0.50	0.37	0.30	0.99	0.75	0.60
4	24	14	1025	0.0098	0.03	0.02	0.02	0.36	0.27	0.21	0.72	0.54	0.43
5	24	14	855	0.0117	0.04	0.03	0.02	0.43	0.32	0.26	0.86	0.64	0.51
6	16	12.5	465	0.0075	0.03	0.02	0.02	0.28	0.21	0.17	0.55	0.41	0.33
7	16	11	590	0.0085	0.03	0.02	0.02	0.31	0.23	0.19	0.62	0.47	0.37

h1 = Upgradient hydraulic head value
h2 = Downgradient hydraulic head value
K = Potential hydraulic conductivity values at Former UST Site 957/970
ne = Potential effective porosity values at Former UST Site 957/970

Table 4-4. Hydraulic Conductivity (K) from Slug Tests, in ft/day

Well	Test Date	Test 1	Test 2	Test 3	Average
MW-1A	6/1/98	2.1	2.5	1.5	2.0
MW-2A	6/1/98	4.7	4.6	5.2	4.8
MW-4A	6/1/98	0.5	2.3	1.1	1.3
SVE-1B	6/1/98	17.4	5.9	4.8	9.4
VW-2B	6/1/98	3.5	3.1	5.4	4.0
970-MW2	6/2/98	9.0	8.6	7.9	8.5
957-MW2	6/2/98	27.4	20.1	18.5	22.0
957-MW4	6/2/98	2.0	2.0	1.5	1.8
957-MW1	6/2/98	8.1	8.1	6.3	7.5

Table 4-5. Total Dissolved Solids Concentrations

Well	Analysis Date	TDS (mg/L)
NA-0	5/28/98	911
MW-1A	6/12/98	545
970-MW4	5/22/98	558
MW-2B	6/12/98	407
VW-2B	5/22/98	581
970-MW3	5/22/98	964
957-MW2	5/22/98	613
957-MW4	5/22/98	596
957-MW1	5/22/98	628
MW-M6	5/28/98	443

Table 4-6. Soil Characterization Data

Sample ID	Depth of Sample Collection (ft)	Date	TOC (mg/kg)	Bulk Density (g/cm^3)	% Porosity
NA-1-10.5-12	10.5-12.0	04/29/98	3,900	1.29	51.3
MW-2A-9.5	9.5-10.0	04/29/98	9.10	1.12	57.7
NA-2-9	9.0-9.5	05/02/98	1,100	1.22	54
NA-5-9	9.0-9.5	05/02/98	1,100	1.4	47.2
MW-1D-9	9.0-9.5	05/03/98	530	1.12	57.7
MW-M3-9	9.0-9.5	05/05/98	1,400	1.22	53.9
MW-M4-9.5	9.5-10.0	05/06/98	1,800	1.0	62
MW-M6-11.5	11.5-12.0	05/06/98	310	1.17	55.8
MW-M7-9.5	9.5-10.0	05/05/98	4,300	1.04	60.8
SVE-4B-8-8.5	8.0-8.5	10/21/98	970	NA	NA
AS-5B-6.5-7	6.5-7.0	10/21/98	1,500	NA	NA
SVE-3B-9.5-10	9.5-10.0	10/21/98	840	NA	NA
AS-4B-10.5-11	10.5-11.0	10/21/98	2,000	NA	NA
AS-6B-8-8.5	8.0-8.5	10/21/98	980	NA	NA
AS-6B-9.5-10	9.5-10.0	10/21/98	1,600	NA	NA
MW-M10-9-10	9.0-10.0	12/07/98	1,200	1.29	51.3
MW-M8-12-13	12.0-13.0	12/07/98	2,000	1.27	52.0
MW-M8-15-16	15.0-16.0	12/07/98	730	1.14	57.0
TW-M2-10-11	10.0-11.0	12/07/98	930	1.40	87.5
MW-M13-8-9	8.0-9.0	12/08/98	920	1.10	58.5
MW-M13-10-11	10.0-11.0	12/08/98	740	1.18	55.5
MP6-3.5-4	3.5-4	10/08/99	NA	1.49	43.8
MP6-1.5-2	1.5-2	10/08/99	NA	1.55	41.5
MP6-2.5-3	2.5-3	10/08/99	NA	1.5	43.4
MP6-8.5-9	8.5-9	10/08/99	NA	1.46	44.9
MP6-6.5-7	6.5-7	10/08/99	NA	1.38	47.9
MP6-4.5-5	4.5-5	10/08/99	NA	1.32	50.1
MP6-7.5-8	7.5-8	10/08/99	NA	1.49	43.8
MP6-5.5-6	5.5-6	10/08/99	NA	1.44	45.7
MP8-0.5-1.0	0.5-1	11/04/99	NA	1.46	44.9
MP8-1.5-2	1.5-2	11/04/99	NA	1.42	46.4

Table 4-7. Range in Values of Porosity

Material	Porosity (%)
Sediments	
Gravel, coarse	24 - 36
Gravel, fine	25 - 38
Sand, coarse	31 - 46
Sand, fine	26 - 53
Silt	34 - 61
Clay	34 - 60
Sedimentary Rocks	
Sandstone	5 - 30
Siltstone	21 - 41
Limestone, dolomite	0 - 20
Karst limestone	5 - 50
Shale	0 - 10
Crystalline Rocks	
Fractured crystalline rocks	0 - 10
Dense crystalline rocks	0 - 5
Basalt	3 - 35
Weathered granite	34 - 57
Weathered gabbro	42 - 45

Source: Domenico and Schwartz (1990).

Table 4-8. Applicable Screening Levels and Maximum Detections for Soil Samples Collected During Hydraulic Lift Removal Activities at Building 970, April/May 2000

Compound	Max. Conc. (mg/kg)	Screening Conc. (mg/kg)	Reference	Comments
Benzene	0.074	0.65	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Toluene	0.12	520	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Ethylbenzene	0.79	230	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Xylenes	3.8	210	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
MTBE	0.14	17	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Naphthalene	1.6	56	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Phenanthrene	0.64	14,000	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	Used anthracene as surrogate PRG
Fluoranthene	0.14	2,300	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
Pyrene	0.54	2,300	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	—
2-Methyl-naphthalene	2.9	56	U.S. EPA Region 9 Residential PRG (U.S. EPA, 2000)[a]	Used naphthalene as surrogate PRG
Total chromium	400	450/210	U.S. EPA Region 9 Industrial PRG/ Residential PRG (U.S. EPA, 2000)[a]	Drum-1-OX-NE3, Drum 2-OX-5.5
Lead	850	750/400	U.S. EPA Region 9 Industrial PRG/ Residential PRG (U.S. EPA, 2000)[a]	EFF-4-E3 exceeded the Industrial and Residential PRG; OS2-N-3.5, Drum2-OX-5.5, EFF-6-3W exceeded the Residential PRG
Nickel	580	1,600	U.S. EPA Region 9 Industrial PRG/ Residential PRG (U.S. EPA, 2000)[a]	Soluble salts
Zinc	140	23,000	U.S. EPA Region 9 Industrial PRG (U.S. EPA, 2000)[a]	—
TPH-G	260	1,000	Upper Action Limit from *California LUFT Manual* (CSWRCB, 1989)	—
TPH-D	8,000	10,000	Upper Action Limit from *California LUFT Manual* (CSWRCB, 1989)	—
TPH-O	780	10,000	Used same as TPH-D	—
TOG	6,300	10,000	Used same as TPH-D	—

(a) Updated November 1, 2000. TPH-G = gasoline range total petroleum hydrocarbons. TPH-O = hydraulic oil range total petroleum hydrocarbons.
MTBE = methyl-*tert*-butyl ether. TPH-D = diesel range total petroleum hydrocarbons. TOG = total oil and grease.

Table 4-9. Estimated Unsaturated Soil Volume Exceeding Screening Criteria and Total Mass of Gasoline Constituents in the Sale Area and the PBC Area After IAS/SVE Treatment

Gasoline Compound	Area	Volume of Soil (yd^3)	Gasoline Compound Mass (kg)
TPH-G[(a)]	Sale Area	0.3	58.1
	PBC Area	1.9	2.7
Benzene[(b)]	Sale Area	16.8	0.4
	PBC Area	0.0	0.0
MTBE[(c)]	Sale Area	0.0	7.3
	PBC Area	0.0	0.1

(a) TPH-G-impacted soil volume is based on concentrations greater than the Upper Action Limit of 1,000 mg/kg (CSWRCB, 1989).
(b) Benzene-impacted soil volume is based on concentrations greater than the Region 9 Residential PRG of 0.65 mg/kg (U.S. EPA, 2000d).
(c) Benzene-impacted soil volume is based on concentrations greater than the Region 9 Residential PRG of 17 mg/kg (U.S. EPA, 2000d).

Table 4-10. Bedrock Well and Nearby Monitoring Well Sampling Results

Bedrock Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Nearby Monitoring Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)
MW-9A	10/21/00	220	<2.0	MW-5A	NS	NS	NS
	11/17/00[(a)]	120/120	<2.0/<2.0		11/13/00	2,300	2.0
	3/1/01	600	16		2/25/01	1,100	<1.0
MW-3D	10/21/00	25,000	<10	957-MW4	NS	NS	NS
	11/17/00	34,000	<10		11/15/00	34,000	2.7
	2/28/01	43,000	<20		2/25/01	10,000	<1.0

NS = not sampled.
(a) Results of duplicate sample are shown.

Table 4-11. Nested Well Sampling Results

Sample ID[(a)]	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)
November 2000						
MW-M14S	11/7/00	13	<2.5	<2.5	<2.5	<2.5
MW-M14D	11/8/00	11	<0.5	<0.5	<0.5	<0.5
MW-M20S[(b)]	NS	NS	NS	NS	NS	NS
MW-M20D	11/16/00	2,000	<1.0	<1.0	<1.0	<1.0
MW-M25S	11/14/00	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M25D	11/15/00	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26S	11/14/00	280	<0.5	<0.5	<0.5	<0.5
MW-M26D	11/15/00	280	<0.5	<0.5	<0.5	<0.5
MW-M27S	11/9/00	<1.3	<1.3	<1.3	<1.3	<1.3
MW-M27D	11/10/00	1.3	<0.5	<0.5	<0.5	<0.5
February 2001						
MW-M14S	2/27/01	39	<10	<10	<10	<20
MW-M14D	2/28/01	30	<0.05	<0.5	<0.5	<1.0
MW-M20S[(b)]	NS	NS	NS	NS	NS	NS
MW-M20D	2/26/01	5,600	<0.5	0.58	<0.5	<1.0
MW-M25S	2/27/01	<10	<10	<10	<10	<20
MW-M25D	2/28/01	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M26S	2/27/01	370	<0.5	<0.5	<0.5	<1.0
MW-M26D	2/28/01	320	<0.5	<0.5	<0.5	<1.0
MW-M27S	2/27/01	1.7	<0.5	<0.5	<0.5	<1.0
MW-M27D	2/28/01	1.7	<0.5	<0.5	<0.5	<1.0

NS = not sampled.

(a) S indicates shallow interval; D indicates deep interval.

(b) MW-M20S was not sampled during this quarterly monitoring event due to dryness.

Section 5.0: EVALUATION OF SITE CONDITIONS

This section presents an evaluation of site conditions that affect the corrective action selection process. The regulatory framework under which corrective action decisions are made is discussed in Section 5.1, site conditions are evaluated in Section 5.2, and remedial action objectives established in the context of the site conditions are presented in Section 5.3.

5.1 Regulatory Framework

The Site is regulated under the California LUFT Program (SWRCB, 1989) as administered by the RWQCB, San Francisco Bay Region, which has final review and signature authority for all sites with gasoline-impacted groundwater in this region. The California LUFT program provides a framework for investigation and remediation of unregulated releases of petroleum products, but cleanup requirements for contaminated environmental media are specified in other regulations and guidance. Applicable regulations and guidance for UST sites come from state and federal codes, various resolutions, and guidance documents.

Final cleanup levels for UST sites are primarily regulated under the Basin Plan of 1995 entitled *San Francisco Bay Basin (Region 2) Water Quality Control Plan* (Basin Plan) (RWQCB, 1995). The Basin Plan provides cleanup standards for groundwater (i.e., water quality objectives) based on beneficial use designations. A hydrologic unit (local aquifer) may be designated for one or more of 23 beneficial uses, such as municipal and domestic supply, agricultural supply, industrial service supply, industrial process supply, freshwater replenishment, and groundwater recharge. The water quality objectives for the hydrologic unit must be protective of the most sensitive beneficial use designated for that body of water.

Groundwater underlying the Former UST Site 957/970 is located within the Novato Valley Groundwater Basin. The RWQCB has designated all groundwater in the Novato Valley Groundwater Basin to be a potential source for use as domestic or municipal water supply. The municipal and domestic supply category, which includes sources of drinking water, requires the most protective standards for groundwater. Therefore, groundwater that is considered a potential source of drinking water is not to contain contaminant concentrations in excess of the Maximum Contaminant Levels (MCLs) and/or taste and odor thresholds outlined in the Basin Plan (RWQCB, 1996).

On July 19, 2000, the RWQCB adopted Order 00-064 establishing a series of tasks to be performed at the Site and a schedule by which those tasks would be performed. This CAP was prepared to comply with Task 6 of Order 00-064. Note that the compliance date has been postponed with the agreement of the RWQCB because of the need for additional risk assessment work requested by the DTSC. The rationale for the delay was based on having a clear understanding of the risk presented by site conditions prior to selecting a corrective action remedy to ensure protection of human health and the environment, including the water resources of the State of California.

The following excerpt from Order 00-064 describes the requirements for the CAP:

6. PROPOSED FINAL CORRECTIVE ACTION PLAN FOR GROUNDWATER

COMPLIANCE DATE: February 28, 2001

Submit a work plan acceptable to the Executive Officer that includes:

a. A feasibility study (FS) to:

1. **Stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site.**
2. **Remediate the highest concentrations of soil pollution detected in Task B.1.**
3. **Reduce and remediate the concentrations of MTBE in Site groundwater.**
4. **Reduce and remediate the concentrations of benzene in Site groundwater which exceed applicable risk based screening levels (RBSLs).**

b. The FS shall contain:

1. **The results of all Site remedial investigations.**
2. **An evaluation of interim remedial actions.**
3. **An analysis and comparison of alternative final remedial actions.**
4. **Recommendation of final remedial actions and cleanup standards.**
5. **If any of the recommended final cleanup standards are less than background levels, the proposed standards must achieve the best water quality reasonably possible, be consistent with the maximum benefit to the people of the state, not unreasonably affect beneficial uses, and may not be set below those set by the Basin Plan and applicable Policies. Further, if the recommended final cleanup standards are less than background levels, provide evidence and analysis showing that it is a) technologically or economically infeasible to achieve background levels, and b) that the constituent will not pose a substantial present or potential hazard to human health or the environment for the duration of the exceedence of background levels.**
6. **Time schedule for implementation of the recommended alternative.**

This CAP was prepared to comply with each of the requirements listed in Task 6 of Order 00-064. The following section (Section 5.2) provides an summary and evaluation of site conditions and establishes the foundation for the selection of remedial action objectives to achieve the cleanup standards as described in the Basin Plan (RWQCB, 1995). Section 5.3 presents the remedial action objectives (RAOs) developed based on the regulatory requirements and the current site conditions.

5.2 Site Assessment

This section evaluates various aspects of site conditions that are relevant to establishing RAOs for the Site. The categories of conditions evaluated are taken from RWQCB Guidance on Cleanup of Fuel UST Sites (RWQCB, 1996) and are standards used by the RWQCB to determine whether a UST site is low risk. Order No. 00-064 is the ruling guidance for the site and states that it is consistent with other RWQCB guidance; therefore the purpose of evaluating site conditions against these low-risk benchmarks is to establish the reasonable time frame within which RAOs can be achieved in compliance with Resolution 92-49. The RWQCB UST Guidance uses six standards to evaluate the relative risk a site presents to human health and the environment:

- ***Have releases been stopped, and have ongoing sources, including free product, been removed or remediated?***
- ***Has the site been adequately characterized?***
- ***Is the dissolved hydrocarbon plume migrating?***
- ***Are any water wells, deeper drinking water aquifers, surface water, or other sensitive receptors likely to be impacted?***
- ***Does the site present any significant risk to human health?***
- ***Does the site present any significant risk to the environment?***

The information presented in the following subsections answers these questions and forms the basis for establishing a time frame within which RAOs must be achieved to comply with Order 00-064 and Resolution 92-49, and to protect human health and the environment.

5.2.1 Assessment of Source (Have releases been stopped, and have ongoing sources, including free product, been removed or remediated?)

5.2.1.1 Former UST Removal. Removal of the former USTs, waste oil tank associated with Building 970, and associated piping occurred in the early to mid-1990s as described in Section 2.1 of this CAP. Soil underlying and adjacent to the tanks and soil from beneath the piping trenches was excavated following the removal of the UST structures. Some hydrocarbon-impacted soils were left in place under the assumption that future remedial activities would be performed at the Site. The IAS/SVE Interim Remedial Action system installed at the Site in 1998 focused primarily on the areas indicated to have elevated hydrocarbon concentrations and achieved significant mass removal. A total of 23,000 lbs of gasoline were removed in vapor extracted from the subsurface during system operation. Refer to Section 3.0 for further detail on the design and results of the interim remedial system. A list of USTs and other subsurface structures that have been removed from the Site is as follows:

- **UST 957:** The tank and underground piping were removed in March 1992 (PRC Environmental Management, Inc., 1992b).

- **UST 970-3:** The tank and associated underground piping were removed on January 5, 1995. During tank removal, it was noted that UST 970-3 had a hole at the fill end of the tank and that the tank was completely filled with water (NPWC, 1996a).

- **Tank 970-Waste Oil:** NPWC personnel removed the 1,000-gallon steel tank on January 9, 1995 (NPWC, 1996a).

- **UST 970-1 and UST 970-2:** The tanks and associated pump island piping were removed on July 3, 1996 (NPWC, 1996b).

- **Building 970 Hydraulic Lift and Oil/Water Separator Removal Activities:** Excavation and removal of subsurface features in and around Building 970 was performed from April 17 to June 22, 2000 (Battelle and RRM, 2000). Overexcavation activities were performed to the extent practicable to remove affected soils encountered during removal activities. Complete removal of affected soil was constrained by the limited work area inside the building and the potential to undermine building foundations. The Industrial PRG (U.S. EPA, 2000d) for lead was exceeded in soils at one sampling location (EFF-4-E3) located near the footing of Building 970; however, no other Industrial PRGs were exceeded. Residential PRGs were exceeded only for lead in four locations, and for chromium in two locations; however, the planned future use of the property where Building 970 sits is commercial/industrial. The risk presented by material left in place are evaluated in Section 5.2.5.

5.2.1.2 Presence of Free Product. Free product was observed in the vicinity of UST 957 during a Geoprobe™ investigation conducted in late 1994 by ERM-West (ERM-West, Inc., 1995a) and free product was also measured in monitoring well 970-MW5 in August 1996 (ERM-West, Inc., 1998). However, the presence of free product has not been observed in any of the Site wells, soils, or purged groundwater since the Navy began interim remedial action predesign investigation activities at the Site in December 1997. During the remedial investigation performed in Fall 2000 (Battelle, 2001b), the Navy advanced Geoprobe™ pushes in the vicinity of former UST tank cavities and in areas of the Site where past observances of free product were noted and found no free product in unsaturated or smear-zone soils. In over 12 quarterly groundwater monitoring events, no free product has been measured in any site wells across the entire Site, including multiple wells in close proximity to former UST cavities. Further indication that free product is not present at the Site is based on the results of the groundwater monitoring data. These data indicate that there are significant decreases in the levels of dissolved gasoline constituents (including benzene and MTBE) in former source areas (i.e., near former UST 970 complex) of the Site (see Figure 5-1). Groundwater concentrations would not likely be decreasing if free product or another ongoing source were present.

5.2.2 Assessment of Adequacy of Site Characterization (*Has the site has been adequately characterized?)*

Extensive site characterization activities have been conducted at the Site. Soil and groundwater characterization sampling was performed on several occasions prior to the fall of 1997 when the remediation system was contracted. Site characterization data was collected during interim remedial action system installation and during MTBE plume delineation activities in 1998. Following the interim remedial action system shutdown, a remedial investigation was conducted in September 2000, which included the collection of additional site characterization data to confirm treatment effectiveness. Continuous soil cores were collected, examined, and logged at nearly every borehole and/or subsurface installation that has historically been advanced across the entire Site. These activities provided a large data set representing soil stratigraphy and subsurface conditions across the Site. A site conceptual model was developed to include the pertinent information from all site characterization activities and was updated with new information as it became available. Refer to Section 2.2 for more detailed information about the site characterization activities performed at the Site. A summary of site characterization activities performed at the Site follows:

- Screening level soil and groundwater sampling was conducted in the area surrounding former UST 957 using a Geoprobe™ in November/December 1994 and January 1995.

The objective of the investigations was to delineate the extent of hydrocarbons released from USTs in the PWC service station area.

- Permanent groundwater monitoring wells were installed in the area surrounding former UST 957 in December 1994 and sampled in January 1995.

- Soil and groundwater sampling was conducted in the area of former UST 970-3 using a Geoprobe™ in October/November 1995, January 1996, and October 1996.

- Groundwater sampling and CPT testing was performed using the Navy's SCAPS in May 1996. The investigation focused on the NEX gas station area around Building 970.

- Six additional permanent monitoring wells (five in the vicinity of former 970 USTs and one in the vicinity of former UST 957) were installed in October 1996.

- Screening level site characterization investigations were performed starting in 1994 and proceeding to 1997 using a Geoprobe™ direct push sampling system. Both soil and groundwater samples were collected and the investigations focused primarily on the PWC service station area and areas downgradient from the PWC service station. The objective of these investigations was to delineate the extent of hydrocarbons released from USTs in the PWC service station area.

- Additional groundwater sampling was conducted in June and July 1997 because MTBE, a constituent of reformulated gasoline, became a concern. The investigation was conducted using a Geoprobe™ for screening level site characterization of MTBE concentrations in groundwater.

- A limited investigation was conducted in March 1998 using a Geoprobe™ system to identify the leading edge of the MTBE groundwater plume prior to the installation of permanent monitoring wells. The investigation was designed to determine the downgradient extent of MTBE based on the delineation performed previously, and revealed that the MTBE plume required more substantial investigations to define its perimeter. The leading edge of the plume was not delineated.

- An extensive groundwater monitoring well network was installed in April/May 1998 at the Site while the interim remedial action system was installed. The network included: 18 groundwater monitoring wells for routine sampling, 8 groundwater monitoring wells for evaluating natural attenuation rates, and 4 multilevel soil gas and groundwater monitoring points for evaluating IAS/SVE system operation.

- A second limited investigation was performed in May 1998 using a CPT to delineate the boundaries of the MTBE groundwater plume. This investigation was based on the previous delineation activities, but was expanded to over 200 ft beyond the boundaries identified by previous contractors. This investigation also failed to identify the boundaries of the existing MTBE in groundwater at the Site.

- Soil gas from beneath Building 973 was collected in June 1998 and analyzed to initially characterize the concentration profile of VOCs like BTEX and MTBE in the soil void spaces from the water table to the building foundation.

- Another investigation using a CPT was performed in August 1998 that delineated the MTBE plume. The MTBE plume was found to extend approximately 1,400 ft downgradient (north) beyond the boundaries previously identified, and was found to have a width of approximately 600 ft.

- Additional permanent monitoring wells were installed around the perimeter and within the MTBE groundwater plume in December 1998. These new wells, as well as selected wells installed by the USACE were monitored monthly for four (4) months to ensure that the MTBE plume had been adequately delineated.

- Surface water monitoring at four locations within Pacheco Creek began in June 2000. Following receipt of the analytical results, four additional locations associated with culvert outfalls were sampled to determine whether the culverts were likely sources of MTBE in Pacheco Creek.

- The Navy performed remedial investigation activities at the Site in September 2000. The remedial investigation activities addressed nine subtasks outlined under Task 1 of Order No. 00-064 by accomplishing four main tasks: (1) reduce the uncertainty related to whether gasoline constituent concentrations in groundwater are decreasing downgradient of the former UST 970 tank complex; (2) install new monitoring wells to augment the existing monitoring well network and replace previously abandoned wells; (3) determine whether a continuing source of gasoline constituents to groundwater existed in the shallow and smear zone soils in and around the former UST locations following the interim remedial action; and (4) determine whether a pathway conducts groundwater flow preferentially to an area north of the Site.

- The Navy has conducted 12 quarterly groundwater monitoring events and 4 quarterly surface water monitoring events as of February 2001. Quarterly monitoring will continue until it is determined with RWQCB approval that less frequent monitoring is acceptable.

The DTSC has recently inquired about the possibility of MTBE storage or transport within bedrock underlying the Site. Although currently available data are unable to alleviate concerns over this issue, the Navy is planning to perform specific field tests to determine the likelihood of MTBE transport or storage in bedrock at the Site. These activities and the resulting information produced will be reported to the RWQCB and the DTSC. Remedial action alternatives will focus on the groundwater overlying the bedrock formation; however, restoring the quality of water in the overlying aquifer will have a positive effect on water that may exist in the underlying bedrock. The Navy recognizes that Order 00-064 as well as applicable RWQCB Plans and Policies apply to the water resource that may exist in the bedrock at the Site.

5.2.3 Assessment of Plume Stability *(Is the dissolved hydrocarbon plume migrating?).* The stability of gasoline constituents in groundwater can be evaluated by various means based on the type of gasoline constituent (i.e., BTEX versus MTBE) and quantity and type of data and analytical tools available. Typically, gasoline constituents having a tendency to sorb onto soil particles, or having a soil-water partitioning coefficient substantially greater than 1, have limited migration potential due to the retardation effect soils have on the compounds. TPH and BTEX constituents in groundwater are typically stable after a limited period of migration during which the sorptive capacity of soils is overwhelmed by advective mass transfer. After that limited migration period, however, the sorptive capacity of soils encountered by groundwater carrying these gasoline constituents is sufficient to retard the net flow velocity to zero, and the plume is considered stable. For MTBE, however, the migration period is

substantially extended due to the very limited tendency of MTBE to sorb onto soil particles. The following subsections discuss the stability of the BTEX and MTBE groundwater plumes based on the extensive set of historical groundwater monitoring and site characterization data that exist for the Site.

5.2.3.1 Evaluation of BTEX Plume Stability. The evaluation of BTEX plume stability is based on quarterly groundwater monitoring data, which is provided in Appendix L. Various procedures can be used to assess plume stability; however, the most desirable procedure is to construct and compare contour maps of gasoline constituent concentrations in groundwater over many quarterly monitoring events. In many cases this approach is not possible due to: (1) an insufficient monitoring well network that is not extensive enough to allow for quarterly plume contouring; (2) a lack of time-series groundwater monitoring data to compare plume behavior and identify significant trends in concentrations over time, and (3) limited funding that does not allow for monitoring of the extensive network of wells necessary for quarterly plume contouring. Sufficient time-series data exists at Former UST Site 957/970 to allow for benzene concentration contour maps to be compared for 12 quarterly monitoring events. In addition, an evaluation of the natural attenuation of BTEX compounds at the Site was performed using groundwater monitoring data collected through January 1999. Quarterly assessment of the occurrence of natural attenuation at the Site was not continued because the mechanisms were deemed active following the results discussed below. The two approaches used to assess BTEX plume stability are discussed below.

5.2.3.1.1 Time-Series Data. Figure 5-2 shows a series of benzene plume contour maps based on groundwater analytical data collected from May 1998 through February 2001. The overall shape and downgradient extent of the benzene plume has remained constant since the third quarter sampling event in 1998. Most variations of the contours are due to changes in the monitoring well network over time and seasonal variations caused by rain infiltration and water table fluctuations. The first six plume maps shown in Figure 5-2 are based on groundwater data collected during IAS/SVE system operation. These plume maps show that the IAS/SVE system effectively decreased dissolved benzene concentrations based on the 1,000 to 10,000-µg/L contour (yellow) shrinking during successive monitoring events. Even following IAS/SVE system shutdown in October 1999 (third quarter 1999), Figure 5-2 shows that elevated concentrations of benzene continue to decrease during each quarterly sampling event.

Table 5-1 provides dissolved benzene mass estimates calculated for each quarterly monitoring event since May 1998. Note that necessary changes in the monitoring well network and refinements in mass estimation methods to improve data quality caused the mass estimates reported in this CAP to vary from previous reports. In all cases, the integrity of the data for their trend identification objective was preserved, and changes in methodology were consistently applied to the entire time-series data set such that meaningful trend interpretations can be made. Figure 5-3 is a graphical representation of benzene mass estimates over time. The data is presented by year so that seasonal variations over time also can be observed. The graphs indicate decreasing concentration trends throughout the 1998, 1999, and 2000 seasonal cycles. The dissolved benzene mass estimate calculated from data collected during February 2001 was 0.34 kg. This estimated benzene mass increased slightly from the previous sampling event (from 0.26 kg to 0.34 kg), which is likely due to an increase in the saturated thickness of the aquifer during the rainy season (November – February); however, the estimate remains significantly lower than the benzene mass estimates from February sampling events in the previous two years (Table 5-1 and Figure 5-3)."

Table 5-2 presents the maximum and average benzene concentrations measured during each quarterly monitoring event and shows that in general, both are decreasing over time. Based on the consistent shape and downgradient extent of the benzene plume, the steady decline of the mass of benzene dissolved in groundwater during each quarterly monitoring event, and the decreasing benzene concentration trends observed within the plume over time, a shrinking benzene plume exists at the Site.

Similar to benzene, the other BTEX compounds are showing decreasing trends. Figure 5-4 shows toluene, ethylbenzene, and total xylenes plume maps based on groundwater analytical data collected in January/February 1999 and February 2001. The overall shape and downgradient extent of the TEX compound plumes are consistent with that of benzene. Elevated concentrations of TEX compounds found during the first quarter of 1999 have decreased dramatically as of February 2001. Based on the consistent shape and extent of the TEX plumes, and decrease in concentrations, the TEX plumes also appear to be shrinking.

5.2.3.1.2 Monitored Natural Attenuation Summary. MNA (also referred to as intrinsic remediation) relies on naturally occurring processes to reduce gasoline constituent concentrations in groundwater and the vadose zone. MNA relies on biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of gasoline constituents to effectively reduce hydrocarbon toxicity, mobility, or volume to levels that are protective of human health and the environment. Evaluation of MNA requires periodic collecting of groundwater data to establish gasoline constituent and biological indicator trends, and data evaluation to predict the potential long-term migration of gasoline constituents under the influence of the natural attenuation processes operating at the Site. The location and extent of gasoline sources, the distribution and concentration of dissolved-phase hydrocarbons and hydrogeologic factors controlling the migration of hydrocarbons in the groundwater must be determined to successfully evaluate MNA. Biological indicator trends are defined by the spatial distribution of electron acceptors and metabolic by-products. Detailed site characterization is required to adequately document, understand, and predict MNA processes at a particular site.

Before extensive historical groundwater monitoring data existed for the Site, indicators of MNA were monitored and evaluated to assess the future behavior of the BTEX plumes. For approximately nine quarters, groundwater samples were collected from selected wells located within the BTEX plumes and analyzed for indicator parameters of MNA. These parameters included electron acceptors (DO, nitrate, and sulfate), metabolic by-products (methane, ferrous iron, and manganese), and general indicators of biological activity (alkalinity and oxidation-reduction potential [ORP]). Results from these analyses coupled with BTEX data were evaluated using statistical analysis approaches to determine whether natural attenuation of BTEX compounds was occurring at the Site. Based on the results of the statistical analyses, there were strong indicators that natural attenuation of BTEX compounds was occurring at the Site through manganese reduction and methanogenesis. For a detailed discussion of the statistical analysis approaches and results of the analyses, refer to Appendix O.

Because more data is available since the MNA statistical analyses were performed, the correlations determined through the analyses are shown to be consistent with the time series data and overall shrinking status of the BTEX plumes. The active mechanisms of MNA that were identified during the statistical analyses help to understand the biological processes that are occurring at the Site in the area of the BTEX plumes (i.e., anaerobic biodegradation via manganese reduction and methanogenesis). These same anaerobic mechanisms have not been found in areas north of Navy property, on former HAAF property, where aerobic conditions currently exist. These aerobic conditions are likely due to the majority of the area being uncovered, thereby allowing the underlying aquifer to be oxygenated by infiltration of rainwater during precipitation events.

5.2.3.2 Evaluation of MTBE Plume Stability . The dissolved-MTBE plume at the Former UST Site 957/970, like most groundwater plumes, is a dynamic system, evolving over time as it is influenced by physical, chemical, and biological processes. The status of the MTBE plume is assessed in the same manner as the BTEX plume; however, no statistical analyses of MTBE concentrations are discussed. Instead, the location of the one-dimensional MTBE center of mass was calculated for two quarterly events that were separated by a period of two years in order to better evaluate the long-term behavior of the MTBE plume. The current status of the MTBE plume at the Site is described below.

5.2.3.2.1 Time-Series Data. Figure 5-5 shows a series of MTBE plume contour maps based on groundwater analytical data collected from November 1998 through February 2001. The overall shape and downgradient extent of the plume has remained relatively consistent over time with the exception of an advance of MTBE concentrations in groundwater on the northeastern tip of the plume. Elevated concentrations of MTBE that originated from the former UST 970 complex and former UST 957 were decreased significantly as a result of IAS/SVE operation from May 1998 to October 1999. Following system shutdown, MTBE concentrations near the former UST 970 complex have continued to decrease and during the last two quarterly monitoring events, MTBE concentrations >10,000 μg/L have only been located near the area of the former UST 957. Table 5-2 shows that in general, maximum and average MTBE concentrations at the Site have been declining during quarterly monitoring events at the Site. The maximum MTBE concentration of 43,000 μg/L detected in February 2001 increased from the previous sampling event (November 2000); however, it is still equal to that of the August 2000 sampling event. Furthermore, maximum and average MTBE concentrations during the February 2001 quarterly monitoring event were less than those observed during February 1999 and February 2000, indicating a long-term decreasing concentration trend rather than fluctuations associated with seasonal variation.

The series of plume maps provided in Figure 5-5 show that the area of elevated MTBE concentrations (>10,000 μg/L) has fluctuated north and south of the railroad tracks since IAS/SVE system shutdown in October 1999; however, the expansion of the 10,000-μg/L contour north of the railroad tracks is an artifact of contour extrapolation, meaning MTBE concentrations >10,000 μg/L have not been detected north of the Navy property since May 1999. Due to natural processes such as aerobic biodegradation of MTBE, dilution of MTBE, and recharge of the underlying aquifer by precipitation events, the MTBE hot spot (concentrations >10,000 μg/L) currently on Navy property does not appear currently to be migrating with groundwater flow to the north.

Of the areas on former HAAF property where MTBE is dissolved in groundwater, Figure 5-5 indicates that the only portion of the plume that may be of concern for migration is to the northeast (near Landfill 26). An increase in MTBE concentrations in wells IT-PZ-9 and IT-GMP-17 was detected during the latest quarterly monitoring event (February 2001); however, IT-GMP-17 had shown an increase in February 2000 that was followed by a leveling off of concentrations. Future monitoring is required to determine whether consistent changes are occurring in the northeastern portion of the plume, or if increases in MTBE concentrations may be a result of seasonal fluctuations. The apparent "funneling" of the MTBE plume near Landfill 26 may be a result of the local hydrogeology in that area of the plume. Ammo Hill is located approximately 550 ft due north of IT-GMP-17, and serves as a barrier to groundwater flow. As groundwater flow nears Ammo Hill it is forced around the bedrock outcropping along a narrow channel. This phenomenon also explains the diverging of the MTBE plume contour on the leading edge (northern edge), as groundwater is forced around (to the east and west of) Ammo Hill.

Figure 5-6 is a graphic representation of MTBE mass estimate over time. The data is presented by year so that seasonal variations over time also can be observed. The graphs indicate decreasing concentration trends throughout the 1998, 1999, and 2000 seasonal cycles, with the exception of the MTBE mass estimate for February 2001 being slightly higher than that for February 2000. Table 5-1 shows the estimated dissolved mass of MTBE during each quarterly monitoring event. Although a general decreasing trend in MTBE mass has been observed at the Site, some variation (i.e., increases) have been observed periodically due to seasonal variations and/or changes to the monitoring well network. An increase was observed from November 2000 to February 2001. This increase is related to an increase in the saturated thickness used in the mass calculations, because water level is higher during the rainy season. The mass calculation assumes that the vertical distribution of MTBE in the aquifer is homogeneous; however, it is possible that water infiltrating during precipitation events remains on the upper layer of the aquifer. If this scenario occurs, the upper layer of the aquifer would likely have a lower

concentration than what was assumed in the mass calculations. Because conclusive evidence to support this hypothesis does not exist, conservative calculations were performed by assuming a homogeneous aquifer.

A total estimated mass of 156 kg of dissolved MTBE was calculated based on groundwater analytical data collected in February 2001 (Table 5-1). Of that 156 kg of MTBE, approximately 82 kg was dissolved in groundwater on Navy property (i.e., south of the railroad tracks) and 74 kg was dissolved in groundwater on former HAAF property (i.e., north of the railroad tracks) (see Table 5-3). By comparison, groundwater analytical data collected in January/February 1999 was used to estimate a total of 256 kg of MTBE dissolved in groundwater over the entire Site, with approximately 116 kg dissolved in groundwater on Navy property and 140 kg dissolved in groundwater on former HAAF property (see Table 5-3). Based on these estimated masses calculated from 3-D plume contour volumes determined with Earthvision™, it was possible to approximate the center of mass of MTBE over the entire Site, on Navy property, and on former HAAF property in January/February 1999 and February 2001.

5.2.3.2.2 Center of Mass. The center of mass of MTBE dissolved in groundwater on Navy property has shifted approximately 100 ft downgradient (north) from January/February 1999 to February 2001. Primarily, this shift was caused by mass removal accomplished by the IAS/SVE system in the area of the former UST 970 complex at the upgradient (southern) extreme of the MTBE plume (Figure 5-7) and the resulting shift in the "balance" of MTBE mass toward the north. Some minor northward migration of dissolved MTBE also may be partially responsible for shifting the center of mass.

Entire MTBE Plume. The center of mass calculation indicates that the overall center of mass of the entire MTBE plume has receded nearly 300 ft upgradient (south) nearly 300 ft over a two-year period of time. The upgradient shift in the center of mass is a substantive observation because the mass removed by the interim remedial action system at the upgradient end of the plume taken alone (if mass elsewhere in the plume were constant) would result in a downgradient (northward) shift in the center of mass. The reduction of the estimated total dissolved MTBE mass from 256 kg to 156 kg and the retreat of the center of mass over a two-year period are strong indicators that the dissolved MTBE plume is being reduced by natural attenuation processes.

Navy Property. The center of mass of MTBE dissolved in groundwater on Navy property has shifted approximately 100 ft downgradient (north) from January/February 1999 to February 2001. This may be explained by the IAS/SVE system removing a significant amount of mass in the area of the former UST 970 complex at the upgradient extreme of the MTBE plume portion. That active removal effort left more MTBE dissolved in groundwater north of the former UST 970 source (Figure 5-7). Northward migration of dissolved MTBE also may be partially responsible for shifting the center of mass estimate downgradient.

Former HAAF Property. The center of mass of MTBE dissolved in groundwater on former HAAF property has remained relatively stable (~50 ft is within the margin of error for the approximate center of mass calculations) over a two-year period of time. The center of mass of MTBE on HAAF property appears to be stable even though the northeast leading edge of the plume has expanded over the past year because the overall mass of MTBE contained in the plume on former HAAF property has decreased by approximately 50% over a two-year period of time (Table 5-3), and elevated concentrations of MTBE dissolved in groundwater on Navy property recently have not been observed to be migrating north of State Access Road. Higher concentrations coming on to former HAAF property from the Navy property would have the effect of shifting the center of mass of this northern portion of the MTBE plume upgradient to the south. The substantial reduction in dissolved MTBE without a large shift in the center of mass to the north are further evidence of the effects of natural attenuation processes, and indicate that

the lower MTBE concentrations on HAAF are very likely to continue to diminish over time at an observable rate.

Based on the MTBE plume maps (Figure 5-5) and the center of mass of estimated MTBE dissolved in groundwater within different portions of the Site (Figure 5-7), the greatest uncertainty appears to be related to the elevated MTBE concentration area at the northern end of the Navy property just upgradient of former HAAF property. Natural attenuation processes currently appear to be closely balanced with the tendency of advective groundwater flow to carry MTBE downgradient. The Navy has identified a natural channel or preferential pathway through which the bulk of groundwater seems to be flowing from the Navy property onto former HAAF property (see Section 4.1.2). This feature can be exploited for remedy selection as well as monitoring purposes.

5.2.4 Assessment of Impact to Water Resources or Other Sensitive Receptors. (*Are any water wells, deeper drinking water aquifers, surface water, or other sensitive receptors likely to be impacted?*).

A well survey was performed through the County of Marin Environmental Health Services (CMEHS) and California Department of Water Resources (DWR). Results of the well survey indicated that no domestic wells exist within a 1.5-mile radius of the Site. However, an agricultural well was referenced by AGS, Inc. (1999) as existing within ½-mile to the west-southwest of Former UST Site 957/970 in a separate stream valley upgradient of the Site. Figure 5-8 shows the locations of the wells identified through the CMEHS and DWR well survey in addition to the agricultural well referenced by AGS, Inc. and indicates their designated use. No domestic, irrigation, or agricultural wells are currently impacted by the dissolved gasoline constituents from the releases at DoDHF Novato.

Pacheco Creek, the surface water body located north of the Site, currently overlies MTBE-impacted groundwater on former HAAF property. Comparisons of the elevation of the water table surface (from recent quarterly groundwater monitoring events) to the elevation of the creek bed shows that the elevation of the aquifer is higher than the streambed elevation in some areas, particularly during winter months when groundwater levels are elevated (Figure 5-9). However, groundwater-surface water interaction is likely limited by the concrete lining of Pacheco Creek, decreasing the potential for infiltration of groundwater into the creek, even during periods of higher water table levels.

Quarterly surface water monitoring activities performed by the Navy indicate the presence of MTBE at low concentrations in the surface water of Pacheco Creek. However, the fact that MTBE has been detected in the surface water does not definitively establish interaction between the groundwater and Pacheco Creek during the wet season. Sampling data indicate that a possible or likely source of the MTBE in the surface water is from a storm sewer outfall that discharges laterally into Pacheco Creek near the North Hamilton Parkway Bridge. During quarterly surface water sampling at the Site, MTBE concentrations have consistently been highest inside the storm sewer outlet and have decreased as the surface water travels downstream. The maximum MTBE concentration detected during all quarterly surface water monitoring events (2,400 μg/L) was found inside the storm sewer outfall; however, that level is well below the water quality objective adopted by the RWQCB (1998) to be protective of freshwater aquatic life (66,000 μg/L). The results of the Human Health and Ecological risk Assessments are summarized in Section 5.2.5 and 5.2.6, respectively.

It cannot be demonstrated that groundwater does not interact with surface water in Pacheco Creek; therefore, risk assessment calculations were based on the conservative assumption that groundwater does discharge to the creek. Based on this assumption, the Tier 3 RBCA human health risk assessment and ecological risk assessment results determined that the MTBE concentrations in groundwater surrounding the creek are not capable of producing unacceptable concentrations of MTBE

within the creek. A more detailed assessment of the surface water pathways for the Human Health and Ecological Risk Assessments are presented in Sections 2.4 and 2.5, respectively.

5.2.5 Assessment of Risk to Human Health. (*Does the site present any significant risk to human health?***)**

A Tier 3 RBCA Assessment (Battelle, 1999c) was prepared for the RWQCB to develop RBSLs that are protective of potential receptors that may come into contact with hydrocarbon-impacted media at the Site. After the Tier 3 RBCA Assessment was considered final, the DTSC opted to exercise their regulatory oversight for the human health risk assessment at the Site and requested the use of their preferred risk assessment method. The DTSC prefers an alternate approach to risk assessment that is outlined in the U.S. EPA's *Risk Assessment Guidance for Superfund* (1989) and the DTSC HERD *Supplemental Guidance for Superfund Risk Assessment* (Cal-EPA, 1992). In the preferred approach, a multimedia, multichemical risk assessment is performed in the *forward* direction to estimate cancer risk and chemical hazard (non-cancer risk), rather than in the *reverse* direction as was done in the RBCA assessment by deriving Risk Based Screening Levels. Therefore, the Navy conducted a risk assessment in the forward direction to estimate cancer risk and noncancer hazard to address specific comments provided by the DTSC on the Tier 3 RBCA Assessment. This risk assessment was submitted as a draft revised risk assessment, which was reviewed by DTSC. Upon receipt of comments from DTSC, the Navy revised the draft report and resubmitted the risk assessment to DTSC as a *Final Revised Risk Assessment* (Battelle 2001c). DTSC agreed with the conclusions of the Final Revised Risk Assessment and issued a letter of approval, which is included in Attachment 2. Results of the *Final Revised Risk Assassment* are favored over those in the Tier 3 RBCA for exposures pathways that were evaluated in both assassments.

Results of the *Final Revised Risk Assessment* (Battelle, 2001c) indicate the cancer risk estimates to the occupational receptor in the Sale Area fall within the risk range (1×10^{-6} to 1×10^{-4}) that warrants a site-specific risk management decision regarding the suitability of the property for its intended future use; however, the total cancer risk estimates in the Sale Area are most likely overestimated because of the following key assumptions that were made during the calculation of risks (Battelle, 2001c):

- Asphalt pavement exists at the site that precludes direct contact with soil; nevertheless, it was assumed that the receptors could be exposed to soil via direct contact by ingestion, dermal contact, and inhalation of dust

- Outdoor-air risks were based on the maximum dissolved groundwater concentrations measured across the entire site in November 2000

- The maximum indoor-air risks were based on soil-gas data collected from locations in the Sale Area that overlie groundwater containing the highest concentrations of dissolved gasoline constituents

- The model that was used to predict indoor-air risks is known to provide conservative estimated of risk due to several key assumptions. For example, the model assumed that the concentrations of gasoline constituents will remain constant in the future; therefore, risks do not change over time. In reality, most of the gasoline constituents at the site, including benzene, are highly amenable to natural attenuation and it is likely that they will degrade in a relatively short timeframe, thereby lowering future risks.

Therefore, these various conservative assumptions indicate that the total cancer risk estimates for the Sale Area are most likely overestimated. The risk assessment was conducted in accordance with DTSC risk assessment guidance, which adheres to U.S. EPA's RAGS (U.S. EPA, 1989) and U.S. EPA Office of Solid Waste and Emergency Response (OSWER) directives, in addition to supplemental guidance provided by DTSC regarding technical or scientific issues. Sites or facilities under DTSC jurisdiction must conform to the guidance in RAGS and OSWER directives (DTSC supplemental guidance at http://www.dtsc.ca.gov/sppt/herd). Per U.S. EPA OSWER directive No. 9355.0-30 (U.S. EPA, 1991), remedial action generally is not warranted at a site if the total cancer risk is below 1×10^{-4} (one in ten thousand) and the total noncancer risk (hazard index) does not exceed 1.0, unless a risk manager decides that there are extenuating circumstances. DTSC concurred with the methodology and results of the risk assessment and the Sale Area is suitable for its intended commercial/industrial use.

The results of the *Final Revised Risk Assessment* indicate that the educational PBC Area and areas outside the Sale Area and the PBC Area overlying groundwater with dissolved MTBE resulting from the former UST releases (i.e., Hamilton Meadows Subdivision) are suitable for unrestricted land use because the total cancer risk falls below 1×10^{-6} and the noncancer risk is below 1.0 (Battelle, 2001c). The results of the Tier 3 RBCA Assessment (Battelle, 1999c) also supports that the current conditions on areas outside the Sale Area and the PBC Area overlying the MTBE plume (i.e., the former HAAF property) are not likely to be associated with adverse health effects for residential receptors that could potentially come into contact with gasoline constituents by ingesting homegrown fruits/vegetables or coming into contact with surface water in Pacheco Creek during recreational activities.

Although the *Final Revised Risk Assessment* did not include ingestion of homegrown produce or exposure to surface water in Pacheco Creek, the risks for these exposures are considered to be minimal. The risk associated with ingestion of homegrown produce for this particular site was assumed to be minimal compared to the other exposure pathways evaluated and was therefore not included in the risk assessment. DTSC agreed with this assumption and states in their approval letter for the *Final Revised Risk Assessment* (Attachment 2), "the risks from this pathway are negligible since: 1) volatile organic chemicals such as benzene, MTBE and toluene have not been shown to bioaccumulate in the types of garden crops which could potentially be grown in the PBC Area; and 2) uptake of these types of highly volatile chemicals by plants from groundwater would be rapidly lost by photosynthetic plants by the process of transpiration/evaporation to the atmosphere." Therefore, ingestion of homegrown produce would not significantly contribute to the overall site risks reported in the *Final Revised Risk Assessment*.

To further support the results of the Tier 3 RBCA Assessment with regard to exposure to surface water in Pacheco Creek, the most recent (May 2001) surface water monitoring data from sampling locations within Pacheco Creek were used to calculate the total risk presented by possible exposure in the creek. Risks were calculated for the inhalation, ingestion, and dermal contact exposure routes. The ratio of the observed average concentration along the length of the creek (14.7 μg/L) to the protective concentration calculated in the Tier 3 RBCA Assessment (Battelle, 1999c) for each of the exposure pathways considered (2,402 μg/L for inhalation; 4,600 μg/L for ingestion; and 9,350 μg/L for dermal contact) was multiplied by the 1×10^{-6} target risk level from which the protective concentrations were derived to estimate the risk associated with each exposure pathway. The avaerage concentration (14.7 μg/L) was used in estimating the risk associated with each exposure pathway because it represents concentrations over the entire likely exposure area (Pacheco Creek). These risks were summed, yielding a total risk of approximately 1×10^{-8} for exposure in the creek. The total risk associated with the creek was minimal compared to the risks associated with the other exposure pathways evaluated at the Site (for example, inhalation of indoor air); therefore the total risk estimated for the surface water in Pacheco Creek would not significantly add to the total site risk as reported in the *Final Revised Risk Assessment*.

The results of the *Final Revised Risk Assessment* pertaining to an excavation worker at Former UST Site 957/970 indicate that precautionary measures should be taken when working at the Site. Recommendations for reducing VOC emission rates during excavation activities are provided by U.S. EPA (1992). Refer to Section 2.4 for more detailed information on the human health risk assessments performed at the Site.

Results of the Tier 3 RBCA Assessment (Battelle, 1999c) and the *Final Revised Risk Assessment* (Battelle, 2001c) indicate that the current nature and extent of gasoline constituents in soil and groundwater do not pose a significant health risk to potential receptors across the entire Site based on the planned future uses. In addition, the evaluation conducted to assess the concentrations of constituents remaining in soil near the footing of Building 970 (i.e., comparison to Region 9 PRGs) indicated that exposure to these constituents in soil would not pose significant health risks to the intended future commercial/industrial receptor. Therefore, remediation decisions will not be driven by risk to human health.

5.2.6 Assessment of Risk to the Environment. (*Does the site present any significant risk to the environment?*)

A draft scoping level ecological risk assessment was prepared to determine if the Site poses a risk to the environment. The report focused on determining the potential ecological receptors and the potentially complete exposure pathways, according to the methodologies described by the Cal-EPA (1996) for scoping assessments and consistent with U.S. EPA guidance for problem formulation (U.S. EPA, 1998a). This report was updated in June 2001 to incorporate the results of surface water sampling. According to Cal-EPA (1996), additional assessment is not required if the scoping assessment determines that either no complete exposure pathways exist or that the impacted areas are not significantly utilized by biota.

Because MTBE was detected in the creek, the surface water pathway is considered complete; however, risk to ecological receptors from MTBE in surface water is negligible. The maximum MTBE concentration detected at the storm sewer outfall (2,400 μg/L) is well below the Recommended Interim Water Quality Objective (or Aquatic Life Criteria) of 66,000 μg/L MTBE for chronic exposure of freshwater organisms (RWQCB, 1998). The hazard quotient, calculated by dividing the exposure concentration by the Water Quality Objective is 0.04. Any hazard quotient below 1.0 is considered acceptable. Therefore, based on the results of the updated scoping assessment, no significant risk is presented to ecological receptors at the Site and remediation decisions will not be driven by risk to ecological receptors.

5.3 Remedial Action Objectives

In compliance with RWQCB Order 00-064 and the Water Quality Control Plan for the San Francisco Bay Basin (the Basin Plan), the proposed ***final cleanup levels*** for Former UST Site 957/970 are to reduce MTBE concentrations to MCLs which should completely restore the groundwater resources at the Site to their potentially most stringent domestic beneficial use. Because risk assessments performed at the Site indicate that an immediate threat to human health or the environment does not exist, in compliance with Resolution 92-49, the proposed final cleanup standards must be achieved within a reasonable time that provides the maximum benefit to the people of the State of California.

Order No. 00-064, Task 6, lists this CAP satisfy the following requirements:

> "1. Stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site

2. Remediate the highest concentrations of soil pollution detected Task B.1.
3. Reduce and remediate the concentrations of MTBE in Site groundwater
4. Reduce and remediate the concentrations of benzene in Site groundwater which exceed applicable RBSLs."

The ***remedial action objectives*** (RAOs) of this CAP are to stabilize and contain the MTBE plume on Navy property as required in RWQCB Order 00-064 and to reduce the time to achieve the final cleanup levels (MCL concentrations) for all gasoline constituents including benzene and MTBE by using a remedial technology that produces the greatest benefit to the people of the State of California considering the total values involved: beneficial and detrimental, economic and social, tangible and intangible. Once the most beneficial remedial technology has been determined and selected, performance goals will be established to determine specific concentrations that will be achieved through operation of the system.

An evaluation of viable remedial alternatives is presented in Section 6 to determine which available technology will produce the maximum benefit to the people of the State of California as measured by the feasibility study criteria given in Order 00-064. Specific performance goals for the proposed remedy are presented in Section 7. These performance goals include the estimated time to achieve stabilization and containment of the MTBE plume on Navy property as measured by observable concentrations in wells at specific proposed locations at the Site, as well as the estimated time required by each alternative to achieve MCLs for all gasoline constituents at the Site including benzene and MTBE as required by the Basin Plan. The Basin Plan (RWQCB, 1995) defines the applicable MCLs for benzene and MTBE as 1 and 5 ppb, respectively. Note that the 5 ppb MCL for MTBE is the secondary MCL.

All remedial alternatives considered in Section 6 will include a monitoring program to ensure that the RAOs are achieved, and that concentrations of gasoline constituents are being reduced to MCLs within a reasonable time. Currently, a monitoring well protection plan and a groundwater monitoring plan are being implemented at the Site in compliance with RWQCB Order No. 00-064 Tasks 5 and 8, respectively. These plans will be modified with regulatory approval as necessary, and extended specific to the proposed remedy.

All remedial alternatives considered in Section 6 will prevent nuisance conditions from occurring downgradient of the Site. All remedies considered will result in stabilization and containment of the MTBE plume on Navy property, and will therefore prevent migration of MTBE in groundwater toward Pacheco Creek or to low topography areas where surface ponding could occur.

RWQCB Order 00-064 requires that the highest concentrations of soil pollution detected in the remedial investigation as described in Order 00-064, Task 1, and performed and reported under Task 2 be addressed in the feasibility study portion of this CAP. Soil concentrations observed during the remedial investigation activities were reported in the Remedial Investigation Report submitted in compliance with Order 00-064, Task 2, and were assessed in the *Final Revised Risk Assessment* submitted June 2001. Other soil pollution was addressed in 1) the hydraulic lift removal activities that involved extensive excavation within and around Building 970, and 2) the Draft Summary Report for Hydraulic Lift and Oil/Water Separator Removal from Building 970 (July 2000) associated with those activities.

These reports document the nature and extent of hydrocarbons in soils in the former NEX service station area. The hydraulic lift removal activities included sampling for some other compounds associated with lifts and automobile repair work, such as PCBs and metals. No PCBs were detected at the Site, and most of the elevated metal and hydrocarbon impacted soils were removed by excavation. Some areas underlying building footers and inaccessible areas could not be excavated and were left in place.

The remaining soil is generally below commercial/industrial PRGs, with only a small number of discrete sample locations exceeding PRGs.

The results of the *Final Revised Risk Assessment* and the recommendations from the hydraulic lift report do not indicate that corrective action is required to protect human health and the environment from these soils. Institutional controls (ICs) will be established as described in Section 6.2.1.3 to manage these soils and ensure that if these soils are disturbed, they will be managed properly and safely. RAOs for soil are therefore considered to have been achieved by the operation of the interim remedial action and the hydraulic lift removal activities. No further active corrective action for soils is required to satisfy Order 00-064 or to protect human health, the environment, or the water resources of the State of California.

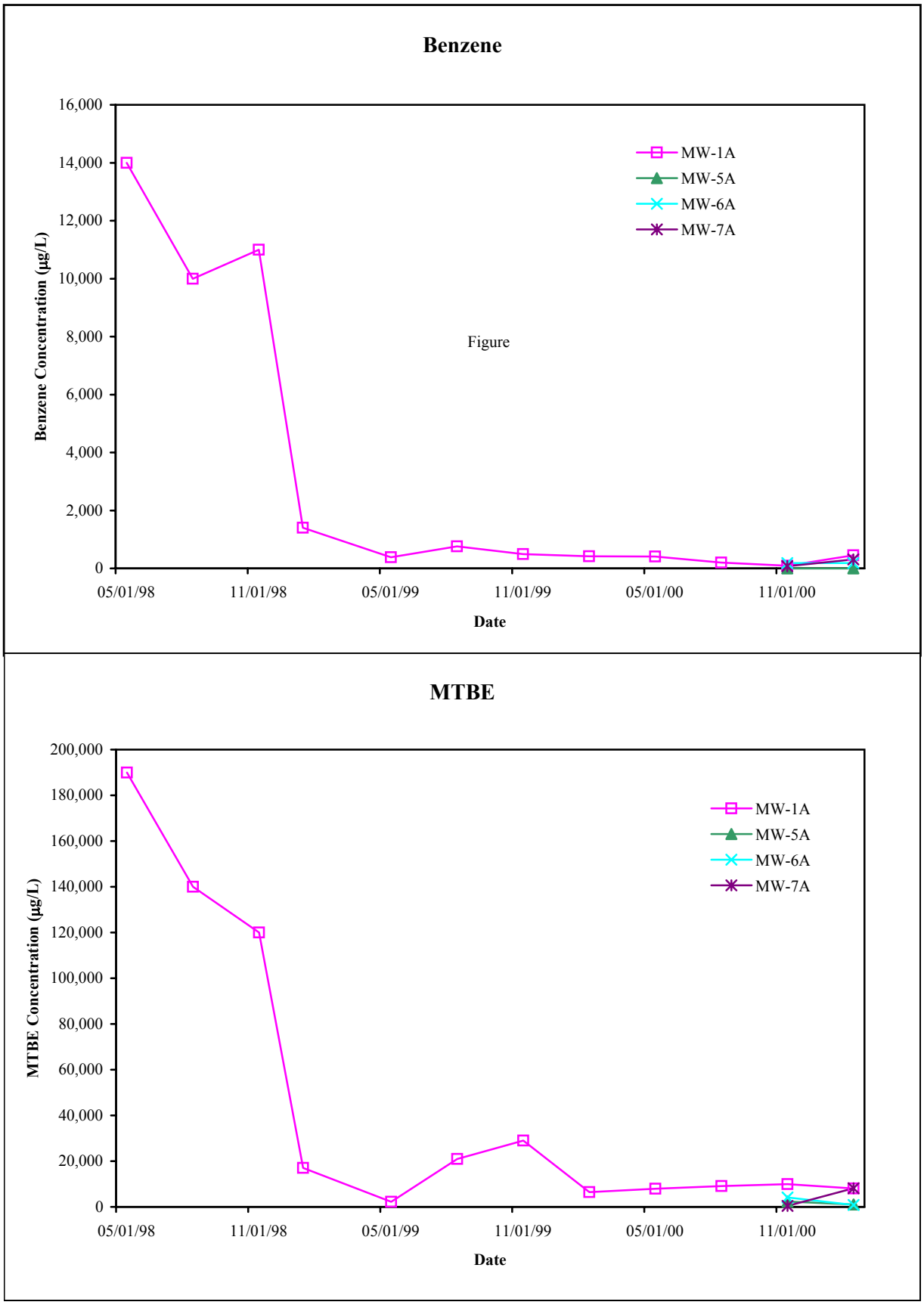


Figure 5-1. Area A (Former UST 970 Tank Complex Source Area) Benzene and MTBE Time Series Graphs for Transect Wells

1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter

1998

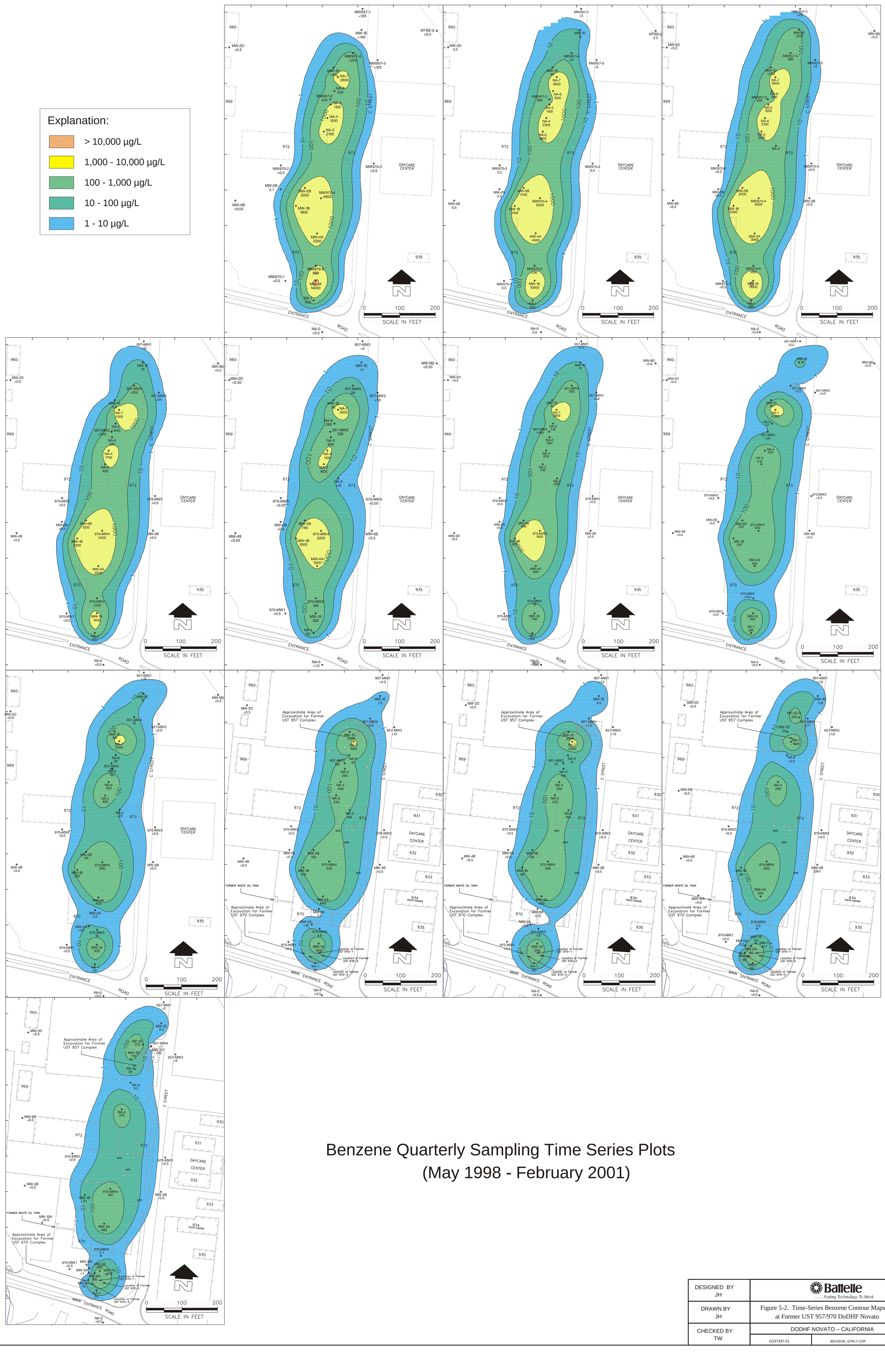
1999

2000

2001

Explanation:

- > 10,000 µg/L
- 1,000 - 10,000 µg/L
- 100 - 1,000 µg/L
- 10 - 100 µg/L
- 1 - 10 µg/L



Benzene Quarterly Sampling Time Series Plots
(May 1998 - February 2001)

DESIGNED BY JH	Battelle … Putting Technology To Work		
DRAWN BY JH	Figure 5-2. Time-Series Benzene Contour Maps at Former UST 957/970 DoDHF Novato		
CHECKED BY TW	DODHF NOVATO – CALIFORNIA		
	G337337-51	BENZENE_QTRLY.CDR	11/01

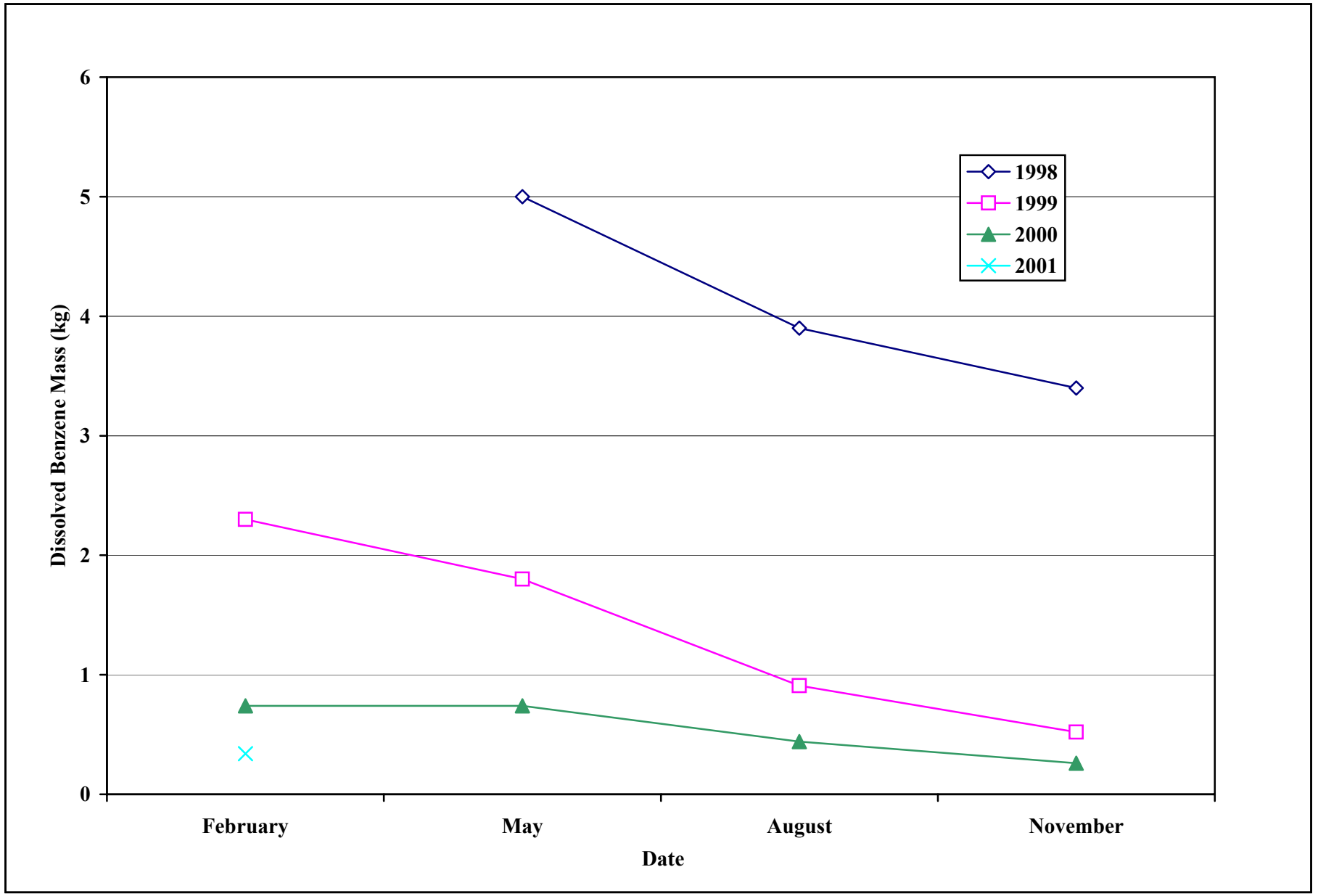


Figure 5-3. Benzene Mass Estimates in Groundwater Over Time

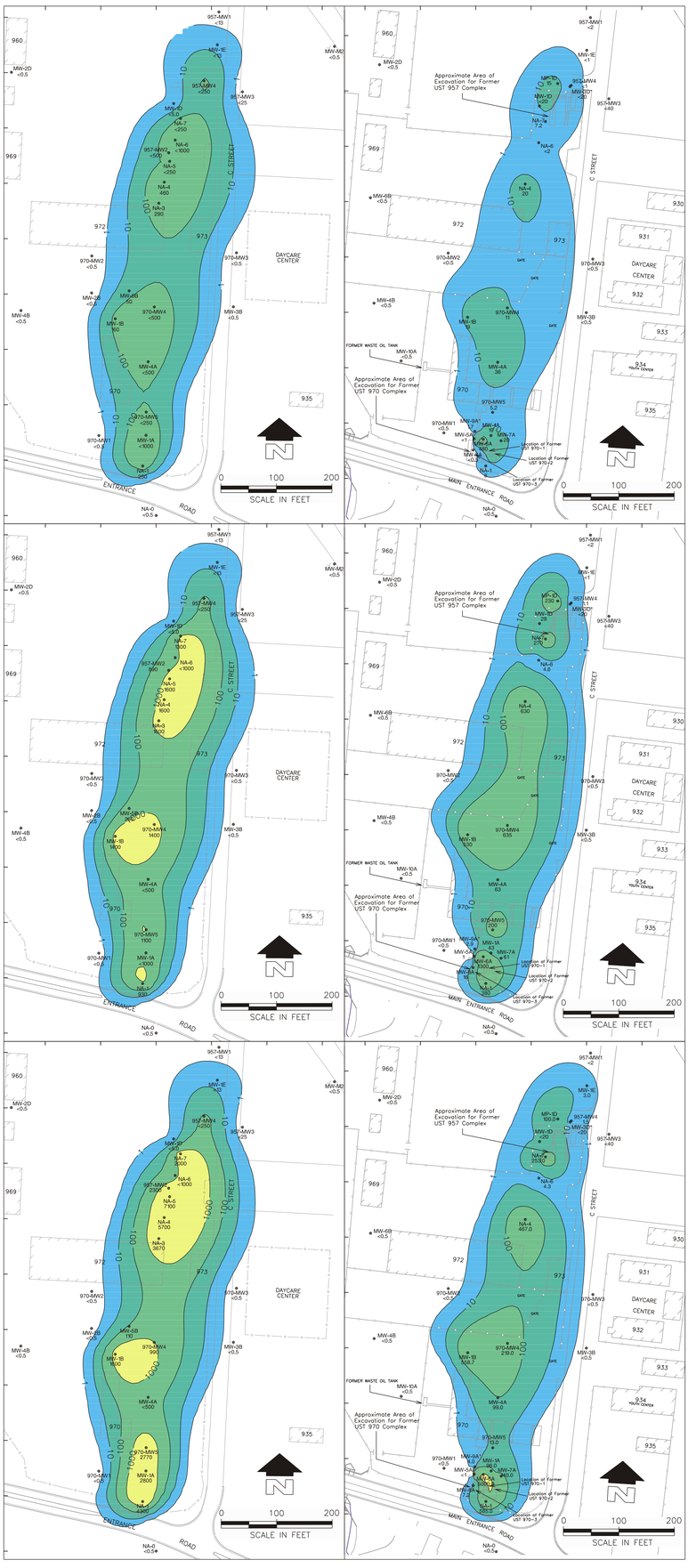
1st Quarter 1999

1st Quarter 2001

Toluene

Ethylbenzene

Xylenes

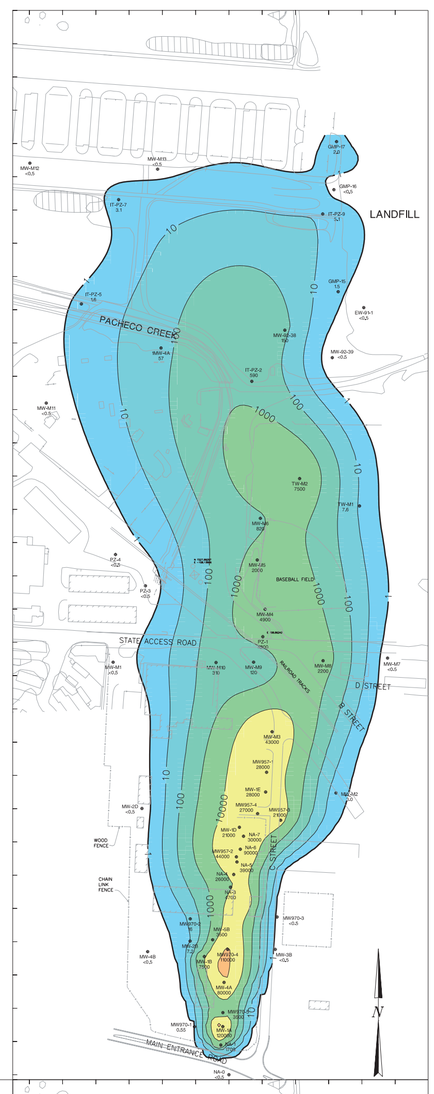
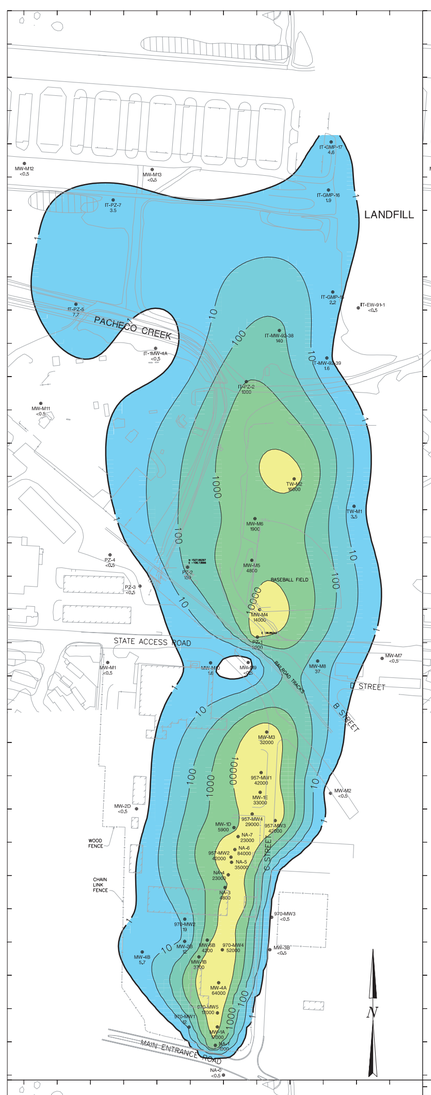
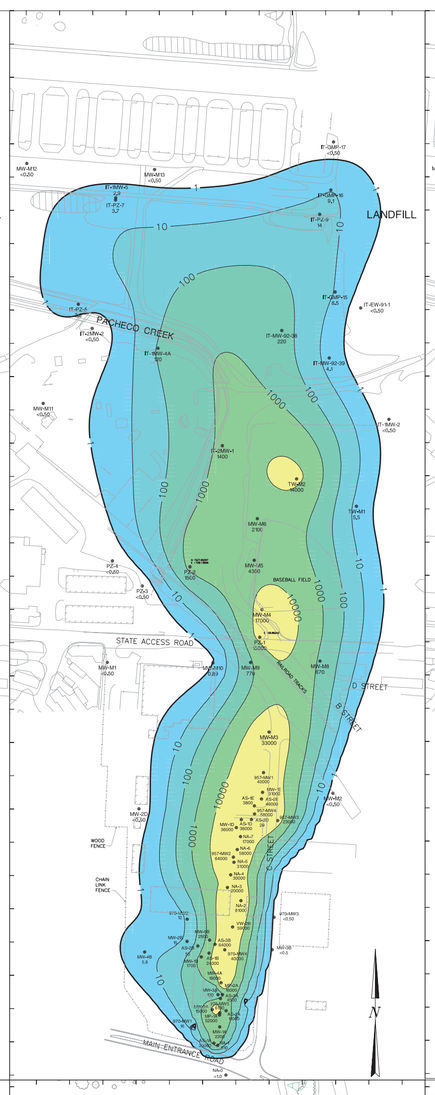
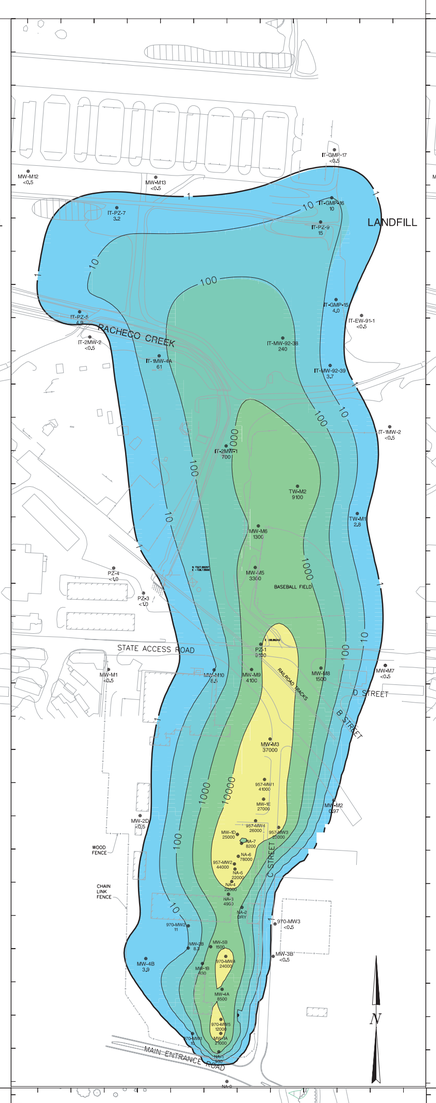
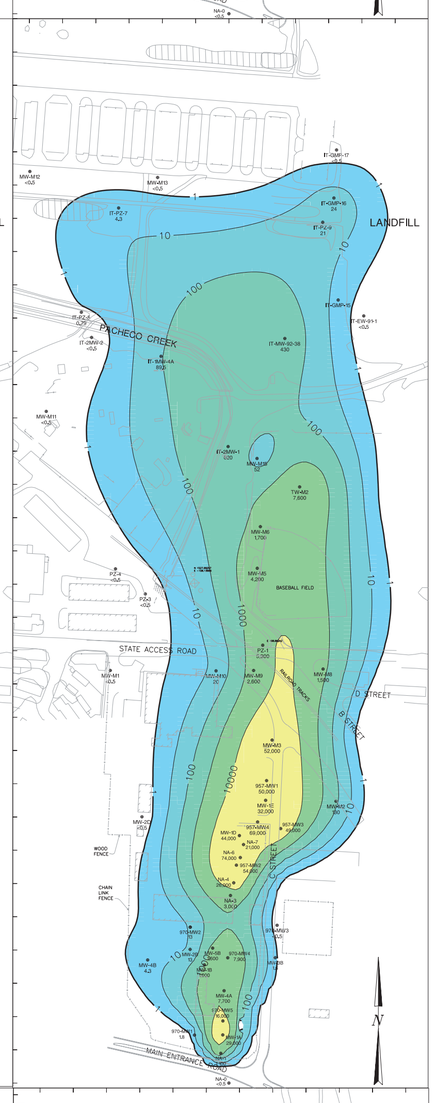
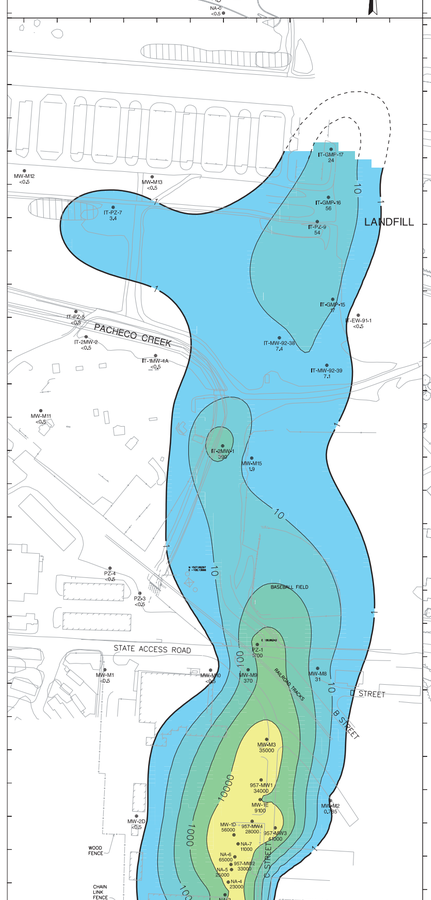
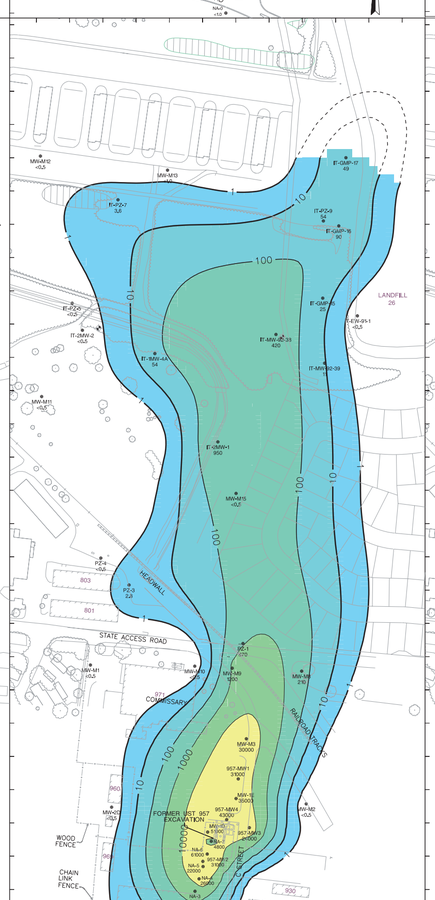
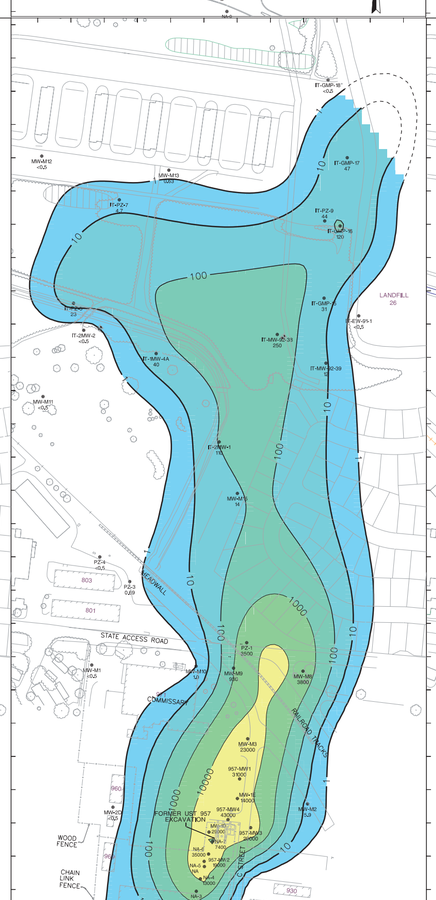
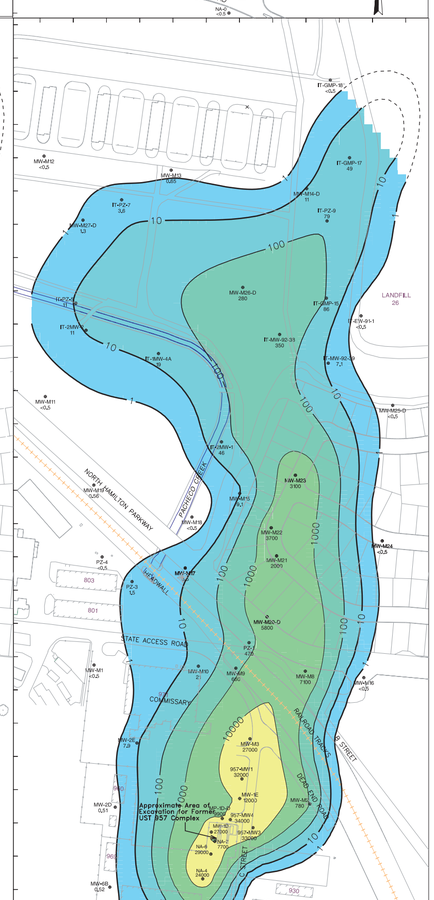
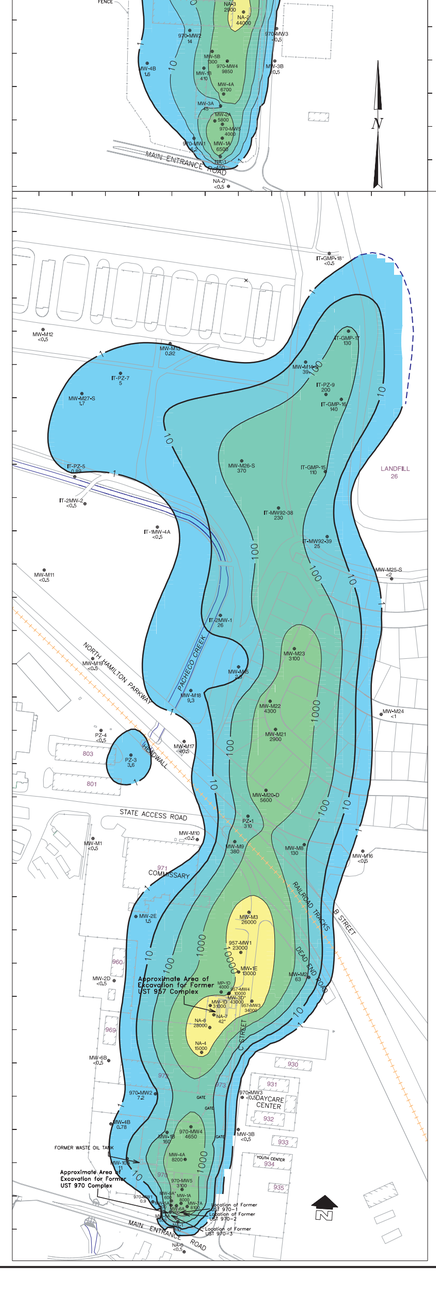


Explanation:

- > 10,000 µg/L
- 1,000 - 10,000 µg/L
- 100 - 1,000 µg/L
- 10 - 100 µg/L
- 1 - 10 µg/L

DESIGNED BY JH	Battelle ... Putting Technology To Work
DRAWN BY JH	Figure 5-4. Contour Maps of Toluene, Ethylbenzene, and Xylenes at Former UST 957/970 DoDHF Novato
CHECKED BY TW	DODHF NOVATO – CALIFORNIA
	G337337-51 | TEX_1STQTR_PORTRAIT.CDR | 11/01

MTBE Quarterly Sampling Time Series Plots (November 1998 - February 2001)

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1998				
1999				
2000				
2001				

Explanation:

- > 100,000 µg/L
- 10,000 - 100,000 µg/L
- 1,000 - 10,000 µg/L
- 100 - 1,000 µg/L
- 10 - 100 µg/L
- 1 - 10 µg/L

0 400 800

SCALE IN FEET

DESIGNED BY JH	Battelle ... Putting Technology To Work		
DRAWN BY JH	**Figure 5-5. Time-Series MTBE Contour Maps at Former UST 957/970 DoDHF Novato**		
CHECKED BY TW	DODHF NOVATO – CALIFORNIA		
	G337337-51	MTBE_NOLEGEND*.CDR	4/01

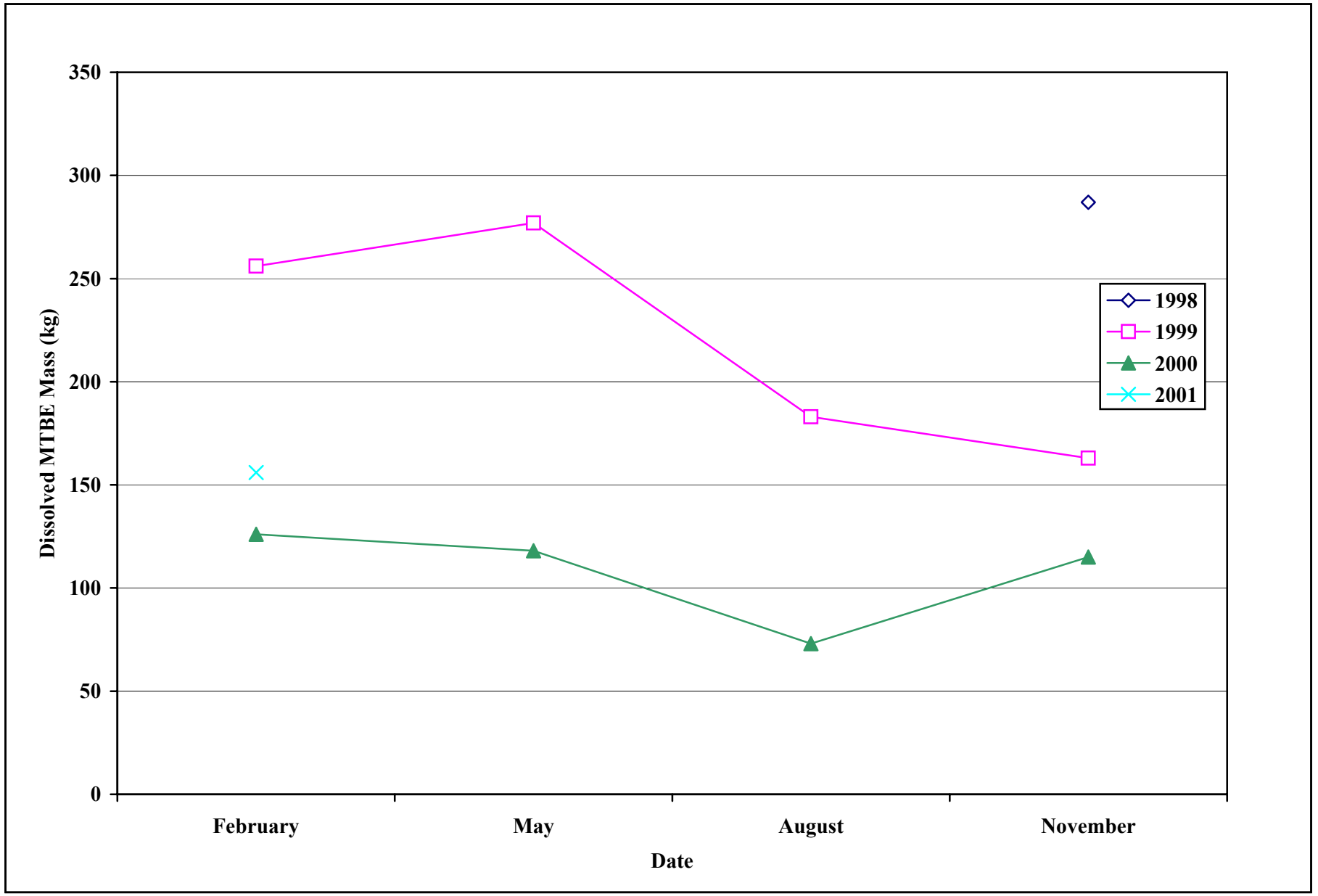
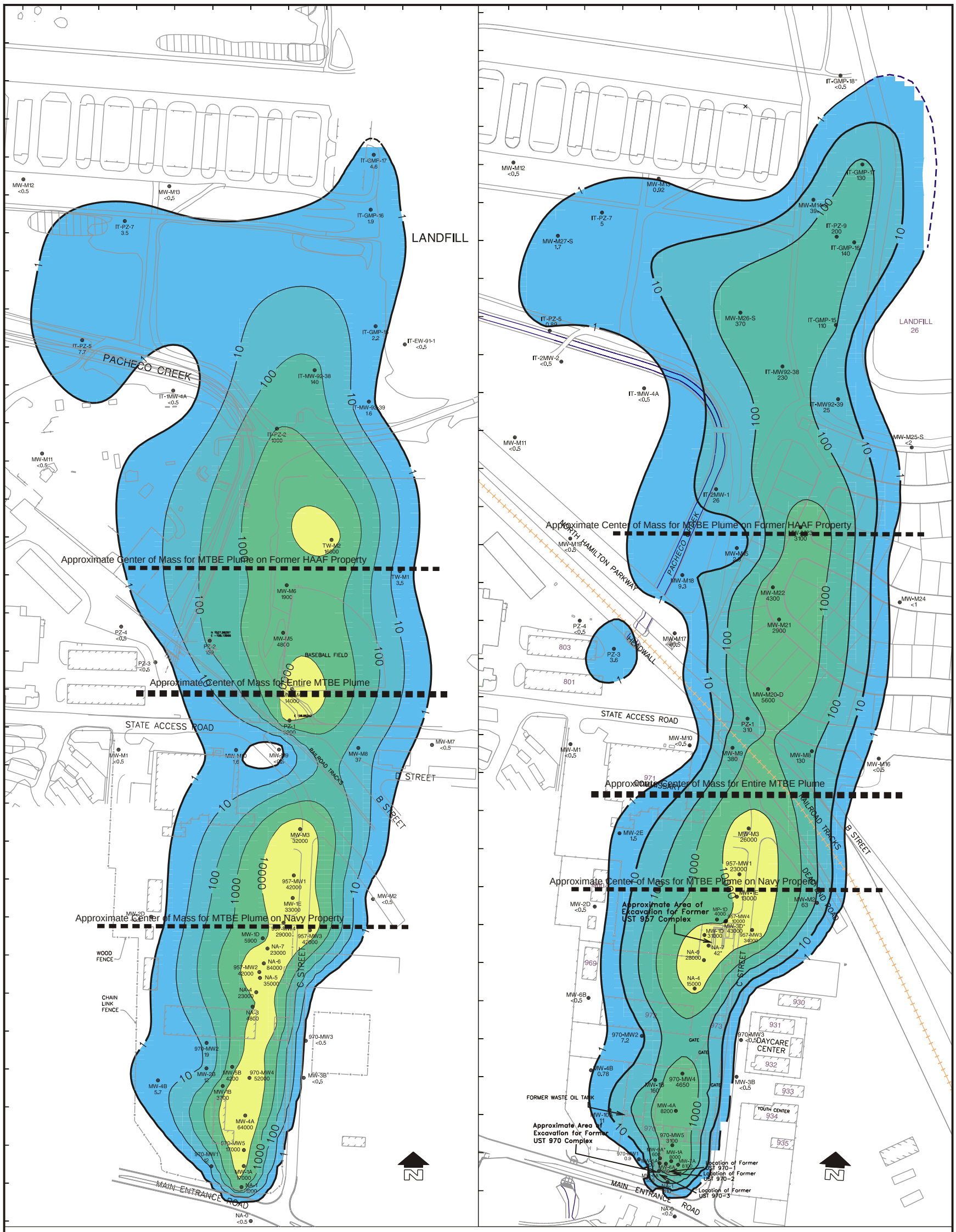


Figure 5-6. MTBE Mass Estimate in Groundwater Over Time



1st Quarter 1999

1st Quarter 2001

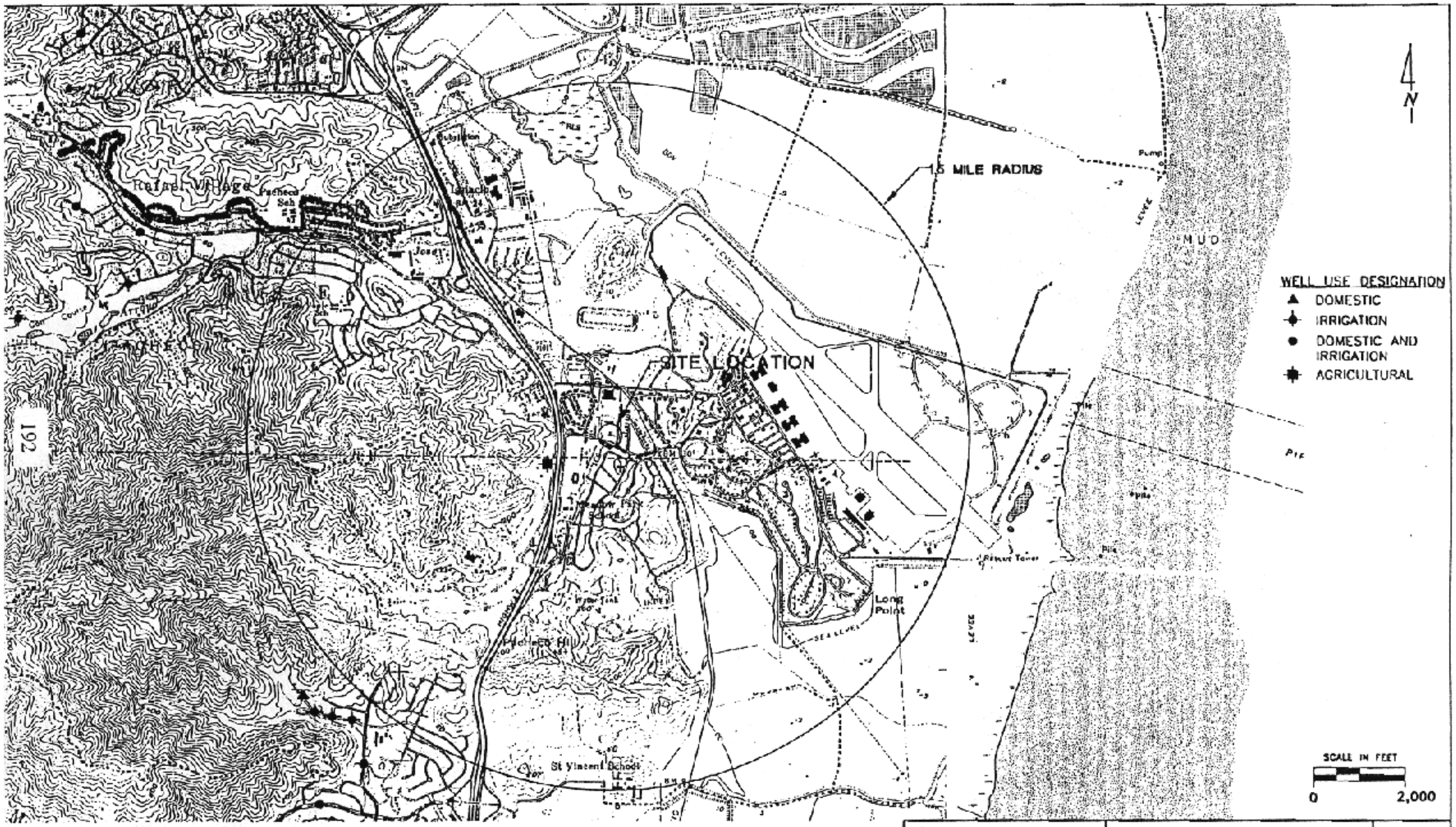
Explanation:

- > 100,000 µg/L
- 10,000 - 100,000 µg/L
- 1,000 - 10,000 µg/L
- 100 - 1,000 µg/L
- 10 - 100 µg/L
- 1 - 10 µg/L

0 200 400

SCALE IN FEET

DESIGNED BY JH	Battelle ... Putting Technology To Work	
DRAWN BY JH	MTBE Center of Mass for 1st Quarter 1999 and 1st Quarter 2001 at Former UST 957/970 DoDHF Novato	
CHECKED BY TW	DODHF NOVATO – CALIFORNIA	
	G337737-51	MTBE_CENTER_OF_MASS.CDR 4/01



PREPARED BY
RRM
engineering contracting firm

WELL SURVEY

DoDHF Novato
Novato, California

FIGURE: 2
PROJECT: IRAC106

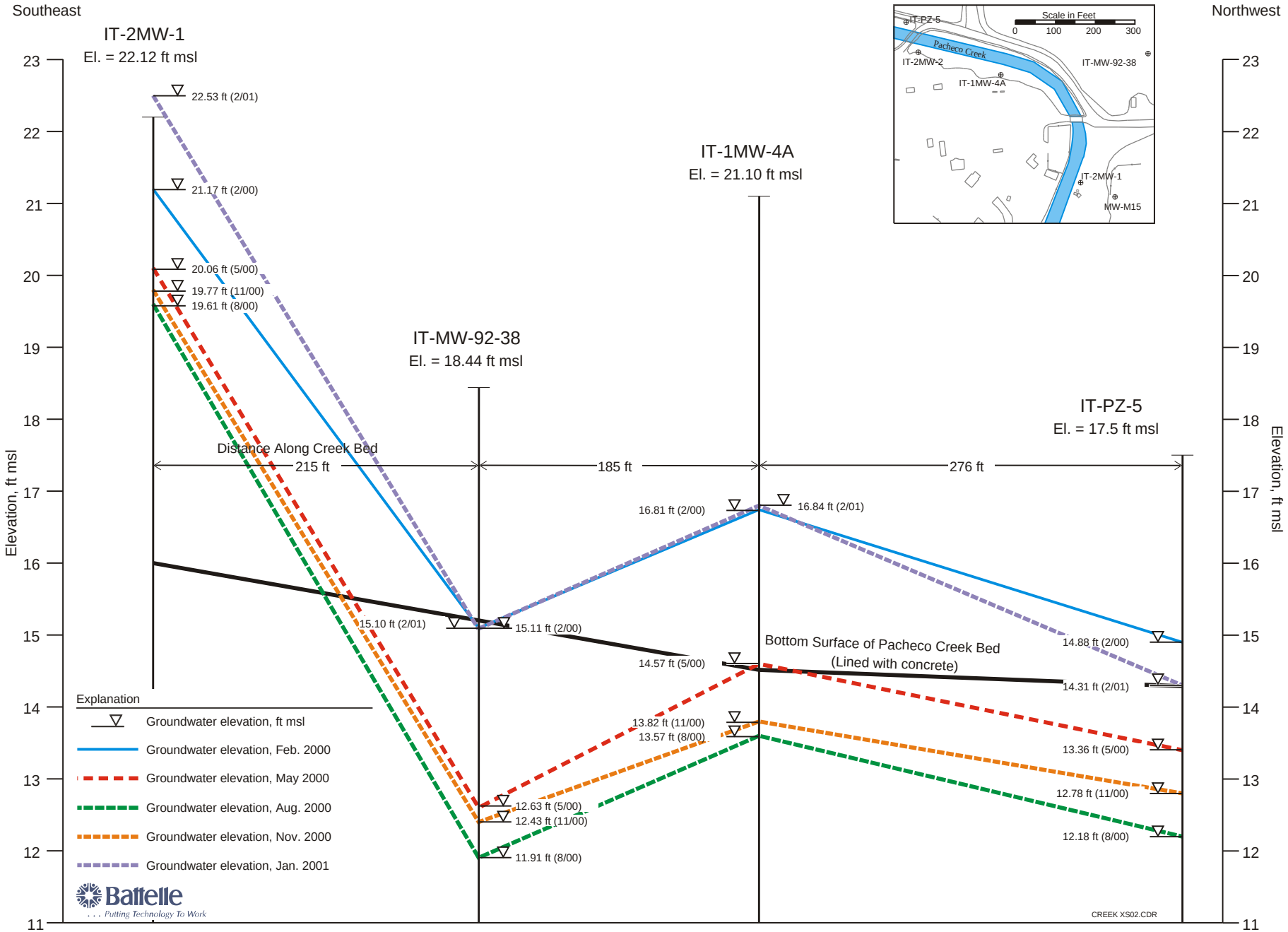


Figure 5-9. Longitudinal Cross Section and Groundwater Levels Near Pacheco Creek

Table 5-1. Dissolved MTBE and Benzene Mass Estimates

Date	Dissolved MTBE Mass (kg)	Dissolved Benzene Mass (kg)
May-98[a]	N/A	5.0
Aug-98[a]	N/A	3.9
Nov-98[a]	287	3.4
Jan-99[a]	256	2.3
May-99[a]	277	1.8
Aug-99[b]	183	0.91
Nov-99	163	0.52
Feb-00[b]	126	0.74
May-00	118	0.74
Aug-00	73	0.44
Nov-00[c]	115	0.26
Feb-01	156	0.34
May-01	120	0.18

N/A = not applicable (MTBE plume not fully delineated at this time).

(a) Estimated mass of MTBE and benzene was modified from past estimates using consistent methods and refinements to improve the data quality for each sampling event.

(b) Monitoring well network modified due to well abandonment.

(c) Monitoring well network modified due to installation of replacement wells.

Table 5-2. Historical Maximum and Average Concentrations of Contaminants

Date	MTBE (μg/L)		Benzene (μg/L)	
	Maximum	Average	Maximum	Average
Nov-96[a]	240,000	73,568	12,000	2,128
Mar-98[a]	77,000	24,004	9,400	1,436
May-98	280,000	32,058	14,000	1,791
Aug-98	140,000	21,645	10,000	1,002
Nov-98	130,000	19,288	34,000	982
Feb-99	84,000	12,360	4,300	418
May-99	140,000	16,762	6,300	368
Aug-99[b]	78,000	9,214	3,900	198
Nov-99	82,000	10,925	4,000	139
Feb-00[b]	65,000	9,425	2,200	114
May-00	61,000	8,162	1,500	94
Aug-00	43,000	5,135	2,300	83
Nov-00[c]	35,000[d]	4,700	1,600	40
Feb-01	43,000	3,779	660	31
May-01	33,000	3,268	350	15

(a) Prior to system installation. Only nine existing wells.

(b) Monitoring well network modified due to well abandonment.

(c) Monitoring well network modified due to installation of replacement wells.

(d) A duplicate sample was collected from this well and reported an MTBE concentration of 29,000 μg/L. An average concentration of 32,000 μg/L was used for the MTBE plume contour map presented in Figure 4 of the Annual Site Status Report (Battelle, 2001a).

Table 5-3. Location of MTBE Plume Center of Mass in Various Portions of the Site

Portion of Site	January/February 1999		February 2001		Difference	
	Estimated Dissolved Mass of MTBE (kg)	Approximate Northing Coordinate of MTBE Center of Mass	Estimated Dissolved Mass of MTBE (kg)	Approximate Northing Coordinate of MTBE Center of Mass	Estimated Dissolved Mass of MTBE (kg)	Approximate Northing Coordinate of MTBE Center of Mass[(a)]
Entire	256	574114	156	573843	100	(271)
Navy Property	116	573492	82.3	573599	33.7	107
Former HAAF Property	140	574478	73.5	574528	66.5	50

(a) A positive value indicates a change in the center of mass toward the north or downgradient from January/February 1999 to February 2001.

Section 6.0: IDENTIFICATION AND ANALYSIS OF REMEDIAL ALTERNATIVES

This section provides a discussion of the screening of remedial alternatives and detailed evaluation of candidate alternatives to select an alternative that will meet the RAOs identified in Section 5.3.

The following information establishes general design considerations of the corrective action that need to be considered for accomplishing the required cleanup:

- The depth to the water table is about 7 to 13 ft bgs
- The depth to the aquitard is about 15 ft bgs
- The groundwater flow velocity is in the range from 100 to 150 ft/yr, variation due to heterogeneity within the subsurface
- The maximum width of the MTBE plume on currently Navy-owned property is about 600 ft and on former HAAF property is about 900 ft
- The approximate total length of the MTBE plume is 3,000 ft
- The maximum concentration of MTBE is located on currently Navy-owned property and is about 31,000 μg/L
- The MTBE inventory in the entire plume (Navy and former HAAF) is approximately 120 kg (260 lbs) based on the May 2001 data.

Section 6.1 screens a variety of screening alternatives, Section 6.2 evaluates four remedial alternatives in detail, and Section 6.3 selects a corrective action.

6.1 Remedial Technology Screening

This section describes the process of screening a variety of technology alternatives that have the potential to meet the RAOs for the Site. The advantages and limitations of the alternatives (see Table 6-1) were considered to provide a basis for selecting alternatives for detailed evaluation.

6.1.1 Alternatives Considered. This section provides an overview of the alternatives considered in the screening process.

6.1.1.1 Closure With No Further Action. Consideration of the no further action (NFA) alternative provides a baseline for comparing other alternatives. The NFA alternative entails no activities to contain or remediate MTBE at the Site, provides no treatment for, and no legal or administrative protection of, human health or the environment beyond current conditions. Under the NFA alternative, existing actions, such as groundwater monitoring, may continue as part of other ongoing site activities.

California Regional Water Quality Control Board Orders have allowed closure with NFA at UST sites with chemical concentrations in groundwater higher than MCLs. Closure typically is possible if site-specific evaluation demonstrates that the following criteria can be met:

- Gasoline constituents are limited to a specific area with both vertical and lateral extent defined.

- Risk to human health and environment associated with leaving the gasoline constituents in place is minimal.
- Groundwater monitoring data demonstrates that the plume is not migrating (i.e., stable or shrinking). It is assumed that at least four quarters of monitoring is required to demonstrate plume status.

  "One hydrologic cycle (four quarters) of monitoring data is usually considered to be the minimum necessary to determine site conditions." (RWQCB San Diego Region, 1996).
- Costs associated with additional corrective action are not "consistent with maximum benefit to the people of the state" (SWRCB Resolution No. 92-49, 1996).
- Remediation of gasoline constituents will be achieved in a reasonable time frame depending on the expected future use of the groundwater.
- Impacted groundwater is not a potential drinking water source within the period of time required for remediation due to a municipal water supply already being provided and low yield measured during pump testing conducted at the site.

6.1.1.2 In Situ Aerobic Biodegradation by Circulating Oxygen-Bearing Solutions. Enhancing in situ aerobic biodegradation can be implemented by circulating oxygenated, treated groundwater using the following general operations (Sims et al., 1996):

- Groundwater is extracted using one or more wells and treated (if necessary to remove residual dissolved constituents)
- Supplemented with an electron acceptor (e.g., H_2O_2 or oxygen) and possibly other additives (e.g., nutrients, enzymes, or cultured microbes)
- Reinjected upgradient of the hydrocarbon-impacted groundwater.

Infiltration galleries or injection wells may be used to reinject the treated water. In an ideal configuration, a closed-loop system is established. If reinjection of the treated water is not allowed, freshwater can be supplemented with the electron acceptor and injected. In this mode, groundwater that is extracted to assist in distributing the supplemented water must be managed appropriately (U.S. EPA, 1995, EPA/510/B-95/007).

The use of H_2O_2 for oxygen enhancement is limited for in situ groundwater treatment. Because concentrations of H_2O_2 greater than 200 ppm in groundwater are inhibitory to the growth of microorganisms, lower concentrations must be maintained, thereby limiting the achievable degradation rate and the effectiveness of the treatment. Also the H_2O_2 tends to react near the injection point, limiting the ability to uniformly oxygenate the hydrocarbon-impacted groundwater.

Limitations on the distribution and mixing of H_2O_2 in situ can be mitigated somewhat by using dissolved oxygen. Air or oxygen is bubbled into the injection wells to oxygenate the circulating groundwater. The low concentration of oxygen in air limits the maximum concentration of dissolved oxygen that can be reached if air is used to oxygenate the circulating groundwater. Pure oxygen can be injected to increase the dissolved oxygen concentration (maximum solubility in water is 40 mg/L). However, cost to implement this system is increased due to the cost to purchase and supply electricity to operate an air separation unit to generate the pure oxygen.

6.1.1.3 In Situ Aerobic Biodegradation Using Oxygen Release Compounds. The oxygen release compounds (ORC®) slowly react with the groundwater to release oxygen, thereby increasing the

dissolved oxygen content in the groundwater and promoting biological degradation of the aerobically degradable organic compounds such as gasoline constituents. A concentrated application of ORC® could be used to promote biodegradation of gasoline constituents throughout the plume volume with elevated MTBE concentrations. Use of ORC® to create a treatment barrier to contain the plume is not expected to be cost-effective due to the high cost of repeated applications.

ORC® bioremediation involves bringing the ORC® into contact with groundwater, thereby allowing it to release oxygen. Contact can be achieved by one of the three following methods:

- Placing porous bags filled with ORC® slurry into conventional drilled wells
- Pumping ORC® slurry into pushed well points or drilled wells
- Injecting ORC® slurry as an infiltration grout.

Injection using closely spaced (e.g., 5-ft centers) pushed points or slurry infiltration generally are the favored methods as these ensure more uniform oxygenation compared to placing porous bags into widely spaced drilled wells. However, the pushed point or slurry infiltration methods can be more costly than the porous bag approach, particularly if existing wells are used to receive the bags.

The ORC® is a proprietary formulation of phosphate magnesium peroxide that is insoluble in water but slowly reacts to release oxygen into groundwater, where it is distributed by natural groundwater flow. An example oxygen release reaction can be illustrated as:

$$MgO_2 + H_2O = Mg(OH)_2 + \tfrac{1}{2} O_2$$

The elevated dissolved oxygen content in the groundwater promotes biodegradation of aerobically degradable compounds. The ORC® reaction produces pure oxygen, so the dissolved oxygen concentration can be five times higher than the saturation limit in a case where air is used to oxygenate the groundwater (i.e., 40 mg/L rather than 8 mg/L). The ORC® typically needs to be replenished about every six months until remediation is complete. However, the reaction rate increases with increasing salt concentration so the replenishment frequency may be higher at sites with brackish groundwater. For example, at a site with a chloride concentration of 950 mg/L, the reaction rate of the ORC® doubled, which increased the required replenishment frequency to every three months (Koenigsberg and Mahaffey, 2000).

6.1.1.4 In Situ Biosparging/Air Sparging. Biosparging/air sparging involves the introduction of clean air into the saturated zone to oxygenate the groundwater to promote biodegradation of aerobic compounds and strip out gasoline constituents that are dissolved in the saturated zone. This alternative is implemented by injecting air in the groundwater below the water table through drilled wells or pushed points. The air is forced into the aquifer at a pressure above the local hydrostatic head, travels from the injection point through the aquifer, and moves to the hydrostatic surface. The airstream removes volatile compounds by physical stripping and aerates the water to help promote biodegradation of aerobically degradable compounds. Depending on factors such as the concentration of gasoline constituents in groundwater and the air injection rate, a soil vapor extraction system may be needed to capture and treat gasoline constituents transferred to the vapor phase.

Two distinct approaches for this technology can be implemented. The objective of air injection can be to enhance aerobic biodegradation (biosparging) or to maximize stripping of dissolved organics from groundwater (air sparging). Biosparging is associated with low air injection rates and can have a secondary objective to minimize volatilization of organics to the atmosphere. Air sparging is

typically associated with greater air injection rates. After air sparging startup, volatilization can level off to a rate below the allowable discharge rate and not require vapor collection and treatment.

Removal mechanisms associated with in situ air sparging have been investigated both in the laboratory and at DoDHF Novato. Aerobic laboratory microcosms made of Novato soils and groundwater showed complete MTBE removal (Battelle, 2001d). Also, interim remedial activities (IAS/SVE) conducted within the former source area at Former UST Site 957/970 showed dramatic decreases of gasoline constituent concentrations in groundwater followed by no rebound (see Section 3.3).

6.1.1.5 Interception/Aeration Trench. An interception/aeration trench contains the MTBE plume by establishing a gravel-filled trench installed to stop movement of gasoline constituents off of currently Navy-owned property. Clean air is injected into the groundwater passing through the barrier, and volatile gasoline constituents (e.g., MTBE) are removed from the groundwater by vaporization into this air. The collection/aeration trench is designed to ensure that the MTBE plume is treated by the injected air just before crossing the boundary of the currently Navy-owned property. Design of in situ treatment barriers requires careful site characterization and hydraulic design; however, design methods have been developed and published (Gavaskar et al., 1998).

An interception/aeration trench would be established by excavating a narrow trench to intercept groundwater flow along the northern boundary of currently Navy-owned property. A horizontal slotted pipe would be placed along the base of the trench to allow injection of sparging air. Piping also would be installed so that an acidic solution (e.g., acetic or hydrochloric acid) could be circulated through the gravel packing for periodic maintenance to remove fouling that could accumulate due to growth of a biofilm or precipitation of iron. If needed, a second slotted pipe could be placed horizontally at the top of the gravel fill to allow collection of sparging air for treatment. The trench would be backfilled with a permeable fill (e.g., gravel), the surface restored to match existing contours, and the existing surface finish (e.g., grass or paving) replaced.

The trench would need to be positioned to minimize the need to relocate utilities at the Site. Based on available utility drawings, a sanitary sewer near the required location of the interception/aeration trench may cause some logistical problems during excavation. Also, the inability to excavate in the railroad easement is a limitation for the trench placement.

6.1.1.6 Collection Trench and Wells With Groundwater Pump and Treat and SVE. Groundwater pumping and aboveground treatment is a remediation technology that relies on the ability to control groundwater movement using withdrawal to create capture zones around wells, and the ability to effectively treat and manage the extracted groundwater. Groundwater extraction is implemented by placing a trench (French drain) and/or vertical wells so that submersible pumps can collect and lift groundwater to the surface (Powers, 1992; Keely, 1996). The French drain and wells must be placed and the groundwater extraction rate selected such that the plume is effectively captured. A French drain typically is more expensive to install compared to vertical wells. However, the French drain allows flow across the full face of the geology and, therefore, groundwater extraction efficiency is less sensitive to permeability variation. Extracted groundwater containing dissolved MTBE typically is treated using air stripping or granular activated carbon adsorption prior to discharge.

The annual operation and maintenance cost for a pump and treat system is expected to be high. The system requires ongoing operation and maintenance of wells, pumps, and water treatment equipment. The pumping and treatment systems are expected to be prone to fouling and plugging problems due to the high iron content of the groundwater, which increases operating cost and difficulty.

Treatment of MTBE in water is difficult due to its properties. Air stripping of MTBE is inefficient due to the compound's high solubility and low Henry's law constant. Granular activated carbon has a limited adsorption capacity for MTBE, so large amounts of carbon are needed to remove small quantities of dissolved MTBE.

6.1.1.7 Monitored Natural Attenuation. MNA uses carefully tracked and evaluated natural processes to contain the plume. In an effort to facilitate site closure and reduce costs associated with active remediation at UST sites, the California RWQCBs have published guidance for establishing low risk soil and groundwater sites (e.g., RWQCB San Francisco Bay Area Region, 1996). If low-risk groundwater criteria are met, the guidance promotes remediation using MNA. Natural attenuation comprises naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of gasoline constituents in those media. This in situ process includes biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of gasoline constituents. Naturally occurring biological stabilization or destruction of gasoline constituents (intrinsic bioremediation) can be a dominant process in the fate and transport of gasoline constituents. Natural attenuation (intrinsic remediation) takes place when naturally occurring microorganisms consume or otherwise degrade gasoline constituents either aerobically or anaerobically. Natural attenuation ultimately transforms the gasoline constituents into harmless by-products such as carbon dioxide and water.

6.1.1.8 Organic Soil Modification. Organic soil modification contains MTBE by creating an in situ volume with a high affinity for adsorbing organic gasoline constituents. The adsorption zone significantly slows the movement of MTBE relative to the groundwater allowing accumulation of MTBE for efficient oxidation. The technology involves three main steps as follows:

- Injection of organic cations into the soil to form a sorption barrier of organically modified soil across the leading edge of the plume.
- Passive sorption of gasoline constituents (e.g., MTBE) onto the organically modified soil as the aquifer water flows through the barrier.
- Injection of Fenton's reagent to destroy gasoline constituents that have accumulated in the treatment zone. The destruction stage occurs after the MTBE plume volume upgradient of the northern boundary of currently Navy-owned property has passed through the treatment zone, or when the treated soil becomes fully loaded with gasoline constituents. If the soil becomes fully loaded before remediation is complete, the injection, passive sorption, and destruction stages would be repeated.

The organic cations consist of molecules with charged ends that have an affinity for ion exchange sites on the soil and organic ends that have an affinity for organic compounds. The ionic end becomes attached to soil surfaces and provides high capacity for immobilization of dissolved organics.

The concentration of MTBE in the sorption barrier will be much higher than in the groundwater due to the sorption capacity formed on the soil surface by the organic cation. Thus, injecting oxidant into an MTBE-loaded sorption barrier allows more efficient and economical treatment compared to application of the oxidant over a large volume of an MTBE-impacted aquifer. Fenton-like treatments can be completed within hours to days compared to months to years for processes that involve treating dilute concentrations throughout the plume.

The ability to remove MTBE from water using soil modification has been demonstrated in laboratory-scale tests. In a study conducted by Battelle from March 2000 to January 2001, three organic cations were evaluated for treatment of soil from the Former UST Site 957/970 (Battelle, 2001d). The

charged end of all three types were based on quaternary ammonium cations. The organic moieties consisted of: a straight-chain 16-carbon tail hexadecyltrimethyl ammonium (HDTMA); a highly branched tail containing multiple tallow groups (Accosoft 501™); and an alkyl betaine (lauryldimethylbetaine). Results showed that soils treated with HDTMA and Accosoft 501™ were able to absorb a large fraction of MTBE from solution. For example, up to 80% of the MTBE in a 20-mL solution at concentrations up to 100 mg/L, was removed by only 4 to 5 g of soil. The alkyl betaine adhered weakly to the soil and exhibited low affinity for MTBE.

6.1.1.9 Phytoremediation. Phytoremediation controls and contains a plume by using plants to increase the transpiration rate and immobilize and/or degrade gasoline constituents. Phytoremediation involves placing plants that extract water and lower the local groundwater elevation providing hydraulic containment of the groundwater plume. The plants remove water only during the growing season so a wide band of plants is needed to ensure hydraulic containment during the winter when the plants transpire water at a lower rate. The density and width of the planting area is designed to ensure that the water table is drawn down sufficiently during the growing season to prevent hydrocarbon-impacted groundwater from escaping the planting zone during winter.

Hydraulic control due to water extraction by the plants is the main control and containment mechanism, but chemical degradation (e.g., phytotransformation and rhizosphere bioremedation) or immobilization (e.g., phytoaccumulation and phytostabilization) also may help to remediate the MTBE (Schnoor, 1997; NFESC, 1998; U.S. EPA, 2000a). Phytoremediation has been successfully used to control migration of hydrocarbon-impacted groundwater (Hong et al., 2000). Implementing the technology requires identifying plants hardy to the area that have a high transpiration rate. Hybrid poplar trees commonly are used for remediation of groundwater, but other species such as eucalyptus also have been studied.

The plantings would improve the appearance of the Site, but would occupy a large area (e.g., a treatment zone about 300 to 1,000 ft in length, parallel to the centerline of the plume over the entire width requiring treatment). A densely planted area would probably be needed due to the rapid rate of groundwater flow at the Site. Land use for the area covered by the planting would be restricted to activities that would not disturb the plantings.

6.1.1.10 Excavation and Dewatering. Excavation and dewatering contains the MTBE plume by excavating a large area of soil at the site, followed by dewateing of the excavated area, and finally backfilling of the excavated area. Structural sheet piling is placed around the perimeter of the excavation to stabilize the opening. Soil is then excavated from the unsaturated and saturated zones down to the fractured bedrock. The excavated soil is trucked to an off-site facility for disposal. The local groundwater level is lowered by pumping to allow excavation to proceed below the water table. Excavation and dewatering is a routine conventional method for site remediation and is expected to rapidly provide effective reduction of the concentrations of gasoline constituents in groundwater. However, the cost would be very high.

6.1.2 Selection of Alternatives for Detailed Evaluation. The basis for selecting alternatives for the detailed evaluation is summarized in Table 6-2. The alternatives selected for detailed evaluation are as follows:

- **Alternative 1** – Excavation to remove soil and dewatering to remove groundwater containing elevated concentrations of gasoline constituents on currently Navy-owned property. Recovered groundwater would be treated and disposed of at an off-site facility. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.

- **Alternative 2** – Interception/aeration trench at the northern boundary of the currently Navy-owned property to treat groundwater by air sparging as it moves through the trench. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.
- **Alternative 3** – Collection trench and wells with groundwater pump and treat to extract groundwater for treatment supplemented with SVE. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.
- **Alternative 4** – Biosparging to remediate groundwater migrating across the northern boundary of currently Navy-owned property and elevated concentrations of MTBE on currently Navy-owned property. A SVE system would serve as a contingency measure for off-gas control during biosparging system operation. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls.

6.2 Detailed Evaluation of Alternatives

The remedial alternatives were evaluated with respect to the following criteria as required by Task 6 of Order No. 00-064:

- Implementability
- Effectiveness
- Benefits
- Impact on Public Health and Welfare and the Environment
- Cost

The feasibility study contained herein complies with guidance provided by, "Subpart F of the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), CERCLA guidance documents with respect to remedial investigation and feasibility studies, Health and Safety Code Section 25356.1(c), State Board Resolution No. 92-49 as amended, and all other applicable State Board Policies" as required by Order No. 00-064, Task 6.

6.2.1 Common Elements. The following common elements will be used in conjunction with the selected remedial alternative:

- MNA to remediate remaining concentrations of gasoline constituents in groundwater
- Monitoring to track groundwater conditions at the Site
- Institutional controls to ensure land use consistent with risk assessment scenarios and to protect operation of the remedial alternative.

6.2.1.1 Monitored Natural Attenuation. Active remediation of the entire volume of hydrocarbon-impacted groundwater under the Site is not required by the risk levels at the Site (see Section 2.4) and would involve an excessive resource commitment. An active remedial alternative (one of the four alternatives described in Sections 6.2.2.1 through 6.2.2.4) will be selected to meet the RAOs identified in Section 5.3. However, gasoline constituent levels will remain above MCL concentrations outside of the active treatment area and will require further consideration. MNA has been selected as a supplement to the active remedial alternative for remediation of remaining concentrations of gasoline constituents to achieve final cleanup levels throughout the gasoline constituent plume (see Section 5.3).

MNA is an in situ remediation technology where naturally occurring physical, chemical, and biological processes attenuate gasoline constituent concentrations in soil and groundwater sufficiently to protect human health and the environment and achieve remedial goals within a time frame that is reasonable in comparison with active remediation. Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials are allowed to reduce gasoline constituent concentrations to acceptable levels.

The effectiveness of natural attenuation depends on site conditions such as alkalinity (pH), temperature, microbial activity, and oxidation-reduction coupling. The natural attenuation of dissolved-phase fuel hydrocarbons in groundwater is well known and understood (Wiedemeier et al., 1995; U.S. EPA, 1998b). A study conducted by the U.S. EPA (2000c) found that natural attenuation of MTBE occurred under methanogenic conditions at some sites with groundwater affected by gasoline constitituents. During the same study, accumulation of TBA, a known transformation product of MTBE, was not detected (U.S. EPA, 2000c).

Implementation of natural attenuation as a remediation technology at the Site entails a comprehensive groundwater monitoring program to provide data to evaluate biodegradation, and to monitor the extent of the plume as a function of time. The monitoring required for MNA can be implemented using standard commercial materials and methods. However, if plume status cannot be determined using standard monitoring and interpretation techniques, specialized modeling and data evaluation techniques are needed to track the progress of the remediation. The required techniques have been described in published protocols (Wiedemeier et al., 1995; U.S. EPA, 1998b; U.S. EPA, 1999).

Progress of MNA will be tracked by analyzing the behavior and size of the MTBE plume over time and calculating the total mass of MTBE on and off the currently Navy-owned property. Typical aspects of the MNA evaluation program that are used for cost-estimating purposes are outlined in Table 6-3. The cost for MNA is included in the total cost for each alternative. Sampling and analysis will be designed to evaluate the effectiveness of MNA over the entire site, including former HAAF property north of the currently Navy-owned portion. Because the selection process relies on identifying differences among the active remedial alternatives, the common element of using MNA to achieve final cleanup goals on former HAAF property does not affect the remedy selection. Therefore, the time associated with MNA on former HAAF property is not presented in comparison discussions or tables. Sampling will be conducted in the monitoring wells using the same methods established in the GMP for monitoring wells already located at the Site (Battelle, 2000a). The Site GMP (Battelle, 2000a), required under Task 5 of Order No. 00-064, will be modified to include specific MNA sampling procedures and schedules before the MNA phase of the corrective action begins.

6.2.1.2 Monitoring. Routine groundwater sampling will be conducted while the active phase of the remedial alternative is being performed on currently Navy-owned property to track the progress of remediation and support appropriate management of residuals produced during the alternative. Different types of monitoring are needed due to the different approaches used for active remediation in each candidate alternative. The monitoring needed to support performance of active remediation for each candidate alternative is summarized in Table 6-4. The costs for this monitoring effort is included in the total cost for each alternative. Monitoring to track the performance of MNA after the active phase of the alternative is completed is described in Section 6.2.1.1.

6.2.1.3 Institutional Controls. Institutional controls will be a component of the selected corrective action. The objectives of the ICs are twofold: to ensure that commercial use of the land at the gas station site (immediate area surrounding Building 970, shown in Figure 1-3) is maintained and that residential use is prohibited in that area; and to ensure that future actions over the entire site do not affect the gasoline constituent groundwater plumes.

The Department of the Navy (DON) developed its assumptions about future land use based on the Reuse Plan of the Local Reuse Authority (Hamilton Local Reuse Authority, 1996), which calls for commercial use in the area immediately surrounding the Building 970 gas station area, and mixed use in the adjacent areas (Figure 1-3). The corrective action selected in this CAP allows the former NEX gas station site and surrounding parcels to be available for the proposed future land use as discussed in Section 7.0.

The primary legal mechanism used to implement land use controls will be restrictions included in the quitclaim deeds for the subject property.

The following restrictions and controls will apply to the entire Site[1]:

- Construction and/or operations on the property shall not interfere with the ongoing monitoring or assessment of work being conducted by or for federal, state, or local regulatory agencies.

- Removal and disposal of contaminated soil or groundwater by the transferee, its successor or assigns, shall be conducted in accordance with all applicable federal, state, and local regulations governing removal, transport, and disposal of hazardous substances and hazardous waste.

- Disturbance of existing groundwater wells is prohibited unless specifically approved by the Navy and the RWQCB. No groundwater production wells may be installed for residential, municipal, agricultural, or industrial use, without written approval of the RWQCB. Monitoring and other test wells are not subject to this provision, including borings for the purpose of testing wells, wells for monitoring the quality of groundwater, and borings to define geology.

In addition to the above restrictions and controls, the following will be applied to the Sale Area[2]:

- Construction and occupation of residential structures or day-care centers is prohibited.

The United States will retain the right to enter and inspect the property to ensure the viability of the selected institutional controls or to perform any additional response actions. In the deeds affecting transfer of the property, the State of California also will be given such right to enter and inspect the property.

---

[1] The Site comprises and area of approximately 13 acres, bounded on the south by Main Entrance Road, and on the north by a set of Golden Gate Company railroad tracks (refer to Figure 1-2). The eastern border of the site runs north-south from the intersection of Main Entrance Road and C Street, and the western border of the site runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street.

[2] The Sale Area comprises an area of approximately 2 acres, bounded on the south by Main Entrance Road, and on the north by Public Benefit Conveyance Parcel 1 (refer to Figure 1-3). The eastern border of the Sale Area runs north-south from the intersection of Main Entrance Road and C Street, and the western border runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Steet.

6.2.1.4 Land Use Covenant. On March 16, 2000, the DON and the DTSC executed a memorandum of agreement (MOA) (U.S. DON and DTSC, 2000). The purposes of the MOA were to formalize the use of model environmental restrictive covenants and agreements; and to describe under what specific conditions the environmental restriction covenants and agreements would be used to give DTSC the same authority as the DON to enforce environmental restrictions imposed on transferring parcels of property.

The DON is willing to enter into an agreement with the State of California, through the DTSC and RWQCB, allowing the State pursuant to the California Civil Code Section 1471 to enforce the restrictions on the use of property for the purpose of protecting human health, safety, and the environment. Such a covenant would be based on the models attached to the March 2000 MOA. This covenant would list environmental restrictions and would serve as the primary legal mechanism to enforce restrictions. Once the covenant is finalized, it will be executed contemporaneously with the negotiation and execution of the conveyance or assignment of the property.

In addition, the DON shall include the same environmental restrictions in the deed between the United States and the transferees pursuant to the California Civil Code Section 1471. These restrictions shall be consistent with restrictions set forth in this CAP and any covenant entered into between the DON and DTSC for the Site.

Because costs to monitor and enforce land use restrictions would be consistent between each remedial alternative and difficult to estimate to any degree of certainty, the costs for institutional controls are not included in the overall remedial alternative estimates.

6.2.2 Characteristics of Candidate Alternatives. This section provides information about each candidate alternative to support evaluation of the alternatives and selection of corrective action.

6.2.2.1 Alternative 1 – Excavation and Dewatering. Alternative 1 involves excavation of soil and extraction of groundwater to remove gasoline constituents from Site groundwater on currently Navy-owned property for management at off-site facilities. Figure 6-1 shows a conceptual diagram of the extent of excavation activities.

6.2.2.1.1 Description. Soil would be excavated to the weathered bedrock (approximately 15 ft bgs) aquitard using conventional earthmoving equipment such as backhoes. The excavation area would be about 300 to 350 feet wide from the edge of the railroad easement in the north to Building 970 in the south. The expected excavation volume is about 136,200 yd^3. The area of soil removal was calculated by determining the maximum concentration of MTBE that could remain in the upgradient portion of the currently Navy-owned property and still allow attenuation by MNA to reduce concentrations to MCLs before the MTBE in groundwater migrated to the property boundary.

Sheet piling would be used as shoring to support the perimeter of the area being excavated. Buildings 970, 972, and 973 would be demolished to allow access for the excavation. During the excavation, clean soils (top 10 feet of soil) would be segregated from the remaining impacted soils (bottom 5 feet of soil). The impacted soils (approximately 33% of the excavated soils) would be trucked off site for disposal as a RCRA hazardous waste in a permitted treatment, storage, and disposal facility (TSDF). The remaining clean soil would be reused to backfill the excavation along with clean backfill coming from an off site source. The soil would be placed and compacted so as to minimize settling. The surface finish would be returned to its original condition (e.g., hydroseeding and mulching for grassy areas and paving for paved areas). Groundwater in the excavation area that leaks in past the piling would be extracted to dewater the Site and allow excavation below the water table. Based on the required volume of the excavation, the estimated volume of groundwater that would be extracted and trucked off site for management at an off-site facility is approximately 2,500,00 gallons.

6.2.2.1.2 Implementability. Excavation and dewatering would be very difficult to implement. Although this alternative can be done using standard commercial materials and methods, site conditions such as extensive paving and buried utilities make field application very difficult. An extensive effort would be needed to find and relocate buried utilities in the area. Site operations would be greatly restricted during excavation.

6.2.2.1.3 Effectiveness. Using Alternative 1 provides for immediate cleanup of Site groundwater. Stabilization and containment of the MTBE groundwater plume at the boundary of the currently Navy-owned property is achieved in about 0.50 years. Remediation of gasoline constituents on currently Navy-owned property is achieved in about 0.50 years.

Use of excavation and dewatering is one of the oldest forms of site remediation. This method ensures that the gasoline constituents are removed from site groundwater resulting in a rapid reduction of the inventory at the Site. Soil excavation and site restoration, both of which are expected to require about 25 weeks to carry out (not including work plan development, reporting, or agency reviews) will be run simultaneously at different areas of the site. Dewatering operations would be conducted throughout the 25-week excavation period.

6.2.2.1.4 Benefits. Based on Task 6a of Order 00-064, this alternative addresses the outlined requirements as follows:

- Using this alternative reduces and remediates the concentrations of MTBE in Site groundwater by removing the groundwater for treatment at a permitted off-site facility.
- Using this alternative reduces and remediates the concentrations of benzene in site groundwater which exceed applicable RBSLs by removing the groundwater for treatment at a permitted off-site facility.

6.2.2.1.5 Impact on Public Health and Welfare and the Environment. Hauling excavated soil off site for disposal would involve movement of trucks on public roads around the Site. The hauling activity creates the potential for risk to off-site populations from vehicle accidents, noise, and dust. The operation is expected to require about 8 truckloads per day for a period of 25 weeks. Transportation risks would be minimized by development of a transportation plan and application of dust and noise control procedures.

The heavy construction activities required to excavate and backfill the large area of soil entail risk to workers from hazards such as operation of excavators and trucks. Workers would require protection from the sidewalls collapsing by installation of shoring systems around the perimeter of the excavation. The risks posed to workers are within the norm for standard construction activities and would be reduced to the maximum possible extent by development of a health and safety plan and application of protective measures.

6.2.2.1.6 Cost. The costs for Alternative 1, including MNA, monitoring, and institutional controls are estimated to be approximately $15,735,000 and are summarized in Table 6-5. A more detailed list of costs included for Alternative 1 is provided in Appendix P. Assumptions that were made in calculating the cost of Alternative 1 are as follows:

- Excavation to a depth up to about 15 ft, 300 to 350 ft wide from the edge of the railroad easement in the north to Building 970 in the south (see Figure 6-1) giving a total volume of 136,200 yd^3

- Twenty-five percent of the excavated soils would be trucked off site for disposal as a RCRA hazardous waste in a permitted TSDF and the remaining 75% of excavated soils would be reused in the excavation as backfill
- The excavation would be backfilled with clean soil and the surface finish returned to original conditions
- Sheet pile shoring would be used to stabilize the excavation perimeter and removed after backfilling is completed
- Extracted groundwater would be managed at an off-site facility
- Buildings 970, 972, and 973 would be demolished to allow access for excavation
- Assumed monitoring schedule for active remediation: one soil sample per day of the excavated material will be collected and analyzed before off-site disposal for duration of removal action (~177days)
- Assumed monitoring schedule for MNA: quarterly groundwater monitoring of approximately 66 wells for 2 years followed by semi-annual groundwater monitoring of approximately 25 wells for 3 years and annual groundwater monitoring of approximately 25 wells for the remaining ten years. An additional 20% of groundwater samples were added to account for QA/QC.

6.2.2.2 Alternative 2 – Interception/Aeration Trench. Alternative 2 involves interception of the plume at the Navy property boundary with a gravel-filled trench where the MTBE can be removed by air sparging. Figure 6-2 shows a conceptual diagram of the interception/aeration trench layout.

6.2.2.2.1 Description. Implementing Alternative 2 would require constructing a trench that acts as a below ground treatment barrier. Air sparging in the barrier would remove dissolved volatile gasoline constituents as the groundwater passes through the barrier. A trench with dimensions large enough to intercept the majority of groundwater impacted by MTBE (approximately 250 ft in length, 4 ft wide, and 20 ft deep) would be excavated perpendicular to the direction of groundwater flow (i.e., in the area where the CPT investigation was performed as described in the Remedial Investigation report [Battelle, 2001b]). The estimated volume of soil that will require removal for the trench would be approximately 750 cubic yards.

The proposed trench would start northeast of Building 971 and run east-southeast for about 250 ft along the railroad easement (see Figure 6-2). Sheet piling would be extended from each end of the trench to funnel groundwater flow toward the treatment area. The trench would be keyed into the weathered bedrock aquitard by excavating a cut about 3 to 5 feet deep into the weathered bedrock for a total excavation depth of about 18 to 20 ft. The total volume of soil needed to be excavated to complete the trench would be approximately 750 yd^3. If the bedrock is too massive to be removed to the required keying depth by a conventional excavator, the key would be cut as deeply as possible and the bottom of the cut would be sealed with a cement/bentonite grout to ensure a low permeability base for the interception/aeration trench prior to placing the piping and gravel backfill. Required piping such as air sparging lines and acid flushing lines (see Section 6.2.2.2.6) would be installed and the trench backfilled with gravel to provide at least 3 ft of gravel fill above the highest seasonal level of groundwater elevation. The remaining depth would be backfilled with native soil. All piping would be located below grade so that the only surface structure would be a small shed to house the air supply compressor. The surface finish would be returned to its original condition (e.g., hydroseeding and mulching for grassy areas and paving for paved areas).

The assumed design specifications of the aeration trench include the installation of four monitoring wells directly within the trench. To monitor the effectiveness of MTBE removal by groundwater aeration in the trench, these newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown.

6.2.2.2.2 Implementability. The interception/aeration trench can be designed and constructed using standard commercial materials and methods. The excavation depth of ~20 ft is well within the capabilities of standard backhoe-type excavators. Forming a competent key where the trench meets the weathered bedrock is expected to require some specialized techniques, but the required methods are well within standard construction practice.

Construction of the trench would require removal and replacement of the paving and would disturb operations in the area until repaving is complete. The trench would cross C Street, so this street would need to be closed and traffic diverted for about 5 to 8 weeks during trench construction. After the trench is complete, Alternative 2 would present minimal limitation to Site operations. The trench and associated piping would be below grade with only a small structure to house the air injection compressor on the Site surface.

Optimum in situ treatment wall design calls for a straight trench placed perpendicular to the groundwater flow. Restrictions on digging in the railroad easement area would limit the eastern extent of the trench if it were placed perpendicular to groundwater flow. Therefore, the conceptual design of the trench has it oriented parallel to the railroad easement at the northern boundary of currently Navy-owned property and spanning across the length of the groundwater plume containing dissolved MTBE at 100 µg/L (see Figure 6-2). Vertical barriers formed using sheet piling would be placed at each end of the trench to funnel groundwater flow into the treatment zone. This configuration will complicate design, but should be feasible (Gavaskar et al., 1998).

The only site utility that is expected to interfere with trench construction is a sanitary sewer located nearby. Efforts would be needed to locate all utilities in the area to be excavated, and precautions would be used to prevent loss of utility services. Possible precautions include removing and relocating the utilities or using impermeable vertical barriers to divert groundwater flow away from the utilities.

Air injected into the permeable fill would displace water in some of the void space, thereby reducing the water saturation of the porosity and decreasing hydraulic conductivity. It is expected that using a very permeable, coarse fill material can mitigate this effect, and a greater hydraulic conductivity than that of the natural formation should be maintained.

Avoiding the potential for fouling and plugging is an important design consideration for Alternative 2. Aeration can cause growth of a biofilm or oxidation and precipitation of iron, which would fill some of the pores in the permeable fill material and downgradient face of the excavation. As a contingency for fouling, an acid washing delivery system would be installed in the trench. Slotted PVC piping would be installed to allow collection of liquid at the bottom of the gravel fill and redistribution at the top so that a pump can be used to flush or circulate an acid solution through the fill. Acid flushing would be a maintenance function that would be performed as needed to remove fouling. The flushing solution would be circulated in the trench for a short period and then recovered for off-site treatment and disposal.

6.2.2.2.3 Effectiveness. In Alternative 2 groundwater would be remediated as it passes through the barrier. Stabilization and containment of the MTBE groundwater plume at the boundary of

the currently Navy-owned property would be achieved once treated water exiting the barrier reaches the boundary which is expected to require about 1.5 years. Remediation of gasoline constituents on currently Navy-owned property is achieved as the groundwater migrates thorough the barrier which is expected to require about 10 years.

Use of a constructed, gravel-filled barrier technology ensures a uniform, permeable media for injection of the sparging air. This approach allows in situ remediation of MTBE in groundwater moving through the trench without requiring groundwater extraction and ex situ treatment. Air distribution is expected to be more efficient in this barrier material than in natural sediments, thereby improving MTBE removal. Reports of two field applications of this alternative were found in the literature, one for removal of BTEX compounds (Tang et al., 1999) and one for removal of MTBE (Thomson et al., 1999). In both cases, the reported removal of gasoline constituents from groundwater flowing through the barrier was 99% or greater.

Migration of dissolved MTBE off of currently Navy-owned property would be prevented by remediating groundwater as it flows through the trench. The rate of cleanup is limited by the flux of MTBE downgradient through the trench, so air sparging in the trench must continue until the entire extent of the MTBE plume on currently Navy-owned property moves through the barrier. This alternative is expected to require approximately 10 years to remediate the Site (based on the length of the plume being approximately 1,000 ft long and the groundwater velocity being approximately 100 ft/yr). However, based on the historical groundwater monitoring data collected at the Site and MTBE plume maps referenced in Section 5.2.3.2 (see Figure 5-5), the MTBE hot spot currently located on currently Navy-owned property does not appear to be migrating at the estimated rate of groundwater flow (100 ft/yr). Figure 5-5 shows the 10,000-µg/L MTBE contour extending across State Access Road, onto Former HAAF property, only once during the last five quarterly groundwater monitoring events. Therefore, if the MTBE hot spot continues this unpredictable trend and does not migrate with groundwater flow to the north, the required treatment duration of Alternative 2 may rely on MNA rates rather than the removal achieved by the trench to achieve RAOs at the Site. Furthermore, even if the groundwater pump and treat system located within Landfill 26 (north of currently Navy-owned property) is turned on, preliminary modeling calculations indicate that there would be little to no effect (i.e., possibly an increase of 5%) to the hydraulic gradient in the area of the interception/aeration trench.

Due to the limited inventory of MTBE and the time required for remediation, the mass removal rate of chemicals in the sparging air would be low. The estimated quantity of MTBE in the volume of groundwater on currently Navy-owned property with dissolved MTBE is 54 kg (120 lbs). Based on the estimated treatment duration of 3,650 days (1,000 ft divided by 100 ft/yr) the MTBE discharge rate would be 0.015 kg/day (0.033 lbs/day). Due to this low release rate, it is expected that no vapor extraction or treatment would be needed in the trench to collect and control release of the sparging air. However, if needed, carbon canisters will be used to treat vapors before thay are directly discharged.

6.2.2.2.4 Benefits. Based on Task 6a of Order 00-064, this alternative addresses the outlined requirements as follows:

- Using this alternative stabilizes and contains the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site by providing an interception/aeration trench at the northern boundary of the Site to remediate groundwater leaving the Site.
- Using this alternative reduces and remediates the concentration of MTBE in Site groundwater over a period of several years as the groundwater travels through the trench.

- This alternative will be accompanied by continued remediation of benzene by MNA. The aeration trench will have no effect on benzene because the benzene plume is stable and does not extend to the proposed trench location.

6.2.2.2.5 Impact on Public Health and Welfare and the Environment. Hauling excavated soil off site for disposal would involve movement of trucks on public roads around the Site. The hauling activity creates the potential for risk to off-site populations from vehicle accidents, noise, and dust. Transportation risks would be minimized by development of a transportation plan and application of dust and noise control procedures.

The heavy construction activities required to excavate and backfill the interception/aeration trench entail risk to workers from hazards such as operation of excavators and trucks. Workers would require protection from the trench collapsing by installation of shoring systems along the trench sidewalls during excavation, pipe installation, and gravel placement. The risks posed to workers are within the norm for standard construction activities and would be reduced to the maximum possible extent by development of a health and safety plan and application of protective measures.

6.2.2.2.6 Cost. The costs for Alternative 2, with MNA, monitoring, and institutional controls, are estimated to be approximately $3,129,550, and are summarized in Table 6-6. A more detailed list of costs included for Alternative 2 is provided in Appendix P. Assumptions that were made in calculating the cost of Alternative 2 are as follows:

- Dimensions of the trench are 250 ft in length, 4 ft wide, and ~20 ft deep
- The expected time required to treat the MTBE plume is 10 years based on the length of the plume on Navy property of 1,000 ft and a groundwater flow velocity of 100 ft/yr
- Installation of 4 groundwater monitoring wells at 15 ft bgs
- No off-gas or vapor treatment required
- Assumed monitoring schedule for active remediation: 1) one soil sample per day of the excavated trench material will be collected and analyzed before off-site disposal during the installation of the trench (~6 weeks), 2) quarterly groundwater monitoring of approximately 10 wells during system operation (~10 years) to track the treatment system efficiency and one additional year to determine whether rebound occurs. An additional 20% of groundwater samples were added to account for QA/QC
- Assumed monitoring schedule for MNA: quarterly groundwater monitoring of approximately 66 wells for 2 years followed by semi-annual groundwater monitoring of approximately 25 wells for 3 years and annual groundwater monitoring of approximately 25 wells for the remaining ten years. An additional 20% of groundwater samples were added to account for QA/QC.

6.2.2.3 Alternative 3 – Collection Trench and Wells with Groundwater Pump and Treat and SVE. Alternative 3 involves aggressive groundwater pumping combined with SVE to remove gasoline constituents from site groundwater. Figure 6-3 shows a conceptual diagram of the layout for the collection trench and wells with groundwater pump and treat with SVE.

6.2.2.3.1 Description. Alternative 3 consists of the following elements:

(1) Groundwater extraction points within a French drain located along the northern boundary of currently Navy-owned property to prevent further migration

(2) Groundwater recovery wells spread throughout the plume on currently Navy-owned property to dewater the Site

(3) SVE of the dewatered saturated zone.

Submergible pumps in the French drain and wells would be used to extract groundwater. The extraction rate is sufficient to lower the local water-table elevation to stop migration of groundwater containing MTBE off of currently Navy-owned property and allow SVE treatment of soil that normally is saturated with groundwater.

The proposed French drain would start northeast of Building 971 and run east-southeast for about 250 ft along the railroad easement (see Figure 6-3). The trench for the drain would be excavated to the weathered bedrock aquitard for a total excavation depth of about 15 to 17 ft and a width of 4 ft. (Note that pumping out of the French drain provides a driving force to capture water, unlike the aeration trench described in Alternative 2 which passively intercepts natural groundwater flow. Therefore, the French drain does not need to be keyed into the aquitard.) The total volume of soil needed to be excavated to complete the trench would be approximately 750 cubic yards. A horizontal drain pipe located at the bottom of the trench would lead water to sumps located periodically along the length of the drain pipe. Pumps located in the sumps would lift the water to the surface. The trench would be backfilled with gravel to provide at least 3 ft of gravel fill above the highest seasonal level of groundwater elevation. The remaining depth would be backfilled with native soil. All piping would be located below grade so that the only surface structure would be a building to house pump controls and water treatment equipment. The surface finish would be returned to its original condition (e.g., hydroseeding and mulching for grassy areas and paving for paved areas).

About 10 extraction wells would be drilled in the higher MTBE concentration areas of the plume. The extraction rate would be designed to significantly reduce the water-table elevation or, if possible, dewater the Site. The benefits of aggressive dewatering are as follows:

- Dewatering would efficiently flush fresh water through the soil to rapidly reduce the concentration of MTBE in groundwater
- Lowering the water table allows SVE treatment of much of the saturated zone to ensure that MTBE is remediated to minimize rebound when the water-table elevation returns to its normal level after pumping is stopped.

The pumps would lift groundwater to the surface where it would move through buried piping to the water treatment system that is also used to treat groundwater extracted from the French drain.

Groundwater collected from the French drain and the wells would be treated on site using granular activated carbon (GAC) adsorption to MCLs or below to allow discharge to surface water at the Site. This discharge would require a National Pollutant Discharge Elimination System (NPDES) permit.

The assumed design specifications of the collection trench include the installation of four monitoring wells directly within the trench. To monitor the effectiveness of MTBE removal by groundwater extraction in the trench, these newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown.

Approximately sixty air extraction wells would be evenly distributed over the entire dewatered treatment area to allow SVE treatment of the unsaturated and dewatered zones. The design

objective of the SVE wells would be the removal and treatment of any residual MTBE contained within pockets of moisture that could not be effectively dewatered. The SVE system would force the circulation of air within the subsurface (dewatered and unsaturated zones) thereby enhancing the effect of removing any moisture left over after the site was dewatered. Air would be withdrawn from the wells using a blower that discharged through GAC treatment units to remove MTBE from the air stream prior to release. Figure 6-3 shows the conceptual placement of the SVE wells for Alternative 3.

6.2.2.3.2 Implementability. Both the French drain and wells and associated pumps, piping, and treatment equipment can be installed using standard materials and methods. The French drain can be designed and constructed using standard commercial materials and methods. The excavation depth of ~17 ft is well within the capabilities of standard backhoe-type excavators. Construction of the French drain would require removal and replacement of the paving and would disturb operations in the area until repaving is complete. The trench for the drain would cross C Street, so this street would need to be closed and traffic diverted for about 5 to 8 weeks during trench construction. After the French drain is completed, Alternative 3 would present minimal limitation to Site operations. The drain and associated piping would be below grade with a structure on the surface to house pump controls and treatment equipment. Alternative 3 requires obtaining an NPDES permit which may increase the time needed for implementation.

The only site utility that would be expected to interfere with French drain construction is a sanitary sewer located nearby. Efforts would be needed to locate all utilities in the area to be excavated, and precautions would be used to prevent loss of utility services.

The SVE system can be constructed using standard commercial materials and methods. A variety of permits and administrative clearances would be required to support SVE installation, but these are routinely obtained. The pipes connecting the wells to the extraction blower system would be placed in trenches to avoid interference with site activities during system operation; however, due to the large scale of the SVE system, the trenching activities would be complicated by existing underground utilities and would significantly effect daily site operations during system installation. The SVE system would present minimal limitations to site operations following installation because all wells and associated piping would be below grade and only a structure to house the extraction system would be present on the Site surface.

6.2.2.3.3 Effectiveness. In Alternative 3 groundwater is extracted for remediation above ground. Stabilization and containment of the MTBE groundwater plume at the boundary of the currently Navy-owned property is achieved once hydraulic control has been established which is expected to require about 0.25 years. Remediation of gasoline constituents on currently Navy-owned property is achieved after sufficient clean groundwater is drawn into the treatment area which is expected to require about 3 years.

The groundwater pumping system would be operated long enough to extract about three times the total volume of the groundwater plume on currently Navy-owned property. Due to the high solubility of MTBE, this flushing should be sufficient to significantly reduce the MTBE concentrations. The concentrations of other gasoline constituents in groundwater should also be reduced. Concentration rebound effects would be minimized by SVE operated while the water-table elevation is lowered to treat the unsaturated and saturated zones. Pumping operations are expected to last about 18 months.

6.2.2.3.4 Benefits. Based on Task 6a of Order 00-064, this alternative addresses the outlined requirements as follows:

- Using this alternative stabilizes and contains the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site by groundwater extraction from a French drain to provide hydraulic control.
- Using this alternative reduces and remediates the concentration of MTBE in Site groundwater by aggressive groundwater extraction from a French drain and vertical wells to remove groundwater for treatment and discharge on Site.
- Using this alternative reduces and remediates the concentration of benzene in site groundwater which exceed applicable RBSLs by aggressive groundwater extraction from a French drain and vertical wells to remove groundwater for treatment and discharge on Site.

6.2.2.3.5 Impact on Public Health and Welfare and the Environment. Treated groundwater would be discharged to surface water at the Site. The groundwater would be treated sufficiently to allow issuance of a NPDES permit to minimize potential negative effects of the treatment.

The heavy construction activities required to excavate and backfill the French drain entail risk to workers from hazards such as operation of excavators and trucks. Workers would require protection from the trench collapsing by installation of shoring systems along the trench sidewalls during excavation, pipe installation, and gravel placement. The risks posed to workers are within the norm for standard construction activities and would be reduced to the maximum possible extent by development of a health and safety plan and application of protective measures.

Hauling excavated soil off site for disposal would involve movement of trucks on public roads around the Site. The hauling activity creates the potential for risk to off-site populations from vehicle accidents, noise, and dust. Transportation risks would be minimized by development of a transportation plan and application of dust and noise control procedures.

6.2.2.3.6 Cost. The costs for Alternative 3, with MNA, monitoring, and institutional controls, are estimated to be approximately $2,912,400, and are summarized in Table 6-7. A more detailed list of costs included for Alternative 3 is provided in Appendix P. Assumptions that were made in calculating the cost of Alternative 3 are as follows:

- Dimensions of the trench are 250 ft in length, 4 ft wide, and ~17 ft deep
- The expected time required to adequately flush Site groundwater is 18 months
- An SVE system would operate during the period of pumping
- Installation of 4 groundwater monitoring wells at 15 ft bgs
- Assumed monitoring schedule for active remediation: 1) quarterly groundwater sampling of approximately 10 wells during system operation (~ 1.5 years) to track the treatment system efficiency and one additional year to determine whether rebound occurs, 2) monthly influent and effluent GAC sampling of groundwater to track its treatment efficiency, 3) weekly vapor sampling of the approximately 60 SVE wells for the first month of operation followed by bi-monthly vapor sampling at approximately 60 SVE wells until system shutdown (~18 cumulative months of operation), and 4) one soil sample per day of the excavated trench material will be collected and analyzed before off-site disposal during the installation of the collection trench (~30 days). An additional 20% of groundwater samples were added to account for QA/QC

- Assumed monitoring schedule for MNA: quarterly groundwater monitoring of approximately 66 wells for 2 years followed by semi-annual groundwater monitoring of approximately 25 wells for 3 years and annual groundwater monitoring of approximately 25 wells for the remaining ten years. An additional 20% of groundwater samples were added to account for QA/QC.

6.2.2.4 Alternative 4 – Biosparging. Alternative 4 involves installation and operation of a biosparging system to contain and treat the plume on currently Navy-owned property. Dissolved MTBE would be remediated by a combination of aeration, biodegradation, and air stripping. Figure 6-4 shows a conceptual diagram of the layout for the biosparging system.

6.2.2.4.1 Description. Implementing Alternative 4 requires installing vertical air injection wells distributed over an area of the plume. Air would be injected using standard vertical wells drilled to the depth of the aquitard (~15 ft to 20 ft bgs). Air pressurized to slightly above the local hydrostatic head would be injected into the groundwater using these wells. The wells would be installed in flush mounts set even with the soil or pavement surface and piping would be buried so that the only surface structure would be a small shed to house the air supply compressors.

It is expected that sparge well installation would occur in two phases. Phase 1 would involve the installation of approximately 40 sparge wells. A dense array of wells would be placed across the width of the groundwater plume near the northern boundary of the currently Navy-owned property. These wells would be supplemented by wells placed in the most permeable zones located within the MTBE hot spot. The sparge wells installed along the boundary would serve as a sparging "curtain" or barrier to contain any elevated MTBE concentrations tending to migrate to the north of currently Navy-owned property. The proposed locations for sparge well installation are shown in Figure 6-4. The actual location and spacing of the sparge wells would be determined by using existing CPT data collected during the remedial investigation (Battelle, 2001b) and additional CPT data which would be collected prior to well installation. Future CPT investigations would focus on identifying sandy areas within the MTBE hot spot that are likely to be conducting MTBE-impacted groundwater to the north; therefore, sparge wells can be positioned laterally in layers where they would most effectively treat the MTBE dissolved in groundwater. Sparge well locations would be adjusted to avoid underground utilities and surface structures (e.g., C Street) where possible, assuming there is no reduction in treatment efficiency.

The assumed design specifications of the biosparging system include the installation of four monitoring wells directly downgradient of the "sparge curtain" to monitor the effectiveness of MTBE removal by groundwater aeration in the area of the curtain. These newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation to track the treatment system efficiency. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown.

After 6 months of operation, performance would be evaluated to determine if a Phase 2, involving installation of more sparge wells, is needed to improve the effectiveness of the treatment system. This second phase of well installation would be based on monitoring data collected during the first few months of system operation using Phase 1 wells. The location of the additional sparge wells would be based on the CPT data collected before the initial operation of the system. The number of wells that may be added during Phase 2 installation is not yet known and would depend on how effectively the initial 40 sparge wells performed. It is possible the Phase 1 sparge wells would prove to be very effective and that no additional wells would be necessary.

The system would be designed to operate in a biosparging mode; that is, the minimum possible airflow rate would be used in an effort to maximize biodegradation. Some biodegradation would

occur in the groundwater due to increased oxygen content caused by the air injection. Also, most of the MTBE that volatilizes into the air is expected to biodegrade as the airstream moves through the unsaturated zone based on results of aerobic microcosm studies conducted by Battelle (2000d). During each phase of the biosparging system installation, SVE wells (including piping) would also be installed in the treatment area. The SVE system would serve as a contingency measure for biosparging system operation. Carbon is the assumed off-gas treatment system and carbon canisters would be procured if SVE operation were required. Shallow soil-gas samples would be collected along pathways to nearby receptors (i.e., day-care center) and analyzed for gasoline constituents to ensure the protection of human health during biosparging system operation. In the event that concentrations of gasoline constituents in soil gas increase to a level that constitutes a potential health risk to nearby receptors, the SVE system would be started.

6.2.2.4.2 Implementability. Biosparging is an innovative technology, but has developed an established record of full-scale application. Design of a biosparging system typically requires performance of an on-site test. However, design methods are sufficiently well established to allow development of a preliminary design that should produce an effective treatment system. In the proposed plan, the design can be refined using data collected during the first phase of system operation and implemented in Phase 2 (Leeson et al., 2000). Furthermore, air sparging already has been implemented at Former UST Site 957/970; therefore, the design of a newly installed system can be developed based on parameters measured during operation of the previous system.

This alternative can be constructed using standard commercial materials and methods. Maintenance of air compressors and piping to supply air to the sparging wells is required for system operation. These materials are standard, off-the-shelf equipment items that typically run reliably with minimal operator attention or maintenance.

Construction of the biosparging system would involve drilling a significant number of wells at the Site. Some wells may be placed on C Street, so this street would need to be closed and traffic diverted for a few days while wells and buried piping are installed. Installation of the below grade piping and wells could be affected by existing underground utilities, but this issue would be averted by reviewing existing utility maps and clearing areas where trenches would be installed. After the wells and buried piping are in place, Alternative 4 would present minimal limitation to Site operations. The wells and associated piping would be below grade and only a small structure to house the air injection compressors on the Site surface would exist. Efforts would be needed to locate all utilities in the area to be excavated, and precautions would be used to prevent loss of utility services. Possible precautions include removing and relocating the utilities in the area.

6.2.2.4.3 Effectiveness. In Alternative 4, groundwater is remediated as it passes through an area being treated by biosparging. Stabilization and containment of the MTBE groundwater plume at the boundary of the currently Navy-owned property is achieved once treated water exiting the treatment zone reaches the boundary, which is expected to require about 1.5 years. Remediation of gasoline constituents on currently Navy-owned property is achieved by natural attenuation supplemented by removal of MTBE hot spots using biosparging and (the MNA) is expected to require about 7 years.

Biosparging/air sparging has been widely applied and has an established operating history for remediating VOCs in groundwater. This approach allows in situ remediation of gasoline constituents without requiring groundwater extraction and ex situ treatment. Numerous case studies were reviewed that applied biosparging and air sparging to remediate fuel constituents. A brief summary of these studies is as follows:

- A survey of MTBE remediation experiences indicated that air sparging was fully successful in 10, and partially successful in 5, of the 16 projects studied (Hitzig, 1998)
- The reported results of field tests of air sparging at four service stations is summarized in Table 6-9 (U.S. EPA, 2000b)
- Pilot testing at one site indicated that some MTBE removal during air sparging was due to biodegradation induced by groundwater aeration (i.e., biosparging) (Javanmardian and Glasser, 1997)
- A proprietary air/ozone microbubble air sparging system was used to stop the advance of an MTBE plume at a site near Lake Tahoe, CA. The MTBE concentration within a radius of 20 ft around each sparging well reportedly dropped from 6 μg/L to <0.5 μg/L after one week of treatment (Kerfoot, 2000)
- Biosparging was found to decrease BTEX concentrations in groundwater from approximately 100 μg/L to 10 μg/L within 4-6 months of system operation at a U.S. Coast Guard site in Traverse City, Michigan (Griffin et al., 1993). Groundwater sampling indicated that DO concentrations increased from 2 mg/L to more than 6 mg/L during the biosparging effort.
- In another study a P&T system was replaced by biosparging to enhance aerobic biodegradation of BTEX compounds and prevent further migration the plume (Gallagher et al., 1996). Biosparging was selected because the P&T system failed to achieve cost effective removal rates of the BTEX compounds. Following a 7-month operational period of the biosparging system, BTEX concentrations at the site decreased to <1 μg/L at most sampling locations. The decrease was attributed primarily to biodegradation rates enhanced through biosparging. Treatment of the plume with biosparging ultimately cost approximately half that of treating with the P&T system (Gallagher et al., 1996).
- Javanmardian et al. (1995) conducted a biosparging pilot test at an Amoco Oil petroleum products storage terminal in Michigan to investigate the effectiveness of the technology for oxygenating soil and groundwater. The results of benzene and total BTEX concentrations were analyzed before and after 1 month of biosparging at a rate 1.5 scfm. The results showed a decrease of benzene concentrations in all the monitoring wells in the study area. The highest benzene concentration in the test area decreased from approximately 250 mg/L to 90 mg/L following 1-month of biosparging operation.

Based on the results of the case studies summarized above and results of the aerobic microcosm studies conducted with native soil and groundwater from the Former UST Site 957/970, biosparging has a substantial likelihood of effectively reducing gasoline constituents dissolved in groundwater. Air sparging already conducted in the former source zone of Former UST Site 957/970 showed dramatic decreases of gasoline constituents in groundwater followed by no rebound (see Section 3.3), consistent with the results reported in Table 6-9. Sparging air would enter the unsaturated zone and aerate the soil, allowing degradation of gasoline constituents vaporized from the groundwater.

Due to the limited inventory of MTBE and the time required for remediation, there is a low mass removal rate of chemicals in the sparging air. The estimated quantity of MTBE in the volume of groundwater on currently Navy-owned property with dissolved MTBE is 54 kg (120 lbs). With an estimated treatment duration of 365 days the MTBE discharge rate would be 0.15 kg/day (0.33 lbs/day). This is a conservative estimate of the release rate in that it assumes no biodegradation. The biosparging system would be operated at the minimum air injection rate to maximize in situ biodegradation of MTBE. Due to this low release rate, it is expected that no vapor extraction or off-gas treatment would be needed

in conjunction with the proposed biosparging treatment design. However, shallow soil gas would be monitored along pathways to nearby receptors to ensure that the biodegradation capacity of the vadose zone is not exceeded by the MTBE mass-loading rate, and that volatile emissions due to biosparging do not present any health risks to nearby receptors.

6.2.2.4.4 Benefit. Based on Task 6a of Order 00-064, this alternative addresses the outlined requirements as follows:

- Using this alternative stabilizes and contains the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site by providing an in situ biosparging barrier at the northern boundary of the Site to remediate groundwater leaving the Site.
- Using this alternative reduces and remediates the concentration of MTBE in Site groundwater by biosparging in the groundwater plume.
- Using this alternative reduces and remediates the concentration of benzene in site groundwater which exceeds applicable RBSLs by biosparging in the groundwater plume.

6.2.2.4.5 Impact on Public Health and Welfare and the Environment. Drilling wells and installing pipes and compressors would involve some risks to site workers during installation of the biosparging system. These risks are within the norm for standard construction activities and would be reduced to the maximum possible extent by development of a health and safety plan and application of protective measures.

6.2.2.4.6 Cost. The costs for Alternative 4, with MNA, monitoring, and institutional controls, are estimated to be approximately $1,855,290, and are summarized in Table 6-8. A more detailed list of costs included for Alternative 4 is provided in Appendix P. Assumptions that were made in calculating the costs of Alternative 4 are as follows:

- Depth to groundwater is approximately 10 ft bgs
- 40 sparge wells installed during Phase 1
- 10 sparge wells installed during Phase 2
- Total depth of sparge wells is 15 ft
- 6-month operation of Phase 1 wells only
- 6-month operation of Phase 1 and Phase 2 wells combined
- Installation of 4 groundwater monitoring wells at 15 ft bgs
- No off-gas or vapor treatment required (note that SVE would serve as a contingency measure)
- Assumed monitoring schedule for active remediation: quarterly groundwater monitoring of approximately 10 wells during system operation (~1 year) to track treatment system efficiency and an additional year to determine whether rebound occurs. An additional 20% of groundwater samples were added to account for QA/QC
- Assumed monitoring schedule for MNA: quarterly groundwater monitoring of approximately 66 wells for 2 years followed by semi-annual groundwater monitoring of approximately 25 wells for 3 years and annual groundwater

monitoring of approximately 25 wells for the remaining ten years. An additional 20% of groundwater samples were added to account for QA/QC.

6.3 Selection of Corrective Action

Alternative 4, biosparging, is selected in favor of the other alternatives based on the proven performance of biosparging/air sparging at the Site, the more flexible implementation options, and better cost-effectiveness of biosparging compared to the other alternatives. Selection of Alternative 4, biosparging, provides the maximum benefit to the people of the State of California. Environmental resources are protected by timely remediation of gasoline constituents in groundwater using the most cost-effective alternative. Table 6-10 provides a summary comparison of the alternatives.

Implementability

Installation of wells allows more flexibility compared to excavation of a large area of the Site or a trench. Excavation of a large area of the Site would significantly disturb underground utilities. A French drain for groundwater extraction or a trench for air sparging must present a continuous surface to intercept groundwater flow. The spacing for the wells needed to implement Alternative 4 can be adjusted, within limits, to avoid interference with structures and utilities (see Figure 6-4). Therefore, implementation of Alternative 4 would be much easier compared to Alternatives 1, 2, or 3.

Effectiveness

Alternative 1 provides the fastest response to the requirements of Order No. 00-064; however, at a cost more than 5 times higher than the next most expensive alternatives (interception/aeration trench and collection trench and wells with groundwater pump and treat and SVE) and more than 8 times higher than Alternative 4 (biosparging).

Using an interception trench and wells to extract groundwater (Alternative 3) would stabilize the plume approximately 6 times faster than biosparging (Alternative 4) by quickly establishing hydraulic control. The estimated treatment time for biosparging is limited by the travel-time of groundwater from the treatment area to the Navy property boundary (~1.5 years). The groundwater extraction rate of the interception trench and wells would be designed to significantly reduce the water-table elevation in areas where the groundwater contains gasoline constituents. This aggressive extraction would ensure that the local groundwater flow direction would be reversed at the boundary of the currently Navy-owned property shortly after pumping is started. Groundwater extraction supplemented by SVE would also speed cleanup of Site groundwater compared to the biosparging approach used in Alternative 4.

The biosparging system provides equal effectiveness in preventing plume migration compared to the interception/aeration trench. Data collected during air sparging at a variety of other MTBE sites and during treatment of the source zone at Former UST Site 957/970 (see Section 6.2.2.4.3) demonstrates the ability to reach low concentrations of MTBE in groundwater and maintain these concentrations after the system is turned off. Avoiding rebound depends on the lack of free-phase LNAPL that slowly releases gasoline constituents back into the groundwater after treatment system operation is terminated. There was no rebound of groundwater concentrations after the former source area of Former UST Site 957/970 was treated with air sparging and soil vapor extraction. One of the subtasks within Task 2 of Order 00-064 had the specific objective of determining if any LNAPL currently exists at the Site. That investigation concluded that no free-phase petroleum was observed at the Site. Rebound of groundwater concentrations of MTBE is not expected, but in the unlikely event of rebound, the biosparging system would be restarted.

Alternative 4 is expected to achieve more rapid and effective reductions in the concentration of MTBE as well as the total dissolved mass of MTBE present at the Site than Alternative 2, thus potentially allowing land use restrictions to potentially be removed earlier and future land use to be affected for a shorter period of time. The biosparging system injects air into the groundwater volume with elevated concentrations of MTBE, whereas the trench acts as a static barrier to intercept migration of MTBE as it moves into the trench barrier. Alternative 4 provides more certain and immediate reduction of MTBE mass and concentrations dissolved in groundwater, because the biosparging/air sparging system would allow for more focused installation in areas containing the greatest mass inventory of MTBE (see Figure 6-4). The biosparging system can achieve cleanup in about 1 to 2 years compared to the trench that is expected to require about 10 years of operation to fully capture the portion of the plume with elevated MTBE concentrations. The predicted treatment duration of the interception/aeration trench assumes elevated MTBE concentrations migrate with groundwater, which is contradictory to MTBE plume maps generated over the past five (5) quarterly monitoring events (Figure 5-5); therefore, the predicted treatment duration to attain RAOs at the Site may rely on MNA rates rather than the removal achieved by the trench.

Benefits

All of the alternatives meet the groundwater cleanup requirements of Order No. 00-064, Task 6, which are as follows:

- Stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site
- Reduce and remediate the concentrations of MTBE in Site groundwater
- Reduce and remediate the concentrations of benzene in Site groundwater which exceed applicable RBSLs.

Impact on Public Health and Welfare and the Environment

Alternative 4 has the least impact on public health and welfare and the environment. Drilling wells require significantly less heavy equipment operation and disturbance of site operations and generate less solid waste for off-site disposal compared to excavating a large area of soil or a trench for groundwater collection or air sparging. The potential for industrial accidents is much lower with Alternative 4 compared to Alternatives 1, 2, or 3.

Cost

Alternative 4 is the lowest cost approach costing about $13.9 million less than Alternative 1, $1.3 million less than Alternative 2, and $1.1 million less than Alternative 3.

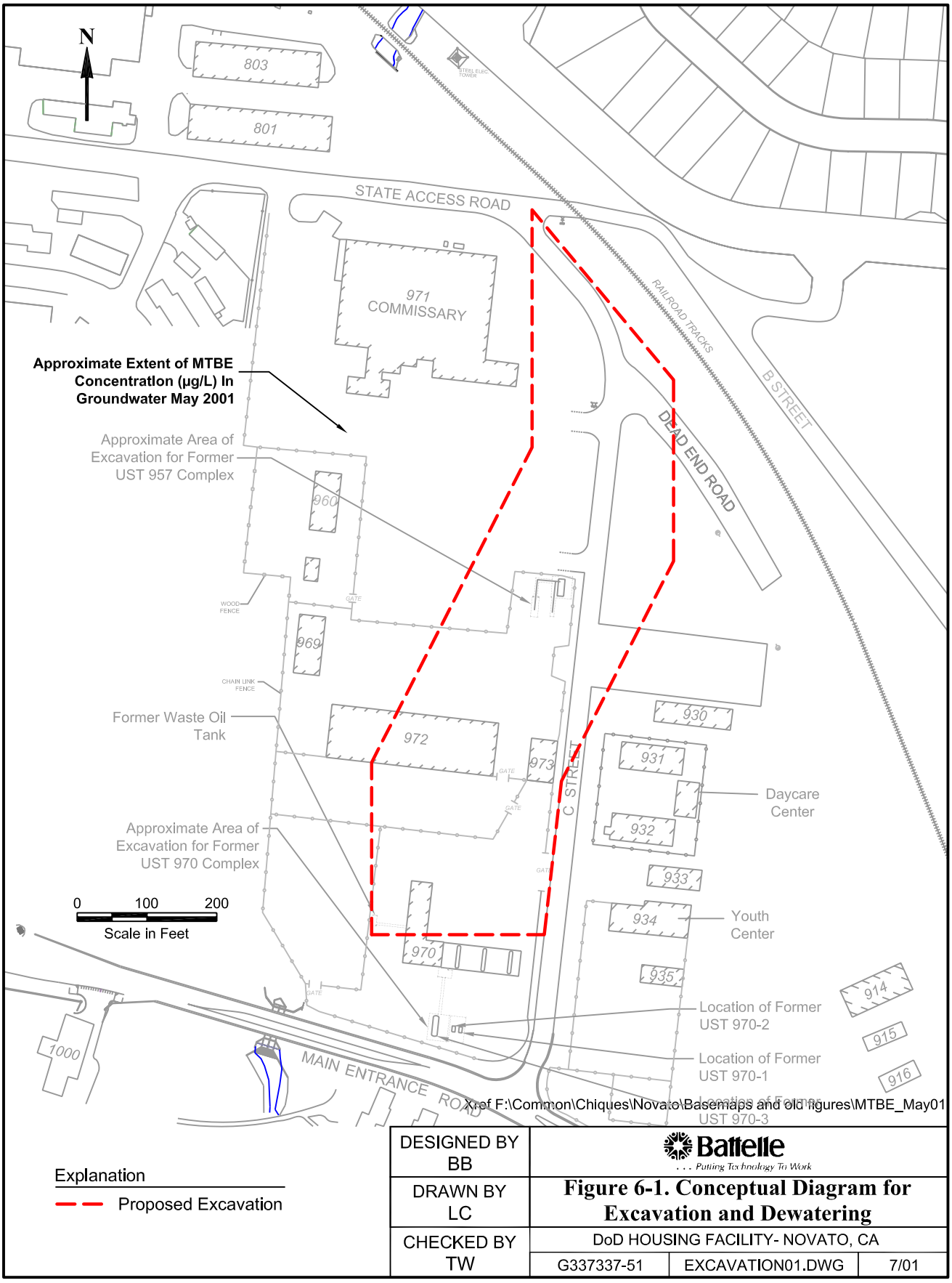
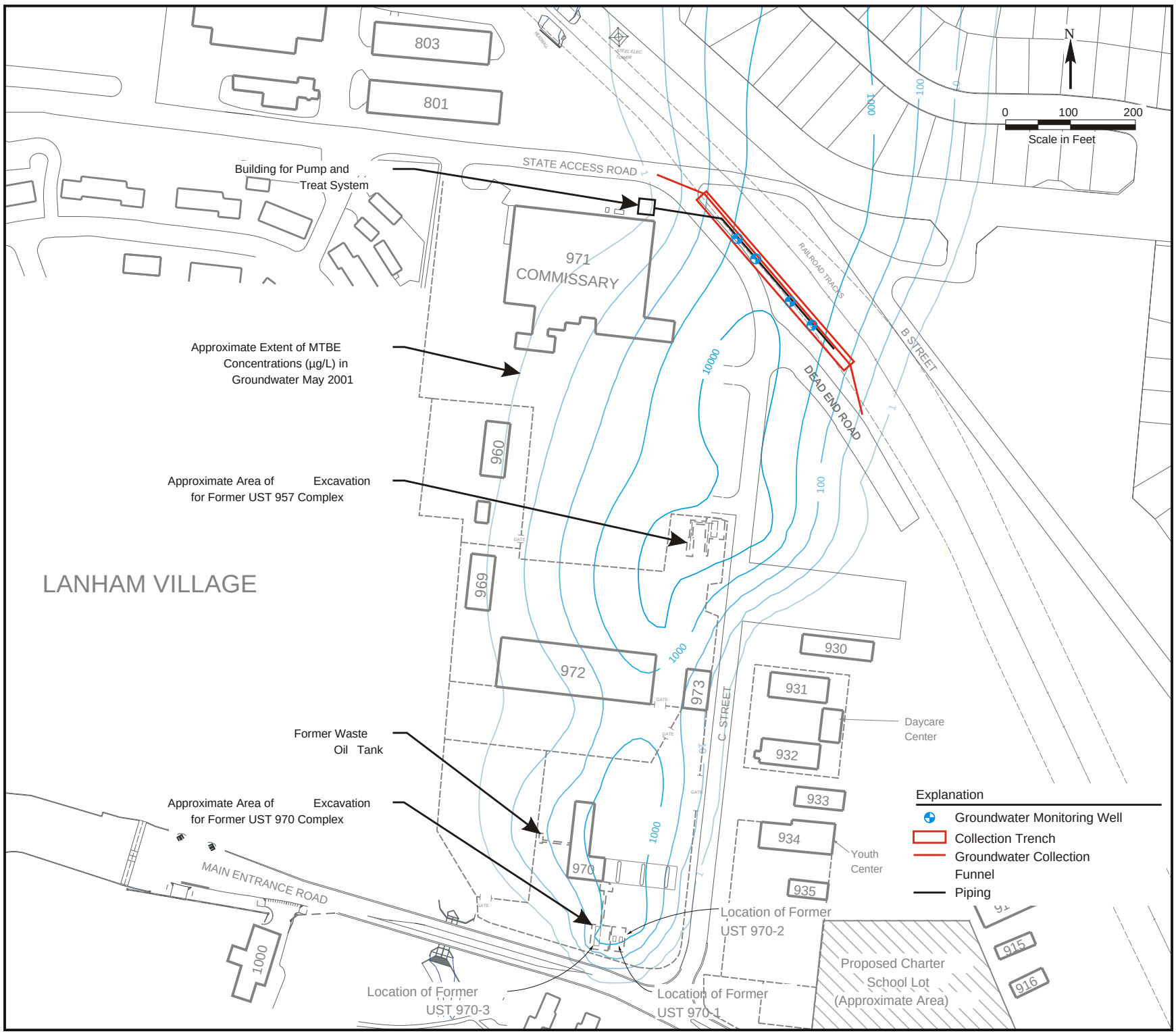
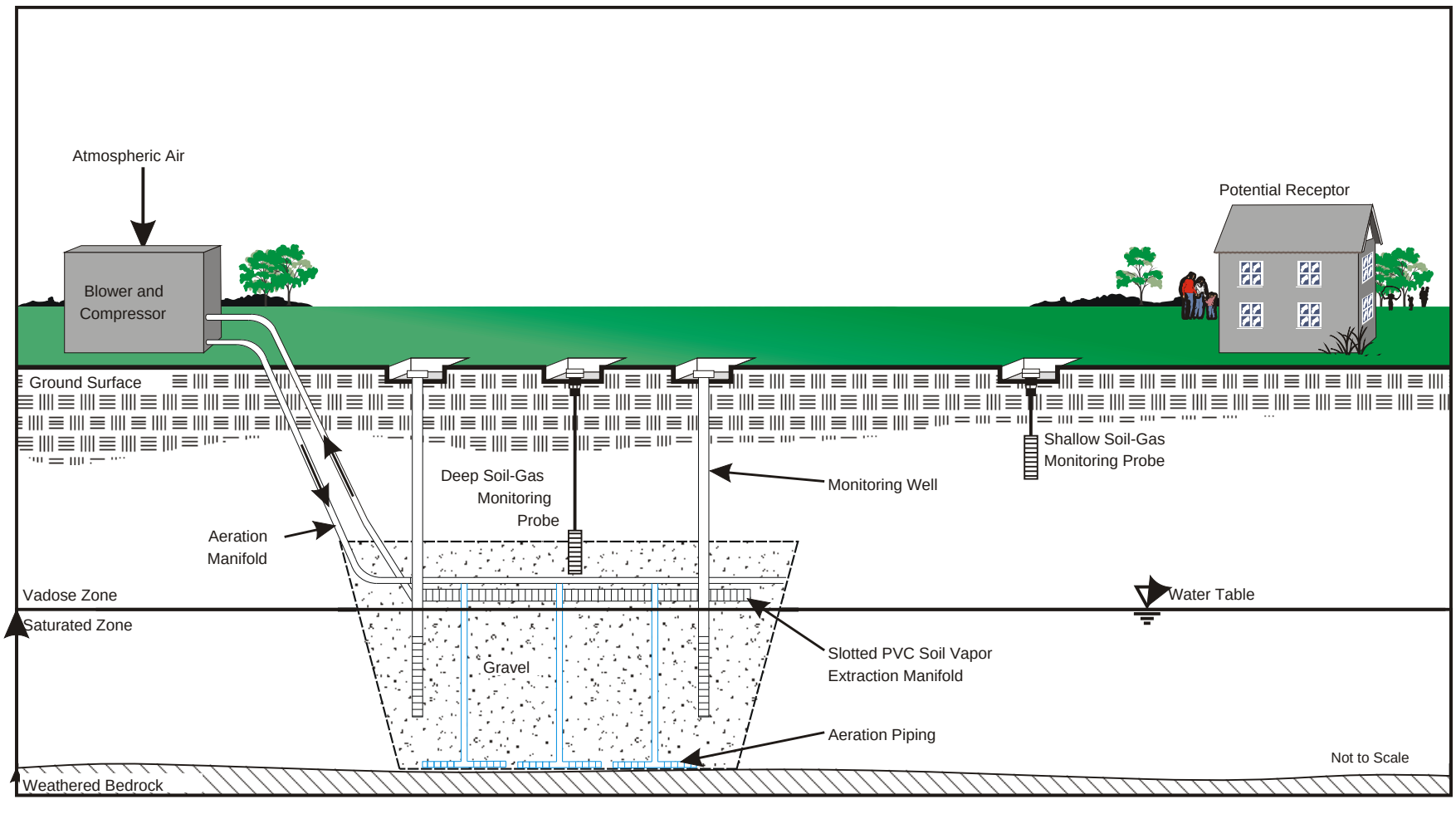


Figure 6-1. Conceptual Diagram for Excavation and Dewatering

Figure 6-2. Conceptual Diagram of Interception/Aeration Trench



Conceptual Plan View of Interception/Aeration Trench at Former UST Site 957/970



Conceptual Diagram of Profile View for Interception/Aeration Trench at Former UST Site 957/970

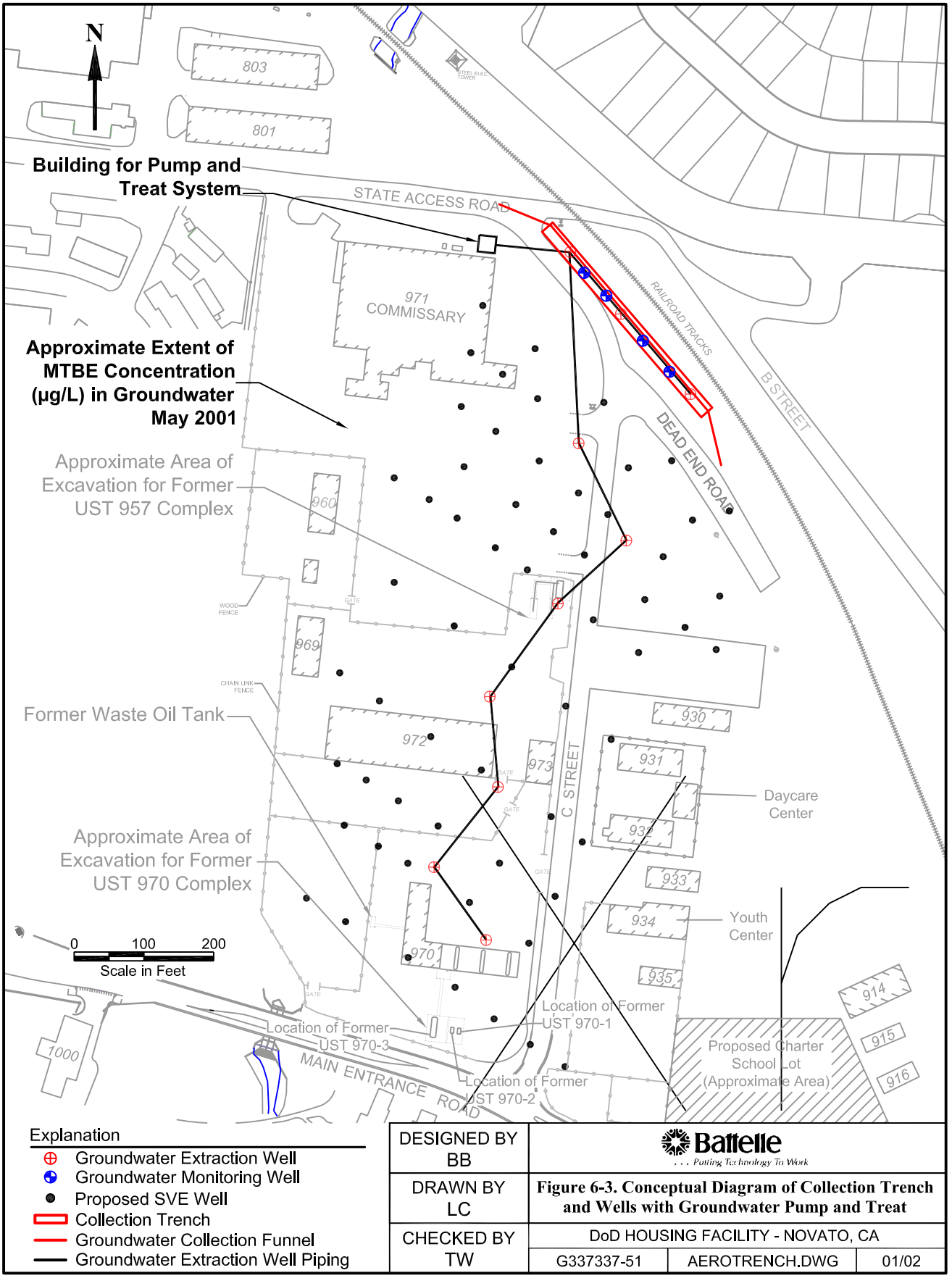
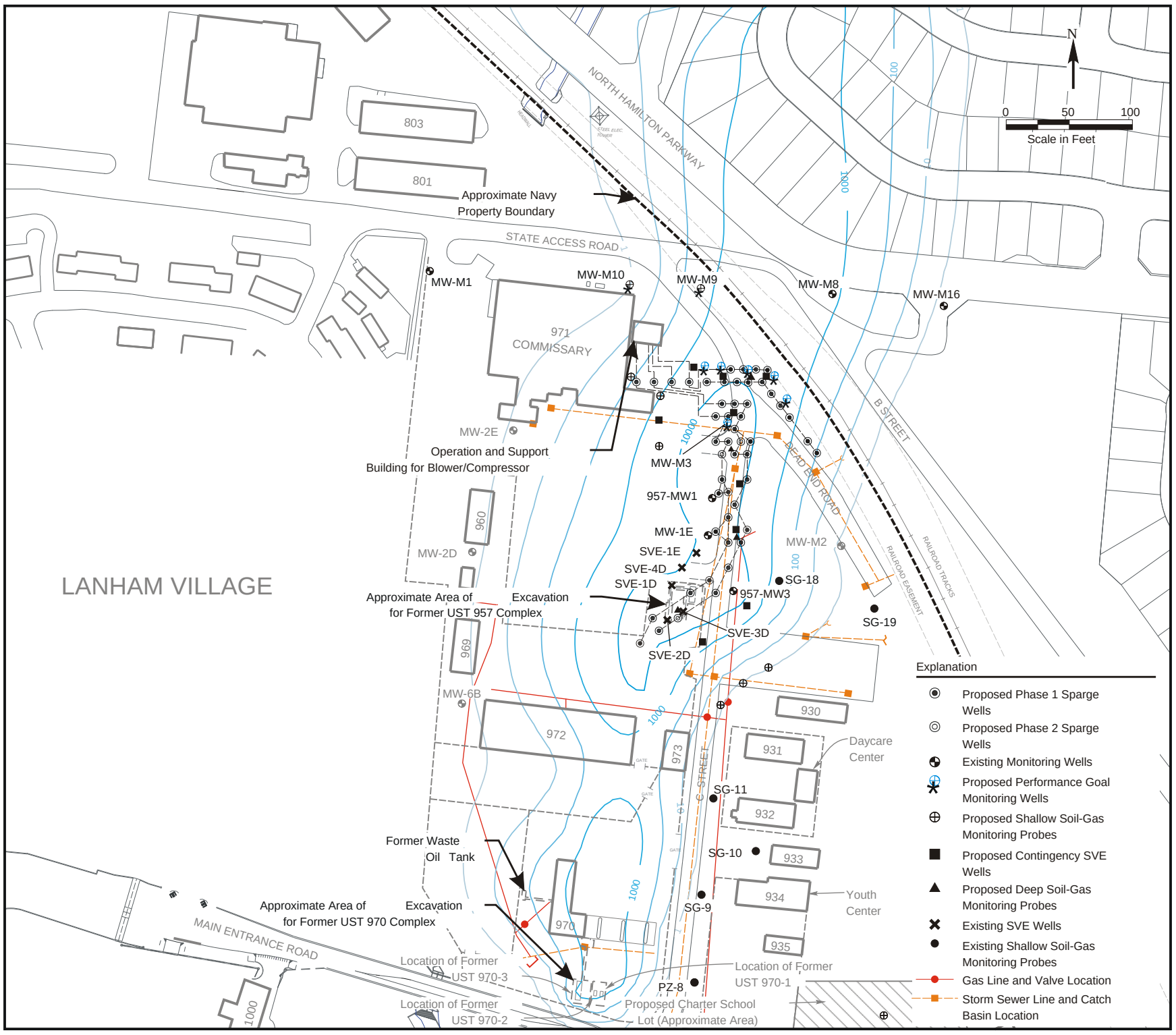
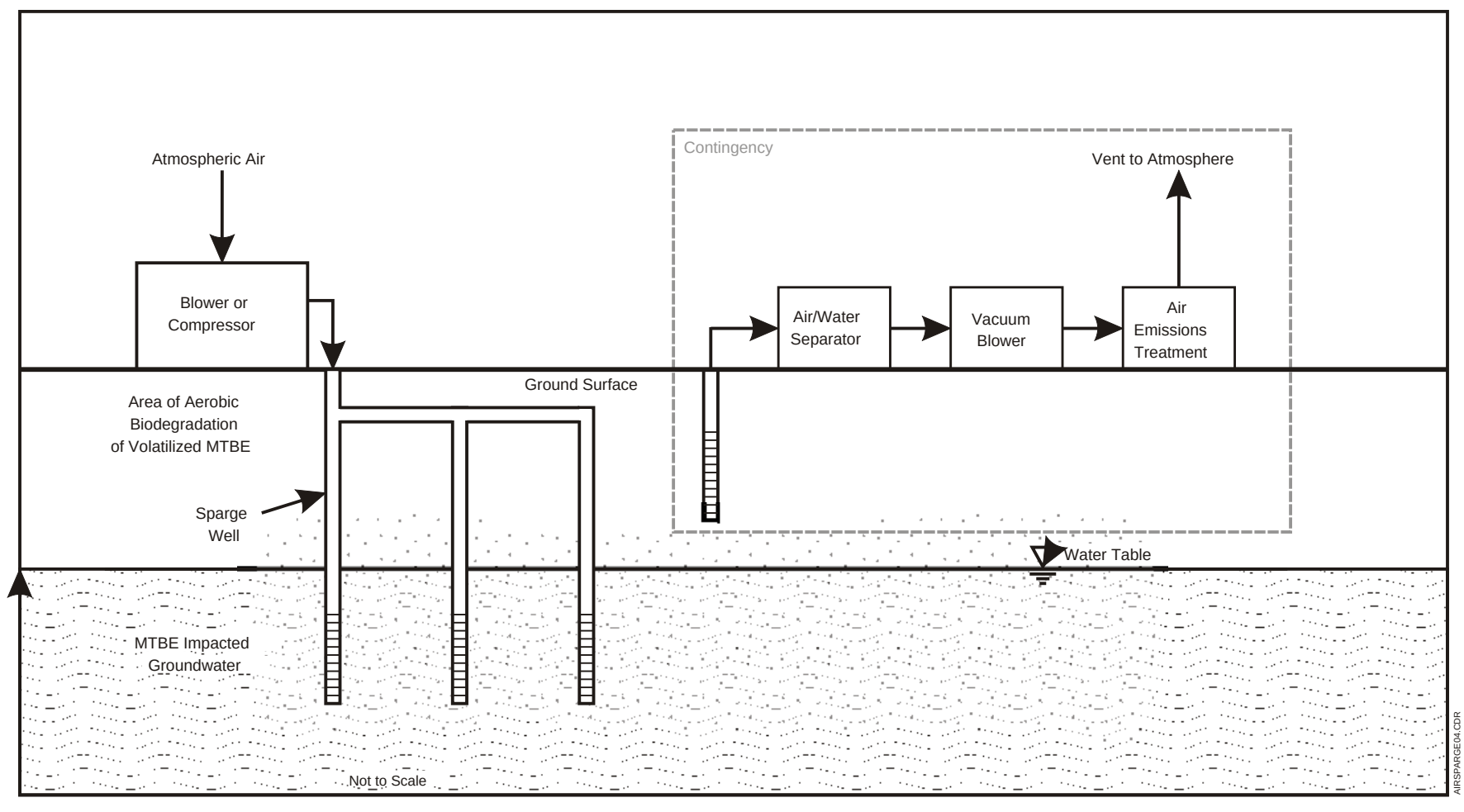


Figure 6-3. Conceptual Diagram for Collection Trench and Wells With Groundwater Pump and Treat

Figure 6-4. Conceptual Diagram for Biosparging/Air Sparging



Conceptual Plan View of Bio Sparging/Air Sparging Configuration at Former UST Site 957/970



Conceptual Diagram of Profile View for Bio Sparging/Air Sparging Configuration at Former UST Site 957/970

Table 6-1. Advantages and Limitations of Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970

Alternatives	Advantages	Limitations
Closure with no further action	No risk to workers or off-site populations during implementation Results in minimal disturbance to activities at the Site Low cost	Does not effectively control the MTBE plume at the boundary of currently Navy-owned property
In Situ Aerobic Biodegradation by Circulating Oxygen-Bearing Solutions	Innovative technology with demonstrated effectiveness for BTEX and MTBE destruction Limited risk to workers or off-site populations during implementation Disturbance to activites at the Site are moderate during a brief installation period and minimal during operation Low to moderate capital and operating cost	Typically requires 1 or more years to remediate a site Requires reinjection or disposal of extracted groundwater In situ delivery of oxygen and in situ mixing with impacted groundwater using hydrogen peroxide (H_2O_2) or dissolved oxygen is inefficient using standard wells Subsurface heterogeneity can make it difficult to deliver amendments throughout the different zones of groundwater containing MTBE Wells and water treatment equipment may require frequent maintenance due to fouling caused by oxidation and precipitation of iron in groundwater
In Situ Aerobic Biodegradation using ORC®	Innovative technology with demonstrated effectiveness for BTEX and MTBE destruction Remediates gasoline constituents without requiring groundwater extraction and ex situ treatment Limited risk to workers or off-site populations during implementation Disturbance to activites at the Site are moderate during a brief installation period and minimal during operation	Typically requires about 6 months to 1 year to remediate a site Initial cost is high due to the cost of the ORC® and additional applications; if required, can significantly increase operating cost Subsurface heterogeneity can make it difficult to deliver amendments throughout the different zones of groundwater containing gasoline constituents

Table 6-1. Advantages and Limitations of Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970 (Continued)

Alternatives	Advantages	Limitations
In situ biosparging/air sparging	Innovative technology with demonstrated effectiveness for BTEX and MTBE removal/destruction Remediates gasoline constituents without requiring groundwater extraction and ex situ treatment Limited risk to workers or off-site populations during implementation Disturbance to activites at the Site are moderate during a brief installation period and minimal during operation Low to moderate capital and operating cost	Typically requires about 6 months to 2 years to remediate a site Subsurface heterogeneity can interfere with uniform air distribution Chemicals with a low Henry's law constant (e.g., MTBE) are more difficult to treat
Interception/ aeration trench	Innovative technology with demonstrated effectiveness for BTEX and MTBE destruction Remediates gasoline constituents without requiring groundwater extraction and ex situ treatment Moderate disturbance to activities at the Site during operation Low to moderate capital and operating cost	Expected to require about 10 years to remediate the Site (based on the length of the plume on currently Navy-owned property being 1,000 ft long, the groundwater velocity being approximately 100 ft/yr, and MTBE migrating with the groundwater without holdup) Some risk to workers during trench excavation and off-site populations during transport of excavated soil to an off-site disposal facility Excavation of the trench may be complicated by the railroad easement and existing underground utilities Extensive disturbance to activities at the Site during trench excavation Permeable fill in trench may require frequent maintenance due to fouling caused by oxidation and precipitation of iron in groundwater

Table 6-1. Advantages and Limitations of Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970 (Continued)

Alternatives	Advantages	Limitations
Collection trench and wells with pump and treat	Conventional technology Pumping rate can be adjusted to ensure plume capture Trench (French drain) supplemented with wells can be used to ensure effective hydraulic control Disturbance to activites at the Site are moderate during a brief installation period and minimal during operation Low to moderate capital cost	High to very high operating cost Expected to require about 18 months to remediate the Site based on the volume of the plume and the achievable extraction rate at the Site Some risk to workers during trench excavation and off-site populations during transport of excavated soil to an off-site disposal facility Water treatment would be expensive (i.e., air stripper with a high air to water ratio or large volume of granular activated carbon due to low sorption capacity of MTBE, stripper off-gas may require treatment prior to discharge) The water treatment operation involves transfer of gasoline constituents from one media to another rather than destruction Wells and water treatment equipment may require frequent maintenance due to fouling caused by oxidation and precipitation of iron in groundwater
MNA	Remediates gasoline constituents without requiring groundwater extraction Limited risk to workers or off-site populations during implementation Results in minimal disturbance to activities at the Site Low capital and operating cost	Can require decades to remediate the Site Not suitable if site risks are excessive or migration would lead to adverse effects to potential receptors Not suitable if free product or other sources are present Not effective for high concentrations of gasoline constituents (e.g., >20,000 mg/L total petroleum hydrocarbons)
Organic soil modification	Passive operation Limited risk to workers or off-site populations during implementation Disturbance to activities at the Site are moderate during a brief installation period and minimal during operation	Emerging technology that would require a year of field pilot testing prior to implementation It may be difficult to obtain regulatory approval for injecting surfactants Expected to require about 10 years to remediate the Site (based on the length of the MTBE plume on currently Navy-owned property being 1,000 ft long, the groundwater velocity being approximately 100 ft/yr, and MTBE migrating with the groundwater without holdup)

Table 6-1. Advantages and Limitations of Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970 (Continued)

Alternatives	Advantages	Limitations
Phytoremediation	Innovative technology with demonstrated effectiveness for hydraulic control of groundwater migration Remediates gasoline constituents without requiring groundwater extraction and ex situ treatment Limited risk to workers or off-site populations during implementation Improves site aesthetics Low capital and operating cost	A year or more would be required for plants to become established Several years of operation may be needed to remediate the Site Supplemental treatment measures, if needed to offset the slow start for plantings, would significantly increase cost A wide dense planting area would probably be needed due to the rapid rate of groundwater flow in high permeability channels Limits land use options in planting area (i.e., plants cannot be disturbed) and would likely require a large area of land surface for remediation
Excavation and dewatering	Conventional technology Provides rapid removal of gasoline constituents from site groundwater Low operating cost	Gasoline constituents are transferred to an off-site location for management Total disruption of activities at the Site during implementation Moderate risk to workers or off-site populations during implementation Increased truck traffic during implementation Very high capital cost

Table 6-2. Basis for Selecting Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970

Alternatives	Evaluation Status	Basis
Closure with no further action	Not considered for detailed evaluation	Does not control migration of gasoline constituents to downgradient locations off of currently Navy-owned property
In situ aerobic biodegradation by circulating oxygen-bearing solutions	Not considered for detailed evaluation	Oxygen delivery in solution typically is inefficient and would be particularly difficult due to the complex geology at the Site Obtaining a permit to reinject groundwater may be difficult and treatment would increase cost
In situ aerobic biodegradation using ORC®	Not considered for detailed evaluation	Provides similar effectiveness compared to in situ biosparging/air sparging but is expected to be more expensive due to high cost of ORC®
In situ biosparging/air sparging	Considered for remediation and migration control of gasoline constituents (in combination with MNA, monitoring, and institutional controls)	Expected to provide effective control of migration and remediate gasoline constituents based on effectiveness of air sparging treatment of source zones and results of treatability testing (Battelle, 2001d). Easily implemented using conventional equipment and methods
Interception/ aeration trench	Considered for remediation and migration control of gasoline constituents (in combination with MNA, monitoring, and institutional controls)	Expected to provide effective control of migration and remediate gasoline constituents based on effectiveness of air sparging treatment of source zones and results of treatability testing (Battelle, 2001d).
Collection trench and well with pump and treat	Considered for remediation and migration control of gasoline constituents (in combination with MNA, monitoring, and institutional controls)	Expected to provide effective control of migration and remediate gasoline constituents based on ability to provide hydraulic control to reverse the hydraulic gradient locally at the northern boundary of currently Navy-owned property and extract groundwater for treatment
MNA	Considered as a common element for final remediation of the gasoline constituents (in combination with containment and treatment of gasoline constituents in groundwater on currently Navy-owned property, monitoring, and institutional controls)	Existing monitoring data indicates that concentrations and mass of gasoline constituents currently are declining. Containing and treating gasoline constituents on currently Navy-owned property would prevent further migration and accelerate the decrease of concentrations on former HAAF property

Table 6-2. Basis for Selecting Alternatives for Remediation of MTBE in Groundwater at the Former UST Site 957/970 (Continued)

Alternatives	Evaluation Status	Basis
Organic soil modification	Not considered for detailed evaluation	Emerging technology that would require a year or more of pilot testing prior to full-scale implementation Obtaining a permit to inject surfactants may be difficult
Phytoremediation	Not considered for detailed evaluation	At least a year or two would be needed for the plantings to mature sufficiently to provide acceptable transpiration rates. Supplementary treatment during this startup period would significantly increase costs.
Excavation and dewatering	Considered for remediation and migration control of gasoline constituents (in combination with MNA, monitoring, and institutional controls)	Expected to provide effective control of migration and remediate gasoline constituents based on ability to rapidly transfer the bulk of gasoline constituents in site groundwater to off-site facilities for treatment and disposal

Table 6-3. MNA Sampling Approach

MNA Program Aspect	Description
Parameters to be monitored	Groundwater MTBE, TBA, TBF, and BTEX concentrations
Monitoring schedule	Quarterly sampling for 2 years, semiannual sampling for 3 years, and annual sampling for 10 years
Number of wells monitored	66 for the first 2 years and 25 for the following 13 years
Approximate time frame to clean up entire site (Navy and former HAAF property) to MCLs	15 years

Table 6-4. Monitoring Approach for Each Candidate Alternative

Monitoring Parameter	Alternative 1 – Excavation and Dewatering	Alternative 2 – Interception/Aeration Trench	Alternative 3 – Collection Trench and Wells with Groundwater Pump and Treat and SVE	Alternative 4 – Biosparging/Air Sparging
Groundwater monitoring	None	Groundwater monitoring quarterly throughout plume during active remediation	Groundwater monitoring quarterly throughout plume during active remediation	Groundwater monitoring quarterly throughout plume during active remediation
Extracted water monitoring	Samples of extracted groundwater to support waste management	None	Monitoring of on-site water treatment system inlet and outlet	None
Soil gas monitoring	None	None	None	Monitor soil gas along pathways to nearby receptors Monitor biodegradation effectiveness within the unsaturated zone of the treatment area
Air/off gas monitoring	Dust monitoring during excavation	Dust monitoring during excavation	Dust monitoring during excavation SVE off-gas monitoring	None
Other	None	None	Water level monitoring to demonstrate plume capture	None

Table 6-5. Summary of Costs for Alternative 1: Excavation and Dewatering

Cost Element	Cost ($)
Excavation and Dewatering	
Installation/Construction/Equipment	$12,725,000
System Closeout	$44,000
System Monitoring	$166,000
System Design	$1,750,000
Travel	$300,000
Total Cost for Excavation and Dewatering	$14,985,000
MNA	
Total Cost for MNA	$750,000
Total Cost for Alternative 1	**$15,735,000**

Table 6-6. Summary of Costs for Alternative 2: Interception/Aeration Trench

Cost Element	Cost ($)
Interception/Aeration Trench	
Installation/Construction/Equipment	$316,200
Operation and Maintenance	$476,250
System Closeout	$58,500
System Monitoring	$1,349,500
System Design	$31,600
Travel	$147,500
Total Cost for Interception/Aeration Trench	$2,379,550
MNA	
Total Cost for MNA	$750,000
Total Cost for Alternative 2	**$3,129,550**

Table 6-7. Summary of Costs for Alternative 3: Collection Trench and Wells With Groundwater Pump and Treat and SVE

Cost Element	Cost ($)
Collection Trench and Wells with Groundwater Pump and Treat and SVE	
Carbon Units	$195,600
Installation/Construction/Equipment	$614,300
Operation and Maintenance	$223,900
System Closeout	$82,600
System Monitoring	$830,000
System Design	$81,000
Travel	$135,000
Total Cost for Trench and Wells with GW P&T	$2,162,400
MNA	
Total Cost for MNA	$750,000
Total Cost for Alternative 3	**$2,912,400**

Table 6-8. Summary of Costs for Alternative 4: Biosparging

Cost Element	Cost ($)
Biosparging	
Installation/Construction/Equipment	$400,490
Operation and Maintenance	$215,500
System Closeout	$73,500
System Monitoring	$290,400
System Design	$40,000
Travel	$85,400
Total Cost for Biosparging	$1,105,290
MNA	
Total Cost for MNA	$750,000
Total Cost Alternative 4	**$1,855,290**

Table 6-9. Air Sparging Performance

Site	Technology Description	Duration (Months)		Gasoline Constituent	Typical Dissolved Concentration Range (µg/L)		
		Sparge	Post-Closure		At Start	At Shutdown	Post-Closure
Pensacola, FL	5 wells, 35 ft spacing, 8 scfm/well (pulsed on daily cycle)	4	6	MTBE	230	<5	<5
				BTEX	3,413	<2	<2
Albuquerque, NM	9 wells, 40 to 50 ft spacing, 6 to 10 scfm/well (continuous flow)	19	13	MTBE	1,600	27	8
				BTEX	64	ND	ND
Sebato, ME	7 wells, 25 to 35 ft spacing, 5 to 10 scfm/well (continuous flow)	14.5	6.5	MTBE	7,200 to 62,000	16 to 980	29 to 115
				BTEX	22,600 to 198,000	6 to 550	2 to 604
				Gasoline	49,000 to 210,000	80 to 3,500	80 to 3,590
ME	6 wells, 30 to 40 ft spacing, 5 scfm/well (continuous flow)	21	Not reported	MTBE	215	Not reported	Not reported
				BTEX	1,230	Not reported	Not reported

Source: U.S. EPA, 2000b, www.ttclients.com/mtbe/summary_table.htm.

Table 6-10. Summary Comparison of Remedial Alternatives

Evaluation Factor	Alternative 1: Excavation and Dewatering	Alternative 2: Interception/Aeration Trench	Alternative 3: Collection Trench and Wells with Groundwater Pump and Treat and SVE	Alternative 4: Biosparging/Air Sparging
Implementability	This alternative is implementable using standard materials and methods. Excavation would greatly hinder current site operations. Extensive work would be needed to avoid damage and/or service interruption with buried utilities.	This alternative is implementable using standard materials and methods. Construction of the trench would require temporary closure of C Street. The trench must be routed to avoid the railroad easement and underground utilities.	This alternative is implementable using standard materials and methods. Construction of the French drain would require temporary closure of C Street. The trench must be routed to avoid the railroad easement and underground utilities. Implementation may be delayed because a NPDES permit must be procured to discharge treated process water to surface water.	This alternative is implementable using standard materials and methods. Well installation may require brief closure of C Street. Well placement is flexible such that all underground obstructions should be easily avoided.

Table 6-10. Summary Comparison of Remedial Alternatives (Continued)

Evaluation Factor	Alternative 1: Excavation and Dewatering	Alternative 2: Interception/Aeration Trench	Alternative 3: Collection Trench and Wells with Groundwater Pump and Treat and SVE	Alternative 4: Biosparging/Air Sparging
Effectiveness	Provides an effective and lasting method for removing gasoline constituents from groundwater on the currently Navy-owned property. The excavation volume would be designed such that the upstream concentrations are sufficiently reduced to ensure that MNA would stop migration of any remaining MTBE from migrating off of currently Navy-owned property.	Provides an effective and lasting treatment method for removing gasoline constituents in groundwater as it passively migrates through the trench. The rate of cleanup is limited by the flux of MTBE so air sparging in the trench must continue until the entire extent of the plume with elevated MTBE concentrations passes through the barrier. This alternative is expected to require about 10 years to remediate the Site but could require much longer if the MTBE plume moves at a slower than expected rate.	Groundwater pumping and treatment is an established method for controlling plume migration and extracting groundwater for treatment above ground. Use of a French drain reduces the sensitivity of extraction performance to permeability variations.	Biosparging/air sparging provides a proven treatment technology that has been widely applied and has an established operating history for remediating VOCs in groundwater. Aerobic laboratory microcosm studies with Novato soils and groundwater have shown complete MTBE removal without TBA or TBF accumulation (Battelle, 2001d). Also, interim remedial activities using a similar approach (IAS/SVE) conducted within the former source area at Former UST Site 957/970 showed dramatic decreases of gasoline constituent concentrations in groundwater followed by no rebound.
Benefits	Requires about 25 weeks to implement a remedial action that stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property, and reduces and remediates MTBE and benzene in Site groundwater.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property immediately after interception/aeration trench operation begins. Reduces and remediates MTBE and benzene in Site groundwater as the water migrates through the trench.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property immediately after groundwater pumping operation begins. Reduces and remediates MTBE and benzene in Site groundwater by groundwater extraction and treatment.	Stabilizes and contains the MTBE groundwater plume on the currently Navy-owned property shortly after air sparging operation begins. Reduces and remediates MTBE and benzene in Site groundwater by air sparging.

Table 6-10. Summary Comparison of Remedial Alternatives (Continued)

Evaluation Factor	Alternative 1: Excavation and Dewatering	Alternative 2: Interception/Aeration Trench	Alternative 3: Collection Trench and Wells with Groundwater Pump and Treat and SVE	Alternative 4: Biosparging/Air Sparging
Impact on public health and welfare and the environment	Short-term risks exist to workers due to the heavy construction activities required for site excavation and backfilling. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility	Short-term risks exist to workers due to the heavy construction activities required to excavate and backfill the interception/aeration trench. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility.	Short-term risks exist to workers due to the heavy construction activities required to excavate and backfill the French drain. Transportation risks exist to off-site populations due to vehicle accidents, noise, and dust resulting from trucks used to move excavated soils to the disposal facility.	Short-term risks associated with this alternative are within those normally associated with light construction activities (e.g., well drilling and installing small-diameter pipe).
Cost	$15,735,000	$3,129,550	$2,912,400	$1,855,290
Time to Plume Stabilization (yrs)[(a)]	0.50	1.5	0.25	1.5
Time to Remediate to Basin Plan Requirements (yrs)[(a)]	0.50	10	3	7

(a) Estimated time to plume stabilization and remediation to Basin Plan requirements for Navy Property only. Because MNA is a common element of each alternative to achieve Basin Plan requirements on former HAAF property, the estimated time of 15 years to reach MCLs on former HAAF property is consistent between alternatives.

Section 7.0: DESCRIPTION OF RECOMMENDED REMEDY

This section describes the design, installation, operation, monitoring, performance criteria, and contingencies for the recommended remedy, biosparging. Additional detail also is provided for the common elements of monitored natural attenuation and institutional controls that will be implemented no matter which remedy was recommended. A schedule is provided to provide a timeline over which the corrective action can be implemented. Before installation activities of the corrective action are performed at the Site, a remedial design workplan will be issued for regulatory review and approval. The workplan will provide more details of actual system design and operation. Specific locations and schedules also will be provided for monitoring system performance and MTBE fate and transport.

7.1 Objective and Scope

As outlined in Section 5.3, the proposed ***final cleanup levels*** for Former UST Site 957/970 are to reduce MTBE concentrations to MCLs which should completely restore the groundwater resources at the Site to their potentially most stringent domestic beneficial use. Because risk assessments performed at the Site indicate that an immediate threat to human health or the environment does not exist, in compliance with Resolution 92-49, the proposed final cleanup standards must be achieved within a reasonable time that provides the maximum benefit to the people of the State of California.

The RAOs of this CAP are to stabilize and contain the MTBE plume on Navy property as required in RWQCB Order 00-064, and to substantially reduce the time to achieve the final cleanup levels (MCL concentrations) for all gasoline constituents at the Site, including benzene and MTBE, using a remedial technology that produces the greatest benefit to the people of the State of California considering the total values involved: beneficial and detrimental, economic and social, tangible and intangible. Performance goals will be established to determine specific concentrations that will be achieved through operation of the biosparging system and based largely on the performance of the air sparging system operated at the Site as an interim remedial action.

7.2 Recommended Corrective Action Alternative

Biosparging with system monitoring, MNA, and institutional controls are recommended as the corrective action alternative to achieve the RAOs at the Site. Biosparging will be used to stabilize and contain the higher concentrations of MTBE in groundwater currently on the Navy-owned portion of the Site. System monitoring will be performed during biosparging system operation to track: (1) the removal efficiency; (2) the estimated time until RAOs are met; and (3) the biodegradation capacity of the vadose zone. After the biosparging system has met its performance goals, the system will be shut down and groundwater monitoring will be performed to verify that concentrations do not rebound. If concentrations remain stable or decrease, indicating the MTBE plume has been stabilized and contained to Navy property, MNA will be used to attain MCLs over the entire Site (Navy-owned property and Former HAAF property). During remediation activities, investigative derived wastes will be managed as outlined in the Interim Site Control Plan (Battelle, 2001e). After the property is transferred, institutional controls will be in place to protect human health and the environment, and to allow the corrective action to progress without the interference of site operations on the property. The following subsections provide further detail for each element of the corrective action.

7.2.1 Biosparging With System Monitoring. In situ biosparging is recommended to stabilize and contain the higher concentrations of MTBE and further reduce benzene concentrations in groundwater currently on the Navy-owned portion of the Site. Biosparging is the injection of pressurized air directly into the aquifer. The injected air delivers oxygen to the groundwater and strips volatile compounds from

the groundwater. The air flows through permeable pathways in the saturated soil column driven toward the water table surface by buoyant forces. The shape and nature of the airflow pathways is determined by soil particle and sediment layering characteristics.

In situ biosparging removes hydrocarbons from saturated soil sediments by two primary mechanisms: (1) increased DO supports and enhances in situ biodegradation of hydrocarbons by indigenous microbes, and (2) volatile hydrocarbons partition into the vapor phase and are carried with the air stream to the vadose zone, where additional biodegradation occurs. The relative contribution of each of these removal mechanisms is dependent on site characteristics, contaminant type and concentration, system design, and operational parameters. The operation of the sparging system will be focused on enhancing the biodegradation of hydrocarbons by injecting the air at relatively low flowrates. The vapor stream reaching the vadose zone will be a biologically reactive mixture of hydrocarbons and oxygen that microbes can utilize based on the results of aerobic treatability studies performed with Novato site-specific media (Battelle, 2001d). Indigenous soil bacteria aerobically respire using oxygen as an electron acceptor and the hydrocarbons as an energy and carbon source. The soil volume in which this degradation occurs is referred to as an in situ bioreactor that in many cases can be exploited and optimized to effectively destroy the vapor stream (see Figure 7-1). The ability of the vadose zone to degrade residual vapors, its biodegradation capacity, is dependent on the type and number of indigenous soil microbes, the type and concentration of hydrocarbon, and the physical characteristics of the vadose zone soils (depth, porosity, specific surface area, heterogeneity, and anisotropy). Aerobic laboratory microcosms made of Novato soils and groundwater showed complete MTBE removal without breakdown product (TBA or TBF) accumulation (Battelle, 2001d); therefore, if the vadose zone soils can be exploited to destroy the residual vapor stream, no vapor collection and treatment systems will be required. However, SVE wells will be installed with the biosparging system to collect vadose zone vapors in the event that the in situ bioreactor is unable to sufficiently destroy the residual vapor stream.

The following subsections discuss design considerations, installation activities, and operations and monitoring requirements for the biosparging system. Also, the performance criteria and SVE contingency plan are explicitly defined for biosparging system operation.

7.2.1.1 Design. The biosparging system will be designed with flexible system controls that allow optimization of the system to achieve the maximum attainable rate of removal via the biological mechanisms described above. Deep soil-gas monitoring probes and groundwater monitoring wells will provide feedback regarding in situ conditions and enable informed decision-making for parameter adjustment. Figure 7-1 shows a conceptual diagram of the biosparging system. The actual locations of sparge wells, SVE wells, soil-gas monitoring probes, and groundwater monitoring wells will be based on site characteristics found during the system installation phase. Table 7-1 outlines the approximate number of subsurface installations and the objective of each. The following subsections provide a general description of design parameters considered for the biosparging system. A complete work plan that provides more specific design information will be produced before installing the system at the Site.

7.2.1.1.1 Design Objectives. The biosparging system will be designed to contain the MTBE-impacted groundwater on Navy-owned property and remove MTBE mass from areas with the highest inventory of MTBE. Benzene concentrations in areas within the system footprint also will be reduced. Sparge wells will be placed in the more permeable, sandy intervals of the subsurface, where preferential flowpaths for groundwater transport have been shown to exist. Much data was collected during the CPT investigation of September 2000 for interpretation of the subsurface lithology in the area east of Building 971 (Battelle, 2001b). Groundwater samples collected from the sandy intervals located east of Building 971 indicate that MTBE concentrations are higher within the zones of higher permeability (see Section 4.1.2). Therefore, installation of the biosparging system will focus on these areas of greater permeability to increase the removal efficiency of the system.

7.2.1.1.2 General System Design. The biosparging system will be designed to deliver at least 25 pounds per square inch (psi) air pressure and 10 cfm airflow rate per sparge well. However, the operational flowrate will be more on the order of 2-6 cfm airflow rate per sparge well to enhance aerobic biodegradation. The equipment layout will be designed to provide an effective framework for meeting the overall design requirements. All equipment will be located and installed in a manner to facilitate simple operation of the biosparging system with efficient utilization of available space. One operation and support building (OSB) will be required to house the equipment for the biosparging system. Either a new OSB will be constructed for the biosparging system (as shown in Figure 7-1) or an existing OSB that was used during the IAS/SVE interim remedial action will be used. One Quincy QRDS-15T1020, 15-hp, 208V three-phase, oilless air compressor is still located at the Site from the interim remedial action. This compressor or a regenerative blower will be used to inject air into each of the sparge wells.

7.2.1.1.3 Sparge Wells. The design objective for the sparge wells will be the effective distribution of compressed air into the subsurface. The sparge wells will be designed to accommodate the required airflow and delivery pressure for the system layout design objectives. Each sparge well will be designed for flexible operation, enabling injection of a range of flowrates under a range of pressures. This flexibility is required to construct a system that is capable of varying operations parameters due to varying field conditions.

Sparge wells installed at Former UST Site 957/970 for the biosparging system will be constructed of 1-inch schedule 40 PVC. Table 7-1 provides specifics for sparge well installation including materials, approximate number, and approximate depth of sparge well installations. Figure 7-2 shows the design details for a typical sparge well.

Preliminary design of the biosparging system calls for a barrier of sparge wells to be installed in proximity to the Navy property boundary (see Figure 7-1). The sparge wells within the barrier will be placed in a relatively narrow channel of more permeable soil deposits (see Section 4.1.2) to treat groundwater as it passes through the barrier, thereby allowing only treated groundwater that is being transported within the preferential flowpath to pass across the Navy property boundary. Sparge wells will also be within the areas of higher permeability, upgradient of the sparge barrier, to decrease the highest concentrations of MTBE and accelerate the remediation process. Approximately 40 sparge wells are planned for the initial installation phase. Additional sparge wells would be installed after the initial installation phase if routine biosparging system operation indicated performance goals might not be achieved within the anticipated time frame. The number of sparge wells that may be added is not known and would depend on how effectively the initial sparge wells performed. It is possible the initial sparge wells would prove to be very effective and that no additional wells would be necessary.

7.2.1.1.4 Vapor Migration Control/Soil Vapor Extraction. The design objective for the SVE wells will be the adequate control of soil vapors caused by air injected by the biosparging system. Based on the results of aerobic microcosm studies (Battelle, 2001d), it is expected that the biodegradation potential of the indigenous microbes at the Site is great enough to completely destroy residual vapors before the vapors are able to migrate to the surface or off site. However, in the event that residual vapors pose a potential risk to nearby receptors (i.e., day-care center and former commissary Building 971), SVE will be initiated to manage the migration and emission of volatilized gasoline constituents. The forced removal of vapors from the vadose zone by SVE will control the migration of vapors. The contingency SVE system components (SVE wells and piping network) will be installed with the biosparging system and will be in place if needed. Figure 7-1 shows approximate locations where contingency SVE wells may be placed during system installation. However, the actual location of SVE wells will be based on site characteristics found during installation. Existing SVE wells that are located within the treatment area (see Figure 7-1) may also be used if necessary to recover soil-gas during biosparging system operation.

The SVE wells will consist of 2-inch-diameter schedule 40 PVC screened from 3 ft bgs to the lowest recorded water table depth (see Table 7-1). Figure 7-3 shows the design details for a typical SVE well.

7.2.1.1.5 Soil-gas Monitoring Probes. Monitoring probes are devices that allow for collection of soil gas from discrete depths. The sampling screens are isolated from each other by using sealant material, usually bentonite, to prevent gas from short-circuiting through the borehole annulus from unwanted locations. The soil-gas monitoring probes will be designed to enable collection and analysis of soil-gas samples from discrete intervals. Data collected from the monitoring probe, such as soil-gas hydrocarbon and oxygen concentrations, will allow the system operator to monitor the effectiveness of the biosparging system. Two different types of soil-gas monitoring probes will be installed at the Site as part of the corrective action: (1) shallow soil-gas monitoring probes to monitor hydrocarbon concentrations between the treatment area and potential receptors; and (2) deep soil-gas monitoring probes to monitor the biodegradation potential within the bioreactor located within the treatment area. Figure 7-1 shows the approximate number and locations where shallow and deep soil-gas monitoring probes will be installed at the Site. Figure 7-1 provides a conceptual diagram of the biosparging system in relation to the placement of each type of soil-gas monitoring probe. As shown in Figure 7-1, the deep soil-gas monitoring probes will be located within the bioreactor to determine its effectiveness and the shallow soil-gas monitoring probes will be located between the biosparging treatment area and potential receptors.

The monitoring probes will be completed at the surface to provide adequate protection for the sampling ports located at the top of the monitoring probe, through the use of vaults (or flush mounts) and caps to protect the quick couplers. Figure 7-4 details the construction of the soil-gas monitoring probes. Materials that will be used to construct the soil-gas monitoring probes and data objectives of each type of monitoring probe are outlined in Table 7-1.

7.2.1.1.6 Performance Goal Groundwater Monitoring Wells. Standard groundwater monitoring wells will be installed in the treatment area to enable the operator to monitor changes in hydrocarbon and DO concentrations. The monitoring wells will be constructed of 2-inch schedule 40 PVC with a screen slot aperture of 0.010 inch and a screened interval extending from approximately 8 to 18 ft bgs. Refer to Table 7-1 for monitoring well construction details, materials that will be used to install the wells, and the approximate number of monitoring wells that will be installed. Construction details for a typical groundwater monitoring well are shown in Figure 7-5. The groundwater monitoring wells installed with the biosparging system will be used to track the biosparging system performance, and will be installed within the preferential groundwater flowpath, if practicable (see Figure 7-1). Actual locations of groundwater monitoring wells will be based on site characteristics found during installation. Specifics regarding the performance criteria and monitoring that will be performed to track remedial progress are discussed in Section 7.2.1.4.

7.2.1.2 Installation. All subsurface installations will be performed in accordance with the Site Health and Safety Plan (HASP) (Battelle, 1998a). The locations of all monitoring wells, monitoring probes, and system wells will be surveyed and included in future project reports. The following subsections give a general description of drilling and assembly activities for the biosparging system. A complete work plan that provides specifics of the biosparging system installation activities will be produced before installing the system at the Site.

7.2.1.2.1 Drilling. A licensed drilling company will conduct all drilling. Prior to beginning any drilling activities at the Site, well permits and a traffic diversion permit will be obtained, and all locations will be located and cleared of utilities.

Either the site supervisor or a delegate will identify the location of the proposed installation. The drill rig will be guided onto the location with care given to obstructions on the ground and overhead. An HSA with and asphalt bit will be used to break through the existing pavement (typically asphalt) until native soil is encountered. A hand auger will be used to bore to 3 ft below the asphalt to ensure safe drilling through the soil zone in which most utilities and piping typically are encountered. If the hand-augered hole is advanced without encountering any obstructions, a split-spoon corer will be used to collect a 2-ft soil core sample. The spoon holding the soil core will be broken open on an examination table at the surface, and a geologist will identify the various soil layers contained therein. All layers identified will be recorded with their corresponding location and depth in the field logbook. After the core sample has been collected, the HSA will be used to drill the borehole through the last cored sampling depth. At that point a clean split-spoon assembly will be used to collect the next 2-ft core sample. Drilling will proceed with soil samples being collected in 2-ft increments to identify the soil lithology within the treatment area.

Wells will be installed to the depths and constructed of the materials described in Table 7-1. Construction specifics for sparge wells, SVE wells, soil-gas monitoring probes, and groundwater monitoring wells are presented in Sections 7.2.1.1.3, 7.2.1.1.4, 7.2.1.1.5, and 7.2.1.1.6 respectively. Wells that are located in high traffic areas (i.e., within C Street) will be finished below grade and system materials will be plumbed to the well in subsurface trenches (i.e., buried). All wells located outside traffic areas will be flush mounted.

All soil cutting generated from the subsurface installations will be containerized and disposed of according to regulatory requirements as described in the Interim Site Control Plan (Battelle, 2001e).

7.2.1.2.2 Assembly. After all subsurface locations are installed and constructed within the treatment area, the materials required for the biosparging system operation will be assembled. System controls, which will effectively control air delivery pressure and flowrate to each sparge well individually, will consist of the following equipment: a shutoff valve, a pressure regulator/gauge, a pressure relief valve, and an airflow meter. Sparge wells will be connected to the system controls via ½-inch airline hose. The ½-inch airline hose will be contained in a PVC protective manifold.

If SVE operation is required, the SVE wells will be manifolded to a feeder pipe that will conduct the vapor through an extraction blower. A detachable water knockout vessel will be placed inline to remove gross moisture from the extracted vapor stream prior to the blower. The vapor will be forced through an appropriate treatment system (either internal combustion engine [ICE], thermal or catalytic oxidizer, or GAC) prior to discharge. Each pipe leading from an SVE well will be fitted with a flowmeter and a sampling port to facilitate monitoring of extracted vapor concentrations and flowrates.

7.2.1.3 Operations and Monitoring. Operation of the biosparging system will consist of maintaining air injection at the desired rates and monitoring concentrations of oxygen and hydrocarbons in situ. The total operational period will depend on reaching the performance criteria outlined in Section 7.2.1.4.

Before the biosparging system operation is initiated, groundwater levels in nearby monitoring wells will be recorded and groundwater samples will be collected from the performance compliance monitoring wells to determine preremediation conditions within the treatment area. Also, initial TPH, oxygen, and carbon dioxide measurements will be performed at the soil-gas monitoring locations. After the baseline conditions are established, biosparging system operation will begin.

The first phase of operation will be a shakedown period to identify and correct installation and construction weaknesses. This phase will be followed by a preliminary operation phase in which the system will be monitored as the various fluid transport mechanisms reach equilibrium. Once equilibrium

is achieved, routine operations will begin, during which only minor adjustments will be made to flow and pressure settings in order to maintain effective mass removal.

7.2.1.3.1 Shakedown. Operation will commence immediately after system installation with a shakedown phase that will test the system at its design limits. All sparge wells will be operated at their design capacity. In this phase of operation, leaks and failures are encouraged to detect weaknesses in the components. The problems will be corrected with mechanical alterations and administrative controls. The system will be checked to ensure all equipment is operating properly. All joints and fittings of the pressurized air distribution system will be leak tested. Water table levels, air injection pressures and flowrates, and in situ soil-gas concentrations will be monitored intensely as system parameters are changed during this period. The shakedown phase will last approximately two weeks.

7.2.1.3.2 Routine Operations. After the shakedown phase is complete and the transport mechanisms have reached equilibrium, routine monitoring operations will begin. Operational parameters that will be monitored are outlined in Table 7-2. The schedule of monitoring operational parameters will vary during the duration of system operation. During the shakedown phase, operational parameters will be regularly monitored throughout the day to determine ranges of fluctuation. As the transport mechanisms reach equilibrium and the routine operation phase begins, the operational monitoring schedule will be less frequent. The monitoring schedule may cycle from daily, to three times per week, to weekly, and to bimonthly as system operation progresses. The objective of monitoring during routine operations is to detect fluctuating conditions that require the adjustment of system parameters to maintain effective mass removal. More specifics of the operational monitoring schedule will be provided in a work plan produced before the system is installed at the Site.

Soil-gas monitoring probes placed at deep depths within the treatment area and shallow depths along the pathway between the treatment area and potential receptors will be sampled during routine system operation. Field instruments will be used to regularly monitor concentrations of TPH, oxygen, and carbon dioxide at both types of soil-gas monitoring probes to identify changing conditions in the vadose zone. Soil-gas samples will be collected and analyzed for BTEX, MTBE, and MTBE breakdown products (TBA and TBF) at an analytical laboratory. The schedule for monitoring and collecting soil-gas samples will be more frequent at the beginning of system operation and less frequent after the first month or two of operation. Again, more specifics of the monitoring schedule will be provided in a work plan produced before the system is installed at the Site.

Routine system operation will focus on removal of MTBE from the groundwater in and around the sparging barrier area (see Figure 7-1) to stabilize and contain the MTBE to currently owned Navy property, while concurrent treatment is performed within the MTBE hot spot (current MTBE concentrations > 10,000 µg/L). During system operation, groundwater samples will be collected from the performance criteria monitoring wells (see Figure 7-1) and analyzed for BTEX, MTBE, and MTBE breakdown products (TBA and TBF) to determine the removal efficiency. Based on historical groundwater monitoring results for the Site, TBA and TBF should only be observed at very low concentrations relative to the parent compound MTBE. It is not suspected that biosparging system operation will promote the accumulation of TBA or TBF because the results of the aerobic microcosm studies (Battelle, 2001d) showed that the breakdown products attenuated similarly to MTBE, and quarterly monitoring has not shown these compounds to accumulate in the aquifer as MTBE is destroyed. However, groundwater monitoring will be performed to verify that the breakdown products are not present at elevated concentrations compared to MTBE, nor that they are accumulating as a result of aerobic biodegradation of MTBE.

246

It is estimated that approximately one year of routine system operation and monitoring will be performed before the RAOs are met at the Site. The performance goals are defined in the following section.

7.2.1.4 Performance Goals. The biosparging/air sparging system can be expected to perform similarly to the IAS system that was operated as the interim remedial action, once some important differences between the two systems are considered, and the expected performance is adjusted for those differences. The biosparging system will be operated at a slightly lower air injection rate than the IAS because its primary objective is the biological destruction of hydrocarbons in a soil region distant and separated from potential aboveground receptors.

In fact, the IAS system was designed and intended to operate at a much greater air injection rate than was actually achieved, but the heterogeneity of soil deposits resulted in many sparge wells being installed in relatively tight soils. Design (or intended) flowrates could not be achieved in many of these air injection wells because of the relatively low permeability in the surrounding soils. At other IAS system air injection wells, greater flowrates were achieved at relatively low backpressures because they were installed in more permeable soil regions. It is impossible to determine where the more and less permeable soil regions are on a small scale in the subsurface without a focused geological investigation to predetermine these features.

The Navy has performed such a focused geological investigation in the area in which the biosparging system wells will be installed in a barrier configuration. This investigation revealed a relatively narrow channel of more permeable soil deposits just south of the Navy property boundary and through which most of the groundwater containing MTBE is suspected to flow (see Section 4.1.2). The biosparging system design will focus on this permeable channel and form a sparging curtain or barrier to treat groundwater as it passes through the formation.

To ensure that containment of the MTBE plume on Navy property is achieved, MTBE concentrations will be reduced by multiple and overlapping sparging curtains. This will be accomplished by a much more dense well distribution in the region just south of the property boundary than was used in the IAS design for the interim remedial action. A less dense well distribution will be used upgradient of the sparging curtain or barrier to remove elevated concentrations of MTBE (and other hydrocarbons) at an accelerated rate.

An estimate of the expected performance from the biosparging system was prepared by considering the rate of MTBE removal achieved by the interim remedial action IAS, and adjusting it for the differences between that system and the recommended biosparging system. The target compound for the biosparging design is MTBE because it has advanced further downgradient than other gasoline constituents; it is likely to be biodegraded more slowly and stripped less effectively than benzene or other hydrocarbons. Summarizing the discussion in the paragraphs above, the factors considered in estimating the expected performance of the biosparging system were:

- Decreased uncertainty regarding character of soil deposits in area of biosparging curtain or barrier
- Increased soil permeability in area of biosparging curtain or barrier
- Increased air sparging well distribution density
- Lower hydrocarbon concentrations (decreases air stripping mass removal rate for a given air injection rate and decreases expected biodegradation rates)

- Biodegradation was observed to be more rapid in Novato saturated soils where only MTBE was present (and other hydrocarbons were not present)
- Average air injection rate per well equivalent to IAS (or slightly less)
- Similar treatment duration targets
- Similar air injection well design.

Assuming that a first order removal rate expression approximates actual system behavior, the concentration decreases observed in the IAS treatment area correspond to an overall removal rate (k) of 0.0042/day during the interim remedial action. First order removal rates are rates that vary proportionally with the current concentration. At greater concentrations removal rates measured in mass per unit time are greater, and when concentrations are lesser, the removal rates diminish. Note that this overall removal rate includes physical, chemical and biodegradation removal mechanisms as observed in monitoring wells. The overall removal rate of 0.0042/day is therefore the rate that will be adjusted to estimate the performance expected from the biosparging system.

It is estimated that the biosparging system in the recommended configuration will achieve a removal rate (k) approximately two to three times that of the IAS for the reasons discussed above. The greater removal rate is likely to yield reductions measured as absolute mass per unit time at a slower rate because of the lower initial concentrations of MTBE currently observed at the Site, compared to the much greater MTBE concentrations that were observed when the IAS was started in 1998. Nevertheless, if the system behaves similarly to the first order model, an overall biosparging removal rate of two times the IAS rate (or 2k) would be expected to result in approximately 95% reduction in concentrations over one year, and an overall biosparging removal rate three times the IAS rate (3k) would be expected to reduce concentrations by about 99% in a year. This range of rates would be expected to remove 51 to 53 kg of the 54 kg of MTBE estimated to be dissolved in groundwater on the Navy portion of the Site (May 2001 estimate) and reduce concentrations by almost two orders of magnitude.

Figure 7-6 illustrates the estimated concentration trends that would be expected given the assumption that the initial average concentration of MTBE in the performance goal monitoring wells is 30,000 μg/L. If system groundwater monitoring reveals that MTBE concentrations are decreasing at a rate substantially below this range (or staying at concentrations near the currently observed concentrations), the biosparging system design would allow for adjustments to improve performance, including:

- Installation of additional sparge wells in selected areas
- Increasing the air injection rate to add more oxygen and increase stripping (this contingency action would be accompanied by careful and frequent soil-gas monitoring to ensure that shallow soil gas between the system area and potential receptors does not exceed a safety threshold)
- Cycling air injection on and off to increase the zone of influence achieved by the system.

Monitoring System Performance. The effect of the active biosparging system barrier and other sparge wells intended to reduce plume concentrations, coupled with natural attenuation mechanisms, the effects of which are already observable at the Site, will overcome the tendency of advection to carry MTBE off-site, and will eliminate flux at the property boundary. This effect is consistent with a stable and contained MTBE plume and will be confirmed by groundwater monitoring to demonstrate rapidly declining concentrations in wells near the property boundary.

The performance goal of a removal rate of 0.0084/day (2k) to 0.0126/day (3k) will be confirmed by monitoring wells that will be installed in the treatment area just south of the property boundary on Navy property. Data from samples collected from sparging wells will not be considered adequate to confirm achievement of this performance goal. Approximately five system monitoring wells placed in the permeable flow channel south of the railroad tracks will provide critical performance data on the water quality just south of the Navy property boundary (see Figure 7-1). The actual location of the wells will be determined based on site characterization data found during installation. In addition, three existing monitoring wells at the site will be used to provide performance data, as requsted by the RWQCB. All performance goal monitoring wells will be sampled monthly during system operation to provide adequate data to evaluate the concentration trend over time and to ensure these trends reflect the expected system performance.

The monitoring wells just south of the Navy property boundary are proposed to provide data regarding the quality of the groundwater that is about to cross the boundary in the permeable channel, whereas some existing monitoring wells are screened in tighter, less-permeable soils which may not represent the quality of groundwater leaving the Site. The current groundwater monitoring program will be continued to view changes in behavior of the MTBE plume as a result of biosparging operation. However, it is not reasonable to expect MTBE concentrations in all monitoring wells located near the Navy property boundary to rapidly decrease due to biosparging operation, or any other viable groundwater treatment alternative, because some wells are placed in tighter, clayey soils that will release MTBE primarily by diffusion. The biosparging system will indirectly treat the MTBE in clayey soils, by establishing a greater concentration gradient, thus increasing the rate of diffusion.

Monitoring for Achievement of RAOs. In addition to collecting groundwater from system monitoring wells for tracking biosparging system performance, groundwater samples will be collected from some existing monitoring wells located within the treatment area to track the behavior of the MTBE plume upgradient (south) of the sparging curtain. Biosparging system operation will focus on achieving a stable or decreasing MTBE plume on Navy property, which is considered the RAO that will dictate the duration of operations. It is expected that this objective will be achieved following approximately one year of biosparging system operation.

The status of the MTBE plume on Navy property will be evaluated by analyzing the behavior and size of the MTBE plume during the biosparging operation. When monitoring data from the performance goal monitoring wells near the property boundary and upgradient in areas with currently elevated MTBE concentrations indicate that the MTBE plume has been contained and stabilized, the biosparging system will be shut down. Groundwater monitoring will then be performed monthly in selected wells for two quarters to confirm that rebound does not occur and threaten compliance with RAOs.

A stable to decreasing plume is defined as one that shows stable to decreasing concentrations in monitoring wells over time. A stable plume will be demonstrated by showing generally decreasing MTBE concentrations in groundwater after biosparging system shutdown. A contained MTBE plume will be confirmed by the observation of MTBE concentrations off-site declining at a rate consistent with the natural attenuation rates already observed throughout the plume, indicating that net flux has been eliminated.

Once a stable and confined MTBE plume is confirmed at the Site, benzene concentrations in groundwater are below RBSLs (410 µg/L), and MTBE concentrations on Navy property are substantially reduced, RAOs will be considered achieved, and groundwater monitoring objectives will focus on the progress of MNA toward achieving final cleanup levels.

7.2.1.5 SVE Contingency. It is recognized that biosparging operations, although intended to destroy hydrocarbon vapors in deeper soil layers, require that soil gas monitoring be performed to ensure that hydrocarbon vapors are not allowed to migrate near potential receptors. A series of shallow soil-gas monitoring probes will be installed (as shown in Figure 7-1) and sampled during biosparging operations to ensure that hydrocarbon concentrations are not elevated beyond a safety threshold. The safety threshold is defined as hydrocarbon concentrations in shallow soil-gas monitoring probes at or below soil-gas concentrations that were used as input values for the PBC Area in the *Final Revised Risk Assessment* (Battelle, 2001c). The risk assessment concluded that existing conditions in the PBC Area at the Site were acceptable for residential use over a 30-year time frame; therefore, because hydrocarbon concentrations are being used that were determined to protect residential receptors over 30 years, and the estimated duration of biosparging operation is short (one year), the health of potential receptors will be protected by the safety threshold. The safety threshold hydrocarbon concentrations in soil gas, along with the EPA-approved analytical methods and detection limits are presented in Table 7-3.

The shallow soil-gas monitoring probes will be monitored to allow adjustments to be made to the biosparging system operating parameters, such as injection rate or cycling frequency, in the event that concentrations are elevated beyond the safety threshold. If adjusting system operating parameters is unable to maintain shallow soil-gas concentrations below the safety threshold, the contingency soil vapor extraction system will be initiated. Figure 7-7 is a flowchart outlining the initiation, operation, and shutdown of the SVE contigency.

The contingency SVE system components (SVE wells and piping network) will be installed with the biosparging system and will be in place if needed. If the SVE contingency is initiated, a vapor treatment system will probably be required until it can be demonstrated that extracted vapors are below some *de minimus* loading rate as determined by the BAAQMD, the agency that enforces Permits to Operate for air dischargers. The existing Permit to Operate for the Site will be renewed or if required, a new one will be procured through the BAAQMD. It is likely that operating the contingency SVE system will provide greater flexibility in the air injection rate, and therefore, may enable greater removal rates to be achieved.

During the operation of the interim remedial action SVE system, it was learned that vadose zone soils, in which SVE wells are installed to collect soil vapor, are generally tighter than the saturated deposits at the Site. It is typically desirable to achieve a total SVE extraction rate two to four times the total volumetric air injection rate; however, the interim remedial action system achieved satisfactory vapor capture, as measured by soil-gas monitoring and a helium capture efficiency test, while only achieving a total extraction rate about the same as the total air injection rate. The heterogeneous deposits are a likely explanation for this observation because vapors are more likely to travel though permeable soil features than to generally disperse in the subsurface.

The performance goal of the contingency SVE system, if initiated and operated, is to maintain soil-gas concentrations as measured in shallow probes to below the safety threshold level, and to comply with air discharge permits, if applicable. In the event that shallow soil-gas concentrations exceed the safety threshold level, action will be taken to correct the condition. If this condition continues, the system will be shut down and the RWQCB will be notified of corrective measures required to maintain soil-gas concentrations below the safety threshold.

7.2.2 MNA. Active remediation of the entire volume of hydrocarbon-impacted groundwater under the Site is not required by the risk levels at the Site (see Section 2.4) and would involve an excessive resource commitment that would not result in the greatest benefit to the people of the state. Biosparging is recommended to achieve the RAOs as described in Section 5.3. However, gasoline constituent levels will remain above MCL concentrations outside of the active treatment area and will require further

consideration. MNA has been selected as a supplement to the biosparging system for remediation of remaining concentrations of gasoline constituents to achieve final cleanup levels throughout the gasoline constituent plume (see Section 5.3).

Implementation of MNA as a remediation technology at the Site will entail a comprehensive groundwater monitoring program to provide data to evaluate intrinsic biodegradation, and to monitor the extent of the plume as a function of time. Analyzing the behavior and size of the MTBE plume over time and calculating the total mass of MTBE on and off the currently Navy-owned property will track progress of MNA and assess the status of the plume. Sampling and analysis will be performed to evaluate the effectiveness of MNA over the entire site, including former HAAF property north of the currently Navy-owned portion. Sampling will be conducted in the monitoring wells using the same methods established in the GMP for monitoring wells already located at the Site (Battelle, 2000a). The Site GMP (Battelle, 2000a), required under Task 5 of Order No. 00-064, will be modified to include specific MNA sampling procedures and schedules before the MNA phase of the corrective action begins.

MTBE in Pacheco Creek (refer to Sections 5.2.4 and 5.2.5) will be addressed by achieving the RAOs discussed in Section 5.3. As the MTBE plume is contained to the Navy property boundary, MTBE concentrations observed in Pacheco Creek will decrease rapidly because of mechanisms such as aerobic biodegradation, photodegradation, volatilization, and flushing. Because Pacheco Creek is located downgradient (north) of the Navy property boundary, immediate reductions of MTBE concentrations observed in Pacheco Creek are not expected due to the travel time required for groundwater passing through the biosparging barrier. Once treated groundwater reaches the point where contact is made with the creek, concentrations in the creek are expected to decline rapidly toward MCLs. Surface water monitoring will be performed to verify that MTBE concentrations are decreasing in Pacheco Creek.

Existing groundwater monitoring data was evaluated to determine the approximate decrease of MTBE concentrations at the Site over time. Assuming a first order removal rate expression approximates that actual biodegradation of MTBE resulting from natural attenuation mechanisms, the removal rate (k_{MNA}) of MTBE is 0.0017/day. If current trends continue as expected, MNA will require approximately 15 years to reach MCLs on former HAAF property and 7 years to reach MCLs on the Navy-owned portion of the Site (after achieving biosparging system RAOs).

7.2.3 Institutional Controls. As described in Section 6.2.1.3, institutional controls will be a component of the selected corrective action. The objectives of the ICs are twofold: to ensure that commercial use of the land at the gas station site (immediate area surrounding Building 970, shown in Figure 1-3) is maintained and that residential use is prohibited in that area; and to ensure that future actions over the entire site do not affect the gasoline constituent groundwater plumes.

The primary legal mechanism used to implement land use controls will be restrictions included in the quitclaim deeds for the subject property.

The following restrictions and controls will apply to the entire Site[3]:

- Construction and/or operations on the property shall not interfere with the ongoing monitoring or assessment of work being conducted by or for federal, state, or local regulatory agencies.

[3] The Site comprises an area of approximately 13 acres, bounded on the south by Main Entrance Road, and on the north by a set of Golden Gate Company railroad tracks (refer to Figure 1-2). The eastern border of the site runs north-south from the intersection of Main Entrance Road and C Street, and the western border of the site runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street.

- Removal and disposal of contaminated soil or groundwater by the transferee, its successor or assigns, shall be conducted in accordance with all applicable federal, state, and local regulations governing removal, transport, and disposal of hazardous substances and hazardous waste.

- Disturbance of existing groundwater wells is prohibited unless specifically approved by the Navy and the RWQCB. No groundwater production wells may be installed for residential, municipal, agricultural, or industrial use, without written approval of the RWQCB. Monitoring and other test wells are not subject to this provision, including borings for the purpose of testing wells, wells for monitoring the quality of groundwater, and borings to define geology.

In addition to the above restrictions and controls, the following will be applied to the Sale Area[4] (see Figure 1-3):

- Construction and occupation of residential structures or day-care centers is prohibited.

The United States will retain the right to enter and inspect the property to ensure the viability of the selected institutional controls or to perform any additional response actions. In the deeds affecting transfer of the property, the State of California also will be given such right to enter and inspect the property.

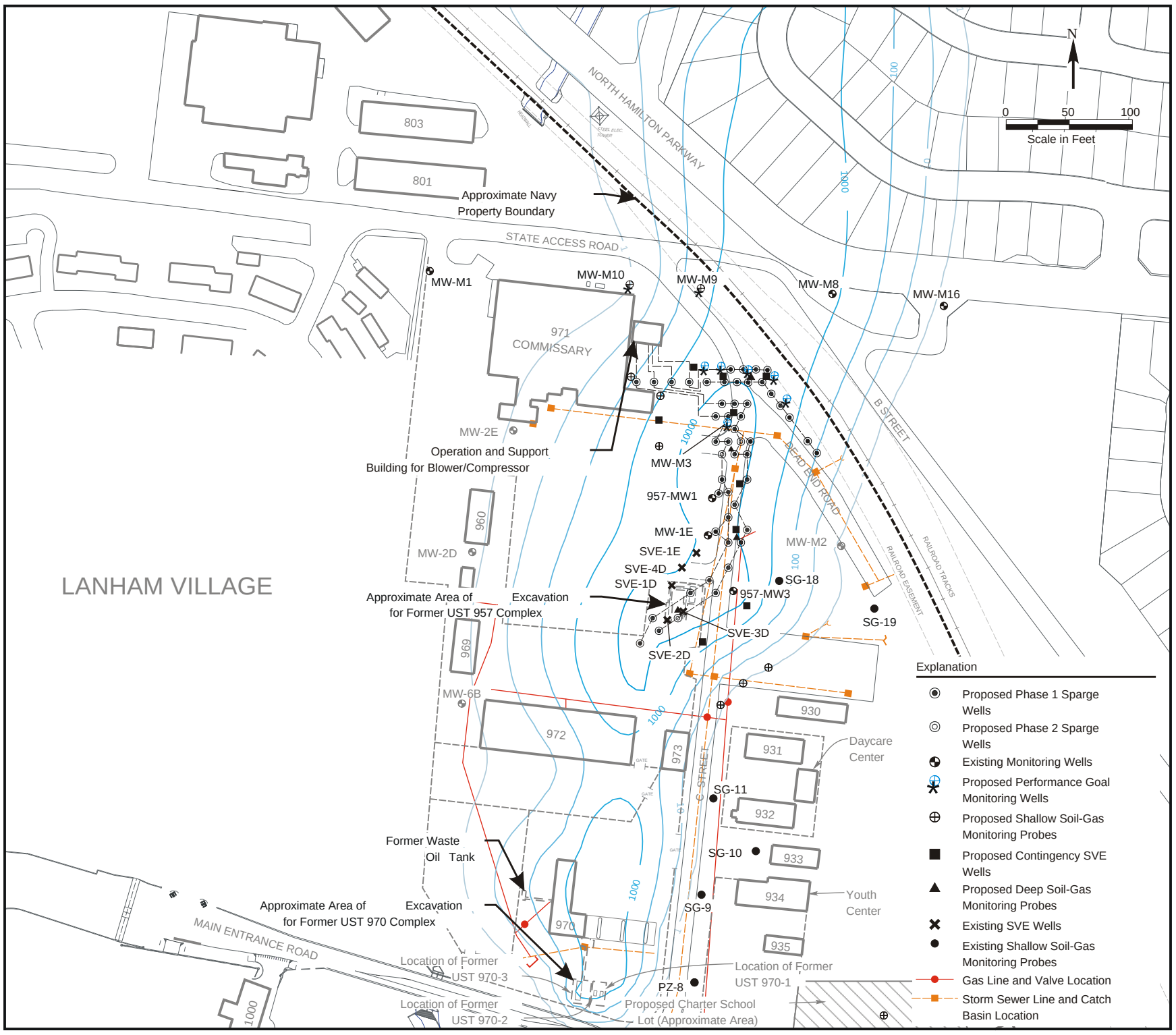
In addition to institutional controls, the DON is willing to enter into an agreement with the State of California, through the DTSC and RWQCB, allowing the State pursuant to the California Civil Code Section 1471 to enforce the restrictions on the use of property for the purpose of protecting human health, safety, and the environment. Such a covenant would be based on the models attached to a March 2000 MOA executed by the DON and the DTSC. This covenant would list environmental restrictions and would serve as the primary legal mechanism to enforce restrictions. Once the covenant is finalized, it will be executed contemporaneously with the negotiation and execution of the conveyance or assignment of the property.

In addition, the DON shall include the same environmental restrictions in the deed between the United States and the transferees pursuant to the California Civil Code Section 1471. These restrictions shall be consistent with restrictions set forth in this CAP and any covenant entered into between the DON and DTSC for the Site. Please refer to Section 6.2.1.4 for more information pertaining to the land use covenant.

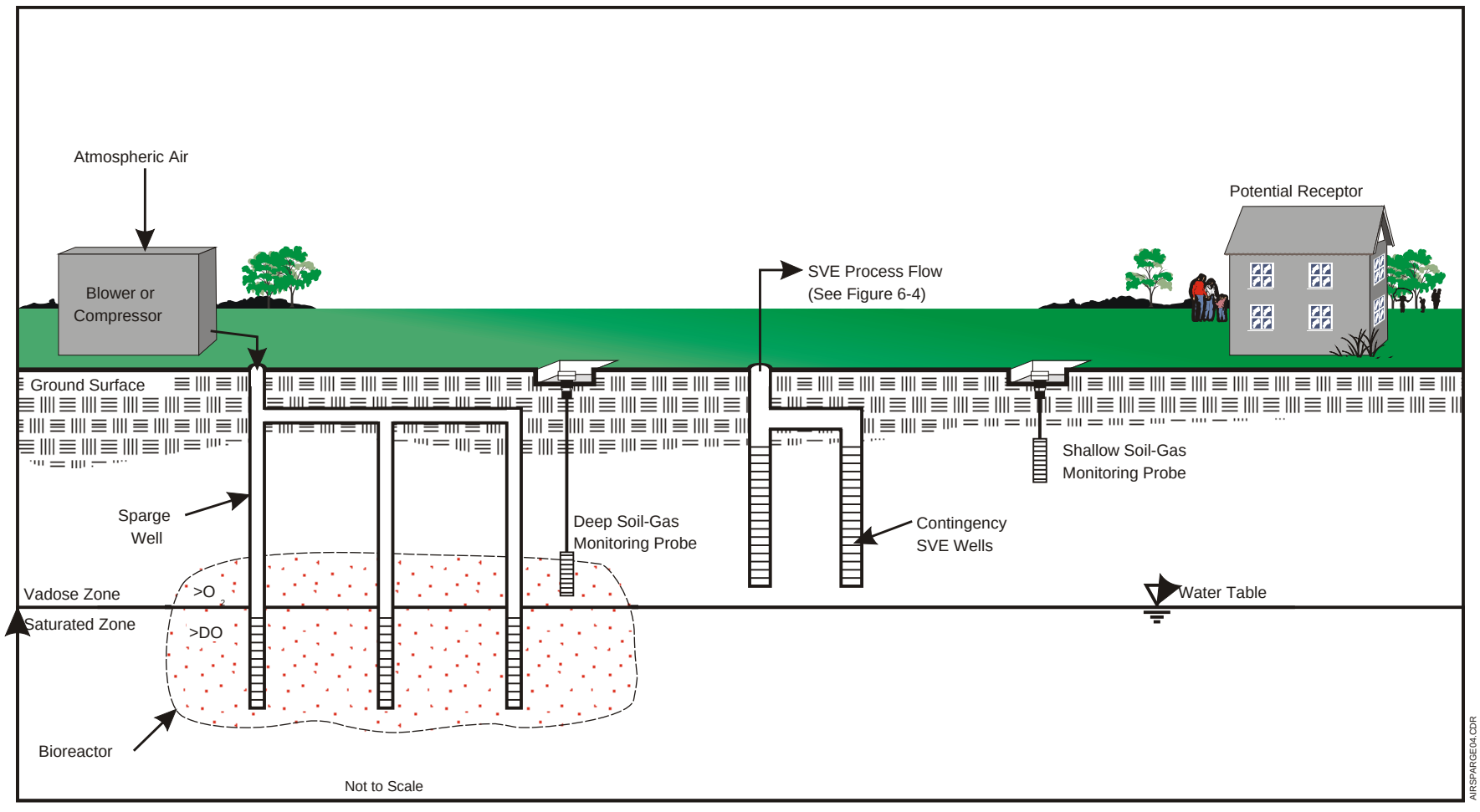
7.3 Schedule. Figure 7-8 presents a tentative schedule of activities to be performed in association with the recommended corrective action. A final schedule will be developed following public and regulatory concurrence with the CAP and will be documented in the system design and work plan to be prepared prior to the initiation of biosparging system installation activities at the Site.

[4] The Sale Area comprises an area of approximately 2 acres, bounded on the south by Main Entrance Road, and on the north by Public Benefit Conveyance Parcel 1 (refer to Figure 1-3). The eastern border of the Sale Area runs north-south from the intersection of Main Entrance Road and C Street, and the western border of the site runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street.

Figure 7-1. Conceptual Diagram for Biosparging at Former UST Site 957/970



Conceptual Plan View of Bio Sparging/Air Sparging Configuration at Former UST Site 957/970



Conceptual Diagram of Profile View for Bio Sparging/Air Sparging Configuration at Former UST Site 957/970

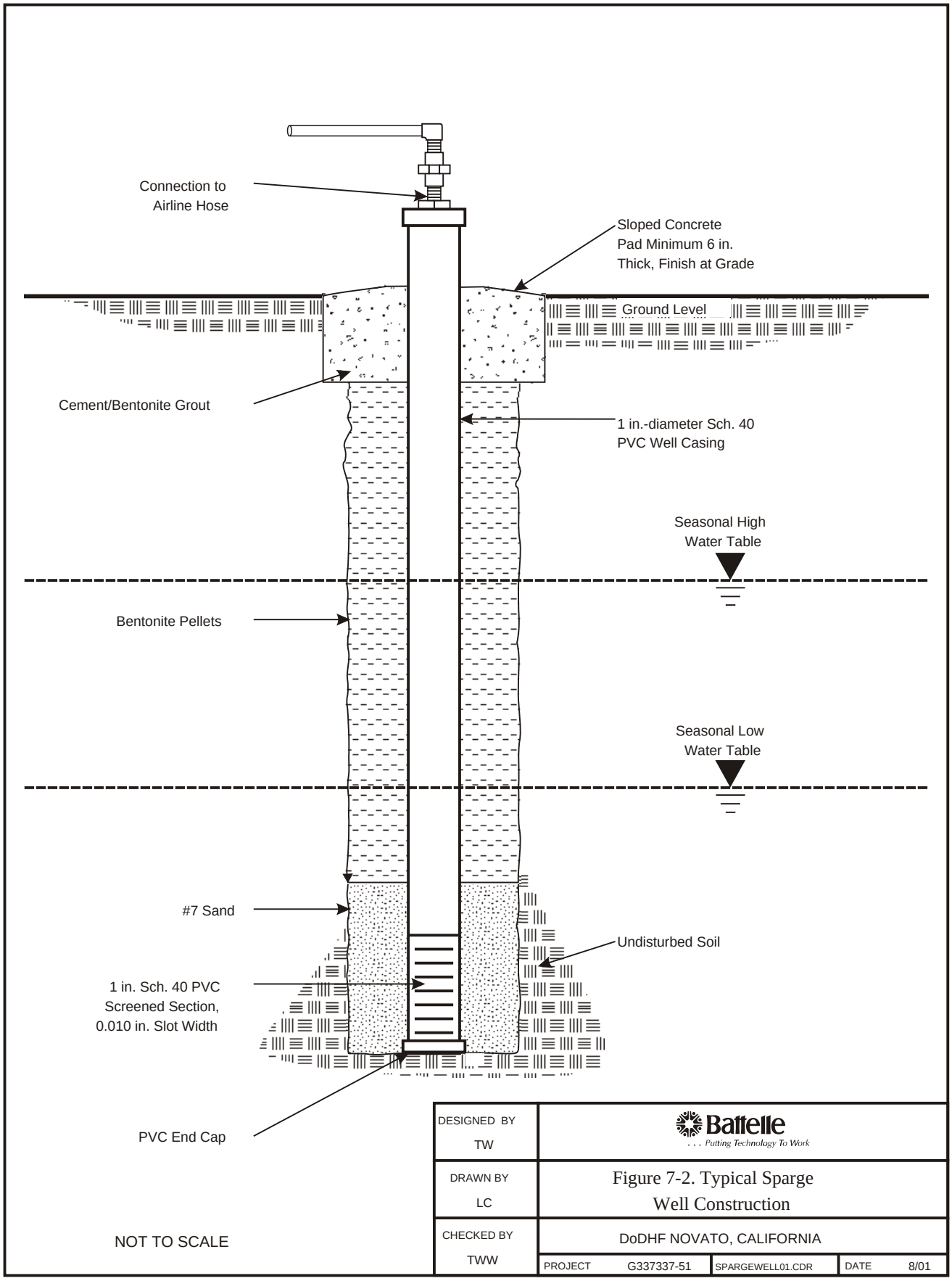


Figure 7-2. Typical Sparge Well Construction

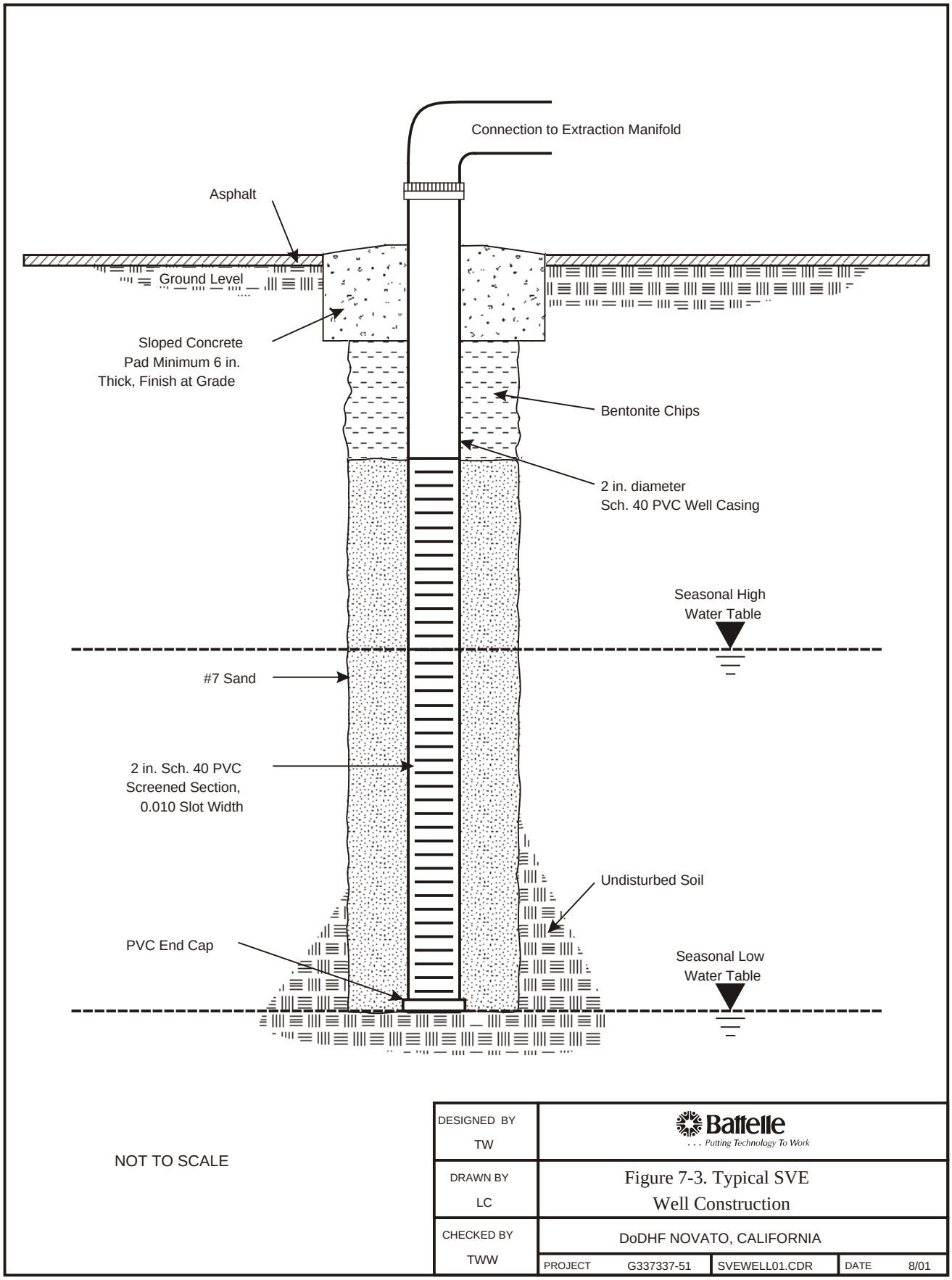
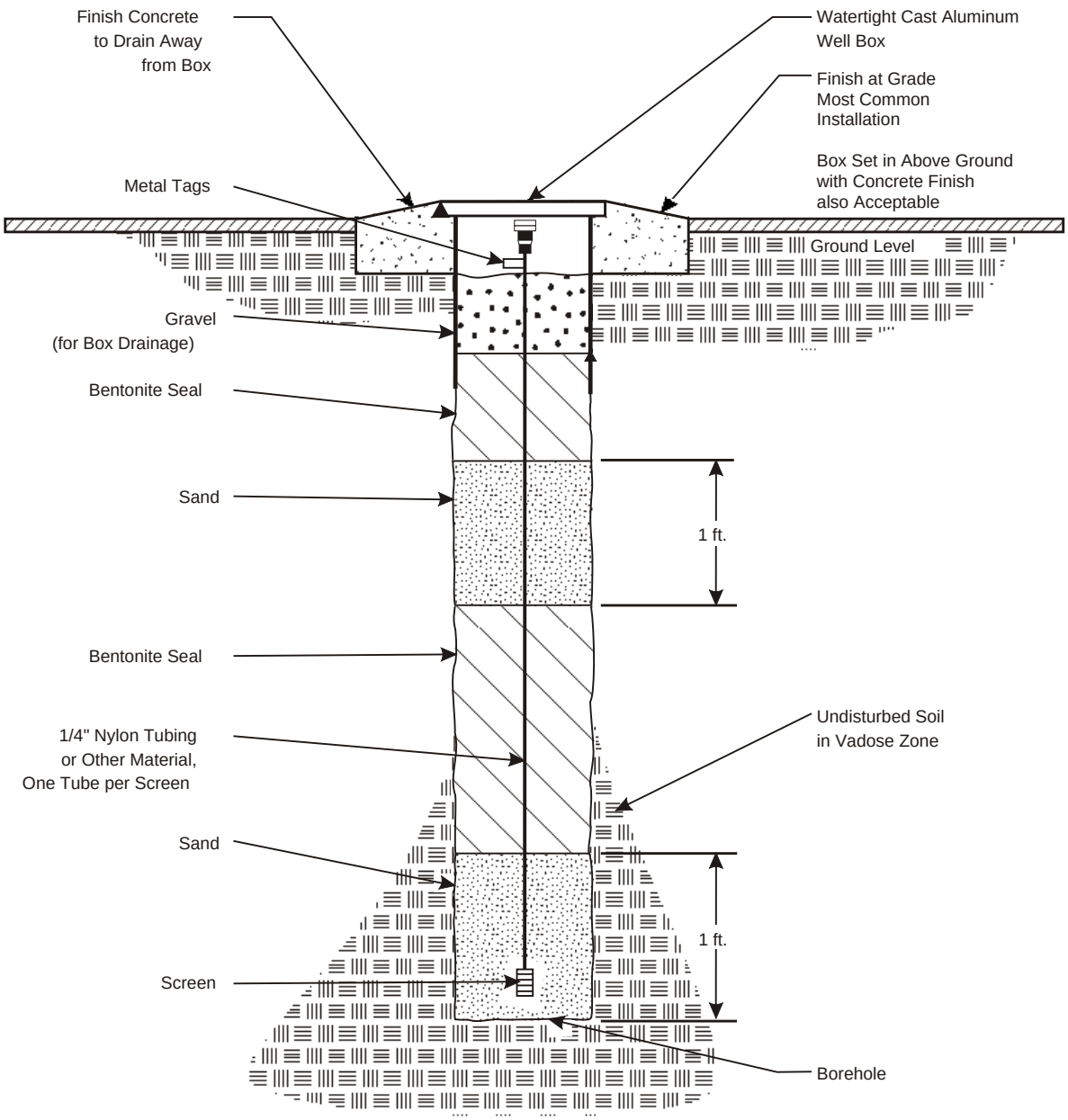


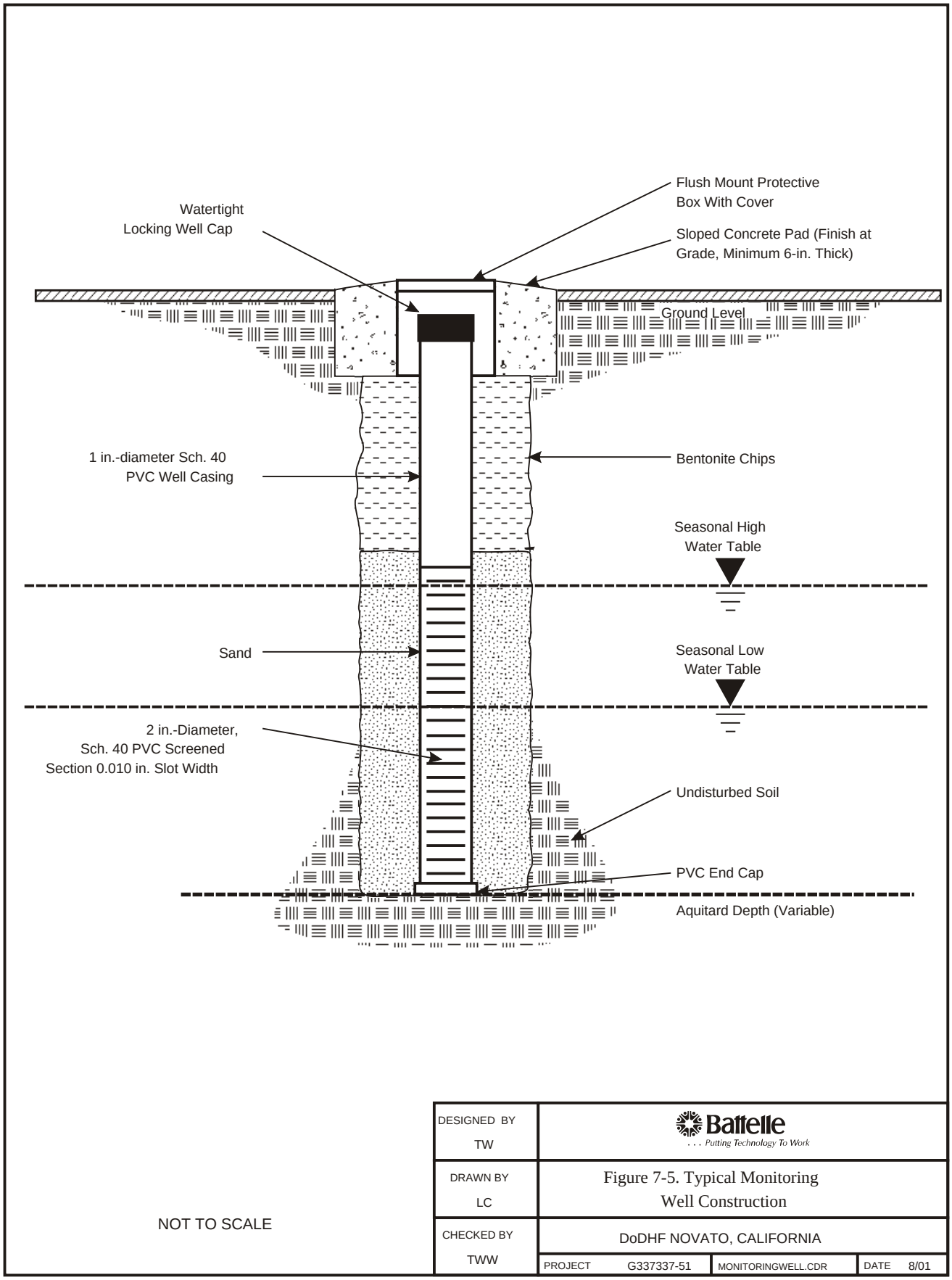
Figure 7-3. Typical SVE Well Construction



NOT TO SCALE

DESIGNED BY TW	Battelle ... Putting Technology To Work		
DRAWN BY LC	Figure 7-4. Soil-Gas Monitoring Probe Construction		
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA		
	PROJECT G337337-51	MONITORINGPOINT.CDR	DATE 8/01

Figure 7-4. Typical Soil-Gas Monitoring Probe Construction



NOT TO SCALE

DESIGNED BY TW	Battelle . . . Putting Technology To Work		
DRAWN BY LC	Figure 7-5. Typical Monitoring Well Construction		
CHECKED BY TWW	DoDHF NOVATO, CALIFORNIA		
PROJECT G337337-51	MONITORINGWELL.CDR	DATE 8/01	

Figure 7-5. Typical Monitoring Well Construction

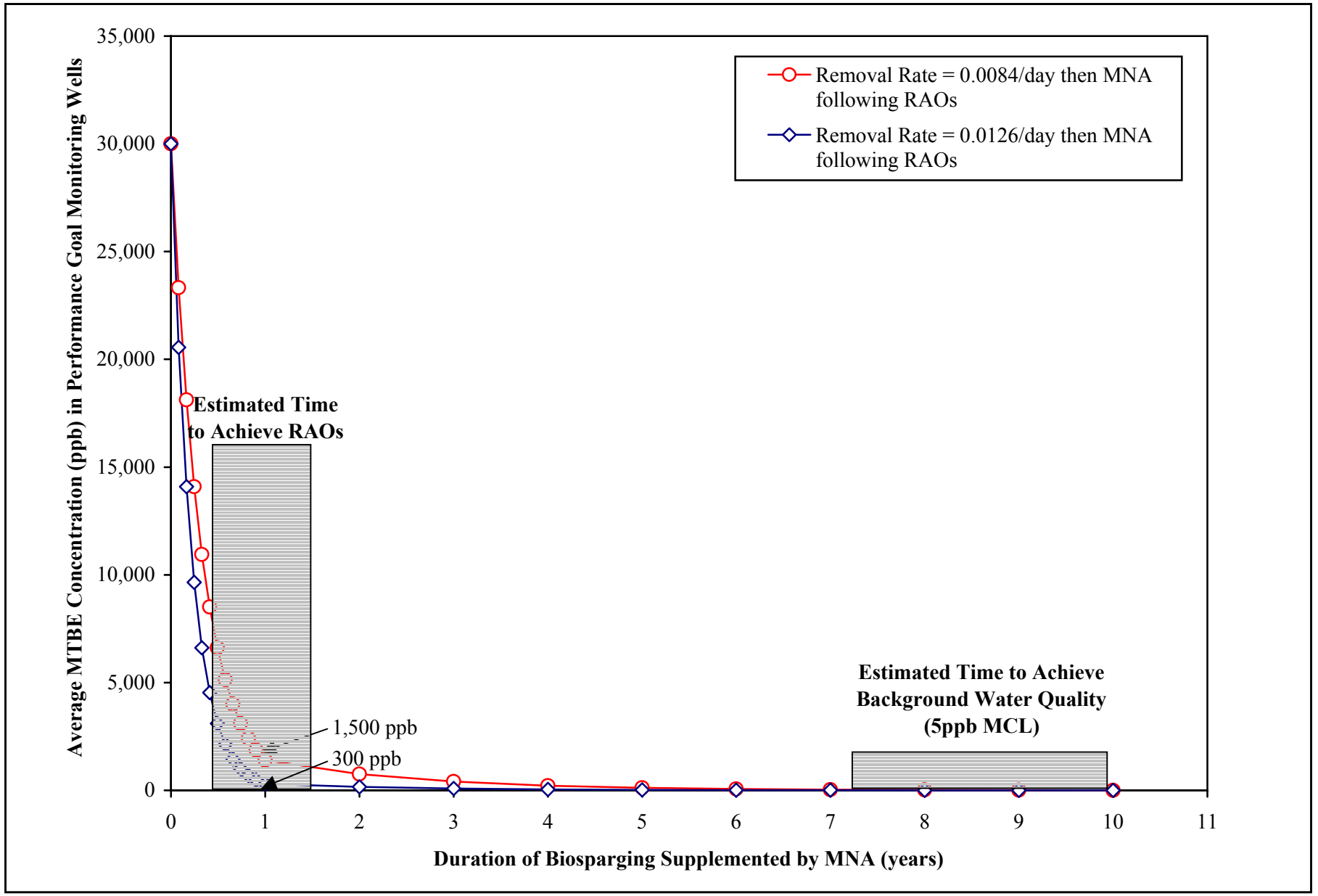


Figure 7-6. Estimated MTBE Concentration Trends in Performance Goal Monitoring Wells Resulting from Biosparging Operation

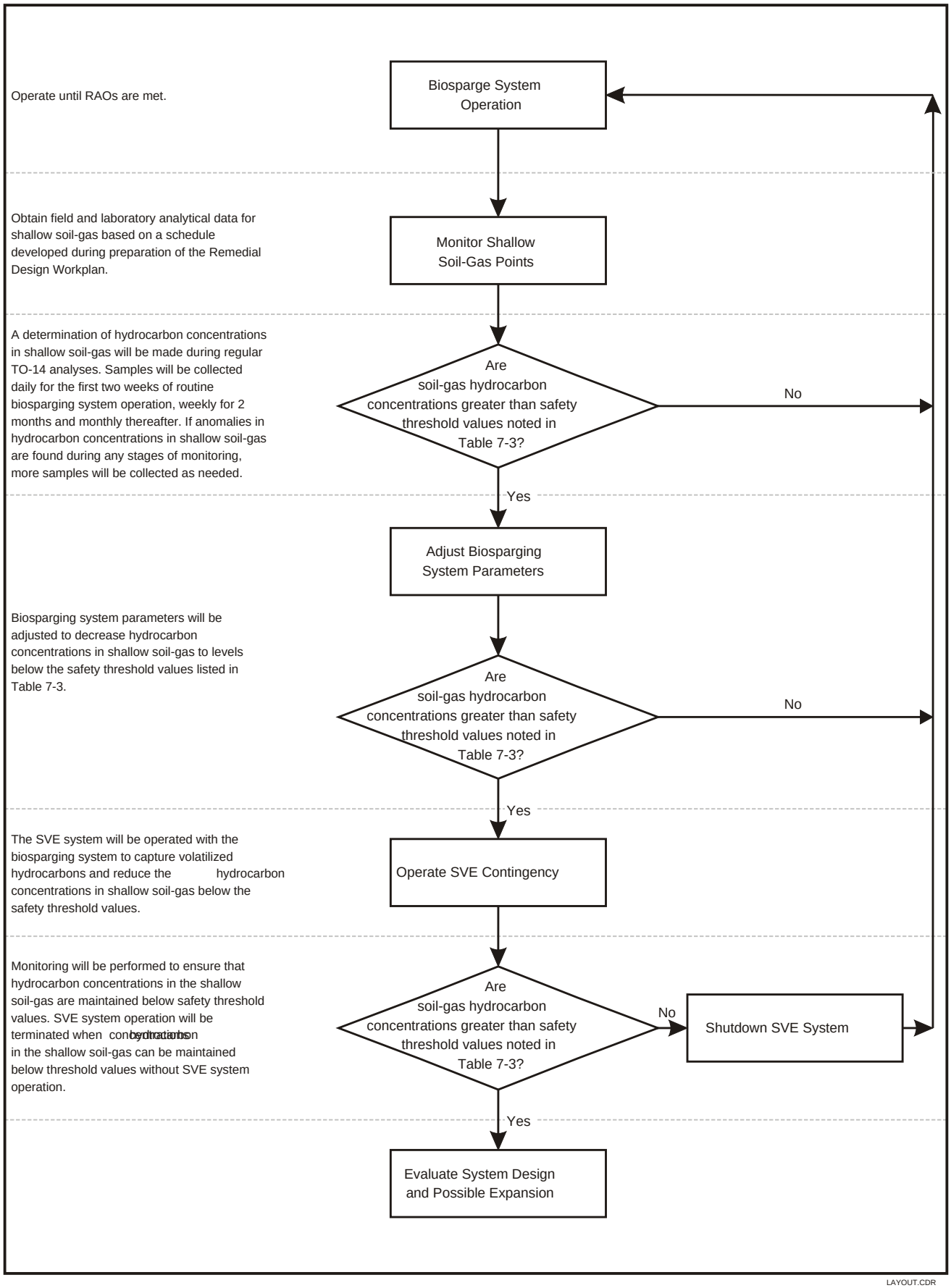


Figure 7-7. Flowchart Depicting SVE Contingency

ID	Task Name	Duration	Start	Finish
1	**CAP**	**306 days**	**Mon 01/08/01**	**Wed 02/20/02**
2	Develop Draft Proposed Final Revision 0 CAP	87 days	Mon 01/08/01	Tue 05/08/01
3	Submit Draft Proposed Final Revision 0 CAP to RWQCB	0 days	Tue 05/08/01	Tue 05/08/01
4	Develop Draft Proposed Final Revision 1.0 CAP	39 days	Thu 06/21/01	Tue 08/14/01
5	Submit Draft Proposed Final Revision 1.0 CAP to RWQCB	0 days	Tue 08/14/01	Tue 08/14/01
6	Receive RWQCB comments on the Draft Proposed Final Revision 1.0 CAP	0 days	Tue 10/16/01	Tue 10/16/01
7	Develop responses to RWQCB comments on the Draft Proposed Final Revision 1.0 CAF	63 days	Wed 10/17/01	Wed 01/09/02
8	Submit Draft Proposed Final Revision 2.0 CAP for 30-day public review period	0 days	Fri 01/11/02	Fri 01/11/02
9	Public review of Draft Proposed Final Revision 2.0 CAP to RWQCB	30 days	Wed 01/16/02	Thu 02/14/02
10	Develop responses to public comments on the Draft Proposed Final Revision 2.0 CAP	5 days	Fri 02/15/02	Tue 02/19/02
11	Submit Final CAP to RWQCB	0 days	Wed 02/20/02	Wed 02/20/02
12				
13	**Remedial Design and Workplan (RDWP)**	**82 days**	**Mon 01/14/02**	**Fri 04/05/02**
14	Develop draft RDWP	43 days	Mon 01/14/02	Mon 02/25/02
15	Submit draft RDWP to RWQCB	0 days	Mon 02/25/02	Mon 02/25/02
16	RWQCB review of draft RDWP	30 days	Mon 02/25/02	Tue 03/26/02
17	Develop responses to RWQCB comments on the draft RDWP	10 days	Wed 03/27/02	Fri 04/05/02
18	Submit Final RDWP to RWQCB	0 days	Fri 04/05/02	Fri 04/05/02
19				
20	**Corrective Action Installation and Operation**	**825 days**	**Tue 03/26/02**	**Sun 06/27/04**
21	Preparation for installation	27 days	Tue 03/26/02	Sun 04/21/02
22	Installation	56 days	Mon 04/22/02	Sun 06/16/02
23	System shakedown	14 days	Mon 06/17/02	Sun 06/30/02
24	Routine Operations	365 days	Sun 06/30/02	Sun 06/29/03
25	Data analysis (monitor for rebound)	365 days	Sun 06/29/03	Sun 06/27/04
26	Begin long-term monitoring (up to 10 years)	0 days	Sun 06/27/04	Sun 06/27/04

Project File: figure 7-8
Plot Date: Mon 04/08/02

Table 7-1. Summary of Biosparging Subsurface Installations

Type of Installation	Approximate No. of Installations	Construction Material	Screen Slot Size	Borehole Depth (ft bgs)	Screened Area (ft bgs)	Objective
Sparge well	40	1” PVC	20 slot	~18	16-18	Increase DO within the preferential flowpath
Soil-vapor extraction well	9	2” PVC	10 slot	15	5-15	Contigency for vadose zone vapor recovery
Shallow soil-gas monitoring probe	3	¼” tubing, 6” screen	NA	NA	3	Monitor hydrocarbons in shallow soil-gas along pathway to nearby receptors
Deep soil-gas monitoring probe	4	¼” tubing, 6” screen	NA	NA	7, 9	Monitor hydrocarbons in the bioreactor within the treatment area
Monitoring well	6	2” PVC	10 slot	18	8-18	Monitor performance goals and MTBE concentrations within the preferential flowpath toward Former HAAF property

Table 7-2. Biosparging Operational Monitoring Parameters

Parameter	Sampling Device	Instrument
DO	Groundwater monitoring wells	Field DO meter
Groundwater BTEX, MTBE, and MTBE breakdown products (TBA and TBF)	Groundwater monitoring wells	Gas chromatograph (laboratory)
Soil-gas BTEX, MTBE, and MTBE breakdown products (TBA and TBF)	Soil-gas monitoring probes	Gas chromatograph (laboratory)
Soil-gas TPH	Soil-gas monitoring probes	TraceTechtor™
Soil-gas O_2	Soil-gas monitoring probes	GasTech O_2/CO_2 analyzer
Soil-gas CO_2	Soil-gas monitoring probes	GasTech O_2/CO_2 analyzer
Water table levels	Groundwater monitoring wells	Water-level indicator
Injection pressure[(a)]	Control panel	Pressure gauge
Injection flowrate[(a)]	Control panel	Flowmeter

(a) Measurements will be recorded for each well operating.

Table 7-3. Safety Threshold Hydrocarbon Soil-gas Concentrations[(a)] and Sampling Information for Shallow Soil-Gas Monitoring Points

Gasoline Constituents Analyzed	Analytical Method	Standard Detection Limit (ppbv)	Safety Threshold Concentration (ppbv) [(a)]
Benzene	TO-14	0.5	29.4
MTBE		2.0	25.5
Toluene		0.5	24.7
Ethylbenzene		0.5	219.4
Total xylenes		1.0	574.2
1,2,4-Trimethylbenzene		0.5	388.2
1,3,5-Trimethylbenzene		0.5	541.8
Isopropylbenzene		5.0	129.2
n-Propylbenzene		5.0	381.5
sec-Butylbenzene		5.0	100.8

(a) Safety threshold concentrations were identified as the hydrocarbon concentrations used as soil-gas input values in the PBC Area for the *Final Revised Risk Assessment* (Battelle, 2001c).

Section 8.0: REFERENCES

AGS, Inc. 1999. *Final Report Remedial Investigation and Corrective Measures Study – Volume 1 for the Underground Storage Tank Site at Building 827, Department of Defense Housing Facility Novato, California.* Prepared for Naval Facilities Engineering Command, Engineering Field Activity West, San Bruno, CA. October 23.

Battelle. 1998a. "Draft Health and Safety Plan for Soil and Groundwater Remediation for the Former UST 957/970 Site at Department of Defense Housing Facility Novato, California: Revision 2.0." Prepared for Naval Facilities Engineering Command, Engineering Field Activity West, San Bruno, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. March 18.

Battelle. 1998b. Draft Work Plan for Soil and Groundwater Remediation for the Former UST 957/970 Site at Department of Defense Housing Facility, Novato, California. Prepared for NFEC, EFA West, San Bruno, California. January 16.

Battelle. 1998c. Groundwater Monitoring Plan for the Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California, Revision 2.0. Prepared for NFEC, EFA West, San Bruno, California. December 29.

Battelle. 1998d. *Preliminary Assessment of Contamination Levels at Site 957/970. Department of Defense Housing Facility, Novato, California.* Prepared for Naval Facilities Engineering Command. February 12.

Battelle. 1998e. *Work Plan for Evaluating Possible Hydraulic Fluid Release from Hydraulic Lift in Building 970.* Addendum 3 to the Work Plan for Soil and Groundwater Remediation for the Former UST 957/970 Site at Department of Defense Housing Facility, Novato, California. Revision 1.0. Prepared for the Naval Facilities Engineering Service Center, Port Hueneme, CA. January 16.

Battelle. 1999a. Draft Ecological Risk Scoping Assessment for Former UST Site 957/970, Department of Defense Housing Facility and Adjoining Portions of Hamilton Army Airfield, Novato, California. December 8, 1999.

Battelle. 1999b. *Tier 2 Risk-Based Corrective Action (RBCA) Assessment for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California and Adjoining Property on Hamilton Army Airfield.* Prepared for NFEC, EFA West, San Bruno, California. March 12.

Battelle. 1999c. *Tier 3 Risk-Based Corrective Action (RBCA) Assessment for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California and Adjoining Property on Hamilton Army Airfield, Version 2.0.* Prepared for NFEC, EFA West, San Bruno, California. November 24.

Battelle. 1999d. Implementing Remediation by Natural Attenuation at Petroleum Release Sites: Operations Manual, Guidelines for Preparing Statements of Work, and Computer Cost Estimating Tool, Appendix C: Statistical Method to Determine a Meaningful Trend in a Set of Concentration Measurements Collected Over Time. Prepared for NFESC by Battelle Memorial Institute, Columbus, Ohio. May 3.

Battelle. 2000a. *Groundwater Monitoring Plan for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California: Revision 4.0 - Final.* Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. September 13.

Battelle. 2000b. *Monitoring Well Protection Plan for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California*, *Revision 1.0 Final*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. September 13.

Battelle. 2000c. "Draft Interim Site Control Plan for the Department of Defense Housing Facility, Novato, California." Prepared for the Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. September 27.

Battelle. 2000d. *Site Status Report (Quarter Ending August 2000) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA, and Naval Facilities Engineering Service Center, Port Hueneme, CA. October 30.

Battelle. 2000e. *Final Work Plan for Hydraulic Lift and Oil/Water Separator Removal from Building 970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA, under NFESC Contract No. N47408-95-D-0730. March 31.

Battelle. 2000f. *Final Work Plan for Remedial Investigation of Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA, under NFESC Contract No. N47408-95-D-0730. August 30.

Battelle. 2001a. *Annual Site Status Report (for the Year 2000) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California.* Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. January 24.

Battelle. 2001b. *Final Remedial Investigation Report for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California*. Prepared for the Southwest Division, Naval Facilities Engineering Command under NFESC Contract No. N47408-95-D-0730. January 31.

Battelle. 2001c. *Final Revised Risk Assessment for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California*. Prepared for the Southwest Division, Naval Facilities Engineering Command under NFESC Contract No. N47408-95-D-0730. June 8.

Battelle. 2001d. "Methyl-Tert-Butyl Ether Treatability Study Summary Report for Department of Defense Housing Facility Novato, California." Prepared for the Southwest Division, Naval Facilities Engineering Command under NFESC Contract No. N47408-95-D-0730. Draft. May.

Battelle. 2001e. *Interim Site Control Plan for the Department of Defense Housing Facility, Novato, California*. Prepared for the Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. October 2.

Battelle and RRM. 2000. "Draft Summary Report for Hydraulic Lift and Oil/Water Separator Removal from Building 970, Department of Defense Housing Facility (DoDHF) Novato, California." Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA. July 28.

Cal-EPA, see California Environmental Protection Agency

California State Water Resources Control Board. 1989. *Leaking Underground Fuel Tank Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure.* Issued by the Leaking Underground Fuel Tank Task Force. October.

California State Water Resources Control Board Resolution No. 88-63. Adoption of Policy Entitled "Sources of Drinking Water." Adopted on May 19, 1988.

California State Water Resources Control Board Resolution No. 92-49 (As Amended on April 21, 1994 and October 2, 1996). Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304.

California Environmental Protection Agency. 1992. *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities.* Prepared by DTSC's Human and Ecological Risk Division, Office of Scientific Affairs, Sacramento, CA. July. Available at: http://www.cwo.com/~herd1.

California Environmental Protection Agency. 1996. *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities. Part B: Scoping Assessment.* California Environmental Protection Agency, Department of Toxic Substance Control, Human and Ecological Risk Division. July 4.

DGI, see Dynamic Graphics, Inc.

Domenico and Schwart. 1990. *Physical and Chemical Hydrogeology*. John Wiley & Sons, New York, 824 p.

Dynamic Graphics, Inc. 1997. Earth Vision, Version 4.0.2.

Environmental Quality Management, Inc. 1997. *User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion Into Buildings*. Prepared for the U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, by Environmental Quality Management, Inc., Durham, NC.

EQM, see Environmental Quality Management, Inc.

ERM-West, Inc. 1995a. "Draft Remedial Investigation Workplan for Former Underground Storage Tank Sites at Department of Defense Housing Facility, Novato, California." Submitted to Department of the Navy, Western Division, NFEC, San Bruno, California. May.

ERM-West, Inc. 1997. "Draft Final UST Investigation Report for Former Underground Storage Tank Site 957/970 at Department of Defense Housing, Hamilton Field, Novato, California." Submitted to Department of the Navy, Western Division, NFEC, San Bruno, California. September.

ERM-West, Inc. 1998. *Final UST Investigation Report for Former Underground Storage Tank Site 957/970 at Department of Defense Housing, Hamilton Field, Novato, California*. Submitted to Department of the Navy, Western Division, NFEC, San Bruno, California. June.

Gallagher, M. N., Payne, R. E., and Nainan, M. M., 1996. Replacing a Pump and Treat System With a Biosparging Cut-Off Wall. In Gallagher et al. (Eds.), Proc. Pet. Hydrocarbons Org. Chem. Ground Water: Prev., Detect., Rem. Conf., pp.123-133. Ground Water Publishing, Westerville, OH.

Gavaskar, A.R., N. Gupta, B.M. Sass, R. Janosy, and D.O'Sullivan. 1998. *Permeable Barriers for Groundwater Remediation*. Battelle Press, Columbus, OH.

Griffen, C. J., Wilson, J. T., Kampbell, D. H., 1993. In-Situ Bioremediation of an Aviation Gasoline Spill by Subsurface Aeration. 86th Proc., Annu. Meet. Air Waste Manage. Assoc. Vol. 15: 12.

Hamilton Local Reuse Authority. 1996. *Hamilton Army Airfield Reuse Plan: Final Reuse Plan.* Prepared by Robert Bein, William Frost & Associates; Edward J. Cass & Associates; Fehr & Peers Associates, Inc.; John Roberto Associates; and Keyser Marston Associates, Inc. Approved by (Novato) City Council on October 24, 1995. Approved by MAB (Marin Advisory Board) on September 26, 1995. Revised in November 1996.

Hitzig, R. 1998. "MTBE Survey of State LUST Programs." Presentation prepared for U.S. EPA Office of Underground Storage Tanks, Washington, DC, and given at the *U.S. EPA OUST's 10th Annual UST/LUST Conference, Long Beach, CA*. March 30. Available at: www.epa.gov/swerust1/mtbe/briefs/ umassrm2/index.htm.

Hong, M.S., W.F. Farmayan, I.J. Dortch, C.Y. Chiang, S.K. McMillian, and J.L. Schnoor. 2000. "Phytoremediation of MTBE from a Groundwater Plume." Accepted for publication in *Environmental Science and Technology*.

IT see IT Corporation.

IT Corporation. 1995. *Draft Ecological Risk Assessment Work Plan BRAC Property, Hamilton Army Airfield Novato, CA*. Contract #DACW05-95-D-0001, DO#0006. Submitted to Department of the Army, U.S. Army.

IT Corporation. 1998. *Site Investigation Report 800-B and Ammo Hill Parcels GSA Phase II Sale Area Hamilton Army Airfield, Novato, California, Final Report*. Prepared by IT Corporation, Martinez, California.

Javanmardian, M., Huber, S. J., Olson, C. B., Schwartz, W. P., Masin, C. A., Kremesec, V.J., 1995. In Situ Biosparging at an Amoco Site: Subsurface Air Distribution and Biostimulation. In Hinchee et al. (Eds.), In Situ Aeration: Air Sparging, Bioventing, Relat. Rem. Processes. pp.191-202. Battelle Press, Columbus, OH.

Javanmardian, M., and H.A. Glasser. 1997. *In-Situ Biodegradation of MTBE Using Biosparging.* In: *213th National Meeting of the American Chemical Society – Abstracts of Papers of American Chemical Society, 213*(1-3). Paper ENVR 242.

Johnson, P., and R. Ettinger. 1991. "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings." *Environmental Science and Technology, 25*(8): 1445-1452.

Keely, J.F. 1996. *Performance Evaluations of Pump-and-Treat Remediations.* In ed. J.R. Boulding , *EPA Environmental Engineering Sourcebook*. Ann Arbor Press, Chelsea, MN.

Kerfoot, W.B. 2000. "Ozone Microsparging for Rapid MTBE Removal." In: G.B. Wickramanayake, A.R. Gavaskar, and A.S.C. Chen (eds.), *Chemical Oxidation and Reactive Barriers*. Battelle Press: Columbus, OH, pp. 187-194.

Koenigsberg, S., and W. Mahaffey. 2000. "Effects of ORC® on MTBE Degradation." *Underground Tank Technology Update, 14*(2): 9-11. University of Wisconsin, Madison, WI.

Leeson, A., P.C. Johnson, R.L. Johnson, R.E. Hinchee, D.B. McWhorter, C.L. Bruce, I.L. Amerson-Treat, T.L. Johnson, C.T. Coonfare, and R. Gillespie. 2000. *Air Sparging Design Paradigm*. ESTCP, Arlington, VA.

McNab, W. W., Jr., *et al.* 1998. Risk-Based Assessment of Appropriate Fuel Hydrocarbon Cleanup Strategies for Area 43 MWR Gas Station, Marine Corp Base, Camp Pendleton, California Cleanup Strategies for Camp Pendleton, Area 43. Appendix C: Evaluation of Hydrocarbon Passive Bioremediation in Groundwater. (UCRL-AR-128220). January.

Naber, S.J., B. Buxton, N. McMillan-Darby, and A. Soares. 1997. "Statistical Methods for Assessing the Effectiveness of Intrinsic Remediation." In *Proccedings of the Fourth International In Situ and On-Site Bioremediation Symposium: Volume 5*. B.C. Alleman and A. Leeson (eds.). pp. 349-354. Battelle Press, Columbus, Ohio.

Naval Facilities Engineering Service Center. 1998. *Phytoremediation*. TDS-2061-ENV. Naval Facilities Engineering Service Center, Port Hueneme, CA.

Navy Public Works Center. 1996a. *Final Summary Report for Underground Storage Tank Removal Building 970, Department of Defense Housing Facility, Novato, California.* Prepared for Engineering Field Activity West by Navy Public Works Center, San Francisco Bay. July 22.

Navy Public Works Center. 1996b. Underground Storage Tank Removal Summary Report for the Removal of Eight Underground Storage Tanks Located at Buildings 827, 203, and 970, Department of Defense Housing Facility, Novato, California. Prepared for Engineering Field Activity West. Prepared by Navy Public Works Center, San Francisco Bay. November.

NFESC, see Naval Facilities Engineering Service Center.

Novato Unified School District. 1996. *Application for Public Benefit Transfer of Surplus Federal Real Property for Educational Uses*. May 31.

NPWC, see Navy Public Works Center.

NUSD, see Novato Unified School District.

Powers, J.P. 1992. *Construction Dewatering*. John Wiley & Sons, Inc., New York, NY.

PRS, see PRC Environental Management, Inc.

PRC Environmental Management, Inc. 1992a. *Underground Storage Tank Removal and Preliminary Investigation, Department of Defense Housing Facility, Novato, California*. Prepared by PRC Environmental Management, Inc. June 15.

PRC Environmental Management, Inc. 1992b. *Tank Sites 11, 957, and 972 Remedial Investigation Draft Field Work Plan, Department of Defense Housing Facility, Novato, California.* CLEAN Contract No. N62474-88-D-5086. Prepared by PRC Environmental Management, Inc., San Francisco, CA. September 25.

PRC Environmental Management, Inc. 1994. *Former UST Sites 11, 957, and 972 Remedial Investigation Field Work Plan, Revised Draft Final.* CLEAN Contract No. N62474-88-D-5086. Prepared by PRC Environmental Management, Inc. San Francisco, CA. March 21.

PRC Environmental Management, Inc. 1996. Draft Final Summary Report, Site Characterization and Analysis Penetrometer System Project, Department of Defense Housing Facility, Novato, California. Prepared for Naval Command, Control, and Ocean Surveillance Center, Environmental Services Division, San Diego, CA.

PRC Environmental Management, Inc. 1997. *Final Environmental Baseline Survey Sampling and Analysis Screening Level Report, Department of Defense Housing Facility, Novato, California.* Prepared for Department of the Navy, EFA West, NFEC, San Bruno, California. April 15.

Rast, R.R. 1997. *Environmental Remediation Estimating Methods*. R.S. Means Company, Kingston, MA.

Regional Water Quality Control Board. 1995. *San Francisco Bay Basin (Region 2) Water Quality Control Plan*. California Regional Water Quality Control Board San Francisco Bay Region, California. June 21.

Regional Water Quality Control Board. 1996. *Regional Board Supplemental Instructions to State Water Board December 8, 1995, Interim Guidance on Required Cleanup at Low-Risk Fuel Contaminated Sites*. Memorandum from Loretta K. Barsamian, Executive Officer, California Regional Water Quality Control Board, San Francisco Bay Region. January 5.

Regional Water Quality Control Board, San Francisco Bay Region. 1998. *Recommended Interim Water Quality Objectives (or Aquatic Life Criteria) for Methyl Tertiary-Butyl Ether (MTBE).* Prepared for Toxics Cleanup Division Staff and Interested Parties. October 1.

RWQCB, see Regional Water Quality Control Board, San Francisco Bay Region.

R.S. Means Company, Inc. 1999. *Environmental Remediation Cost Data--Assemblies*. R.S. Means Company and Taliman Partners, Ltd., Kingston, MA, and Englewood, CO.

Schnoor, J.L. 1997. "Phytoremediation." Groundwater Remediation Technologies Analysis Center Web Site. TE-98-01, Ground-Water Remediation Technologies Analysis Center, Pittsburgh, PA. Available at: www.gwrtac.org.

Sims, J.L., J.M. Suflita, and H.H. Russel. 1996. "In Situ Bioremediation of Contaminated Ground Water." In ed. J.R. Boulding, *EPA Environmental Engineering Sourcebook*. Ann Arbor Press, Chelsea, MN.

SWRCB, see California State Water Resources Control Board.

Tang, J., G.R. Walter, and M.K Kuhn. 1999. "Field Pilot Study of Trench Air Sparging for Remediation of Petroleum Hydrocarbons in Groundwater." In: B.C. Alleman and A. Leeson (eds.), *Proceedings of the 5th International In Situ and On-Site Bioremediation Symposium, Vol. 3: In Situ Bioremediation of Petroleum Hydrocarbon and Other Organic Compounds*. Battelle Press: Columbus, OH, pp. 59-69.

Thomson, B.M., D.J. Finfrock, and C.P. McHaley. 1999. "Development of Permeable Barriers for Groundwater Remediation: Air Stripping of Methyl Tertiary-Butyl Ether (MTBE)." *Journal of Environmental Science and Health, 34*(2): 263.

United States Department of the Navy and the California Department of Toxic Substances Control. 2000. Use of Model "Covenant to Restrict Use of Property" at Installations Being Closed and Transferred by the United States Department of the Navy. Memorandum of Agreement between the Parties. March 16.

United States Environmental Protection Agency. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final*. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington, DC. December.

United States Environmental Protection Agency. 1991. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions.* OSWER directive No. 9355.0-30. April 22. Available at: es.epa.gov/oeca/osre/910422.html. Web page last updated February 27, 1998.

United States Environmental Protection Agency. 1992. *Estimation of Air Impacts for the Excavation of Contaminated Soil*. EPA/450/1-92/004. Report No. ASF-24 of the Air/Superfund National Technical Guidance Study Series. Prepared by the U.S. EPA's Office of Air and Radiation, and Office of Air Quality Planning Standards, Research Triangle Park, NC. March 18.

United States Environmental Protection Agency. 1995. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers*. EPA/510/B-95/007. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency. 1998a. *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. U.S. EPA Risk Assessment Forum, Washington, D.C. April.

United States Environmental Protection Agency. 1998b. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*. EPA/600/R-98/128. Office of Research and Development, Washington, DC.

United States Environmental Protection Agency. 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. OSWER Directive 9200.4-17P. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency. 2000a. *Introduction to Phytoremediation*. EPA/600/R-99/107. Office of Research and Development, Washington, DC.

United States Environmental Protection Agency. 2000b. "Air Sparging at Four Sites." *MTBE Treatment Case Studies and Web Site*. www.ttclients.com/mtbe/summary_table.htm.

United States Environmental Protection Agency. 2000c. *Natural Attenuation of MTBE in the Subsurface under Methanogenic Conditions*. EPA/600/R-00/006. Office of Research and Development, Washington, DC.

United States Environmental Protection Agency. 2000d. Region 9 Preliminary Remediation Goals (PRGs) Table. Available from http://www.epa.gov/region09/waste/sfund/prg/index.html. Updated November 1.

U.S. DON and DTSC, see United States Department of the Navy and California Department of Toxic Substances Control.

U.S. EPA, see United States Environmental Protection Agency.

Wiedemeier, T.H., J.T. Wilson, D.H. Kampbell, R.N. Miller, and J.E. Hansen. 1995. *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*. Air Force Center for Environmental Excellence, Brooks Air Force Base, San Antonio, TX.

ATTACHMENT 1

California Regional Water Quality Control Board
Order No. 00-064

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

ORDER NO. 00-064

SITE CLEANUP REQUIREMENTS FOR:
UNITED STATES NAVY
for the property located at the
DEPARTMENT OF DEFENSE HOUSING FACILITY
former HAMILTON AIR FORCE BASE
NOVATO,
MARIN COUNTY

The California Regional Water Quality Control Board, San Francisco Bay Region (hereinafter Board), finds that:

1. **Site Location**: The Site is located within the Department of Defense (DoD) Housing Facility (DODHF-Novato), at Hamilton Air Force Base on the eastern edge of the City of Novato, Marin County, California. It includes an approximate 65-acre rectangular area where petroleum was released from leaking underground, fuel storage tanks associated with two former gasoline service stations. As depicted on Attachment A, the rectangular area which defines the Site is bound on the north by the former Hamilton Army Airfield (HAAF) property line, on the south by Main Entrance Road, on the west by the DODHF-Novato property line to State Access Road and projected northward to the former HAAF property line, and on the east by a north-south trending line located approximately 400 feet east of, and parallel to C Street.

2. **Site History:** Originally, the DODHF-Novato property was part of HAAF. HAAF was constructed between 1932 and 1935 and encompassed approximately 927 acres. In 1947, HAAF was transferred to the U.S. Air Force and was renamed Hamilton Air Force Base (HAFB). By 1964, additional housing to the west of the airfield increased the size of HAFB to 2,184-acres. In 1974, the U.S. Air Force deactivated the facility and initiated transfer of excess property; residential housing units were transferred to the Navy in 1975 as DODHF-Novato, and the remaining property was transferred to various federal agencies.

   From the mid-1970s through the early 1990s, the Navy operated two service stations at the DODHF-Novato. The first service station, Building 957, contained a 12,000-gallon underground storage tank (UST) designated UST-957 (see Attachment A). In March 1992, Building 957 UST and associated piping were removed. Analytical results for soil and groundwater samples collected from the excavation detected significant concentrations of total petroleum hydrocarbons (TPH) as gasoline, and benzene, toluene, ethylbenzene, and xylene compounds.

The second service station, called the Naval Exchange Service Station (NEX), operated from the mid-1970s through the mid-1990s. The NEX was located in Building 970, at the northwest corner of "Main Entrance" Road and "C" Street (see Attachment A). In the early 1990s, when the NEX was closed, three single-walled, steel 10,000-gallon USTs, which formerly contained unleaded gasoline, and one 1,000-gallon waste oil UST were removed. The three gasoline USTs were located approximately 70 feet south of Building 970 and were designated UST-970-1, UST-970-2, and UST-970-3.

During 1995 and 1996, UST-970-1, UST970-2, UST-970-3, and 80 feet of piping leading from the tanks to the pump islands were removed. Although UST-970-1 and UST-970-2 were observed to be in good condition at the time of their removal, UST 970-3 contained a hole at the fill end of the tank, groundwater was encountered at two feet below ground surface (bgs), and hydrocarbon contamination was observed on the excavation sidewalls and tank pit groundwater. Analytical results for soil and groundwater samples collected from the excavation detected significant concentrations of total petroleum hydrocarbons (TPH) as gasoline, diesel, motor oil, jet fuel, benzene, toluene, ethylbenzene, xylenes and methyl tertiary butyl ether (MTBE).

MTBE-impacted groundwater originating in the vicinity of the former USTs flows northward, onto the adjacent HAAF parcel, portions of which are currently owned by the City of Novato and Shea Homes. MTBE-impacted groundwater seasonally discharges to Pacheco Creek (See Attachment A).

3. **Named Dischargers**: The United States Navy is named as the discharger because it owns the property and owned the property during the time of the activity that resulted in the discharge. The Navy had knowledge of the discharge or the activities that caused the discharge, and had the legal ability to prevent the discharge. The Army-drafted Statement of Condition for Ammo Hill and 800-B Parcels, Phase II GSA Sale Property, Hamilton Army Airfield, Novato, California, states "Since the United States Navy is responsible for the source of the contamination, they are also responsible for any necessary investigative, monitoring, assessment and/or remediation action required to reduce the MTBE concentration levels and the spread of the plume."

   Current plans are for the Navy to retain ownership of a portion of the Site that contains the former NEX. The remainder of the property is expected to be transferred to the Novato Public Finance Authority (NPFA), the Novato Unified School District (NUSD), and/or a privately owned development company or some other grantee, at some unspecified future date. If the property is transferred to the NPFA, or to any other party or parties, anyone acquiring the property may be added to this Order.

4. **Regulatory Status:** This site is currently not subject to Board order.

5. **Site Hydrogeology:** Groundwater at the Site occurs within unconfined, unconsolidated alluvial materials and generally flows northward. In the area of the Site, the unconfined

alluvial aquifer rests on top of eroded and fractured basement rock. In the past two years, depth to groundwater in the immediate vicinity of former UST-970-3 has ranged between 7 feet and 11 feet below ground surface. As reported in the April 21, 1999 GSA Phase II Sale Area Monitoring Report for the Hamilton Army Airfield, the depth to groundwater northward and downgradient of the Site, shallows and seasonally discharges to Pacheco Creek and to the ground surface along the southern end of Ammo Hill (see Attachment A).

Pacheco Creek is the primary surface water drainage feature downgradient of the Site and empties into Ignacio Reservoir, ultimately flowing to San Pablo Bay via Novato Creek.

Hydraulic conductivity was measured using slug and aquifer pumping tests on several wells in the NEX area. Hydraulic conductivities measured from slug tests ranged between 1.3 and 22.0 feet per day, and those measured using pumping tests ranged between 3.1 feet to 11.7 feet per day, respectively.

Site groundwater contains an average of 624 mg/L total dissolved solids (TDS).

6. **Remedial Investigation**: Remedial Investigation (RI) at the Site, performed to assess the nature and extent of soil and groundwater contamination, can be broadly subdivided into four general phases of RI activity. These include:

   a. The NEX USTs and piping removal and characterization.
   b. The Building 957 UST and piping removal and characterization
   c. The NEX hydraulic lift investigation.
   d. MTBE plume delineation.

   Each phase of RI activity is summarized below.

   a. <u>NEX USTs and Piping Removal and Characterization:</u>
      UST 970-3 and product piping were removed by the Navy in January 1995. Visible hydrocarbon contamination of soil and water were observed during the excavation and a hole at the fill-end of UST970-3 was noted in the field. Groundwater was removed from the excavation and the excavation was allowed to recharge. Analytic results of this second tank pit water sample reported TPH-G at 21,000 µg/L, benzene at 640 µg/L, toluene at 1,200 µg/L, and xylenes at 2,600 µg/L. On February 22 and 23, 1995, the gasoline tank pit was over-excavated by three feet on each of the north, west, and east sidewalls. On March 27, 1995, a third set of soil samples were collected from the excavation. Constituents reported in the tank pit excavation included TPH-G up to 520 milligrams per kilogram (mg/kg), and minor detections of benzene, toluene, ethylbenzene, and xylenes. Approximately 0.5 foot of separate phase hydrocarbons (free product) were reported in monitoring well 970-MW-5 in 1996.

      UST 970-1, UST 970-2, and the product piping leading from tanks to pump islands were removed in July 1996. Five soil samples were collected from the sidewalls of the tank pit excavation and three soil samples were collected beneath the piping (12 to 16

inches below ground surface) at each pump island. Soil samples contained TPH-G at 1,200 to 6,800 mg/kg, benzene at 8.8 to 61 mg/kg, toluene at 340 mg/kg, ethylbenzene at 13 to 67 mg/kg, xylenes up to 310 mg/kg, and MTBE up to 22 mg/kg. Ground water from within the tank pit excavation reportedly contained 170,000 µg/L MTBE.

b. Building 957 UST and Piping Removal and Characterization:
In March 1992, the Building 957 12,000 gallon UST and underground piping for UST 957 were removed. Confirmation soil samples collected from the tank pit reported an unidentified hydrocarbon as TPH between 150 to 220 mg/kg, 0.36 mg/kg benzene, 0.56 mg/kg toluene, 1 mg/kg ethylbenzene, and 3.8 mg/kg xylenes. Soil samples collected from the piping trenches contained unidentified TPH up to 1,200 mg/kg. Analysis of tank pit groundwater showed TPH-G at 60,000 µg/L and concentrations up to 4,400 µg/L for the combined benzene, toluene, xylene, and ethylbenzene constituents. In 1994 and early 1995, an RI using a Geoprobe sampler indicated the existence of free product in areas adjacent to and downgradient of the UST-957.

c. NEX Hydraulic Lift Investigation:
In 1995, a limited soil investigation was conducted in the vicinity of the NEX hydraulic lifts to evaluate the extent of a hydraulic fluid release from the northernmost of the two hydraulic lifts. Two soil samples were collected from depths of 4.0-5.0 and from 9.0-10.0 feet bgs and analyzed for TPH. Groundwater in the vicinity of the lifts was not analyzed at this time. The soil samples collected from 4.0-5.0 feet bgs reportedly contained 15,000 mg/kg TPH as motor oil (TPH-MO). The soil sample collected from 9.0-10.0 feet bgs at the northernmost hydraulic lift reportedly contained 12 mg/kg TPH-MO.

In 1998, a second GeoProbe investigation was conducted 1 foot and 5 feet downgradient (north) of the northernmost hydraulic lift. Groundwater samples were collected from these two pushes as well as from two pushes located approximate 25 feet and 50 feet downgradient of the hydraulic lift. TPH-MO was reported at 18,000 mg/kg in a soil sample collected at 4.5 to 5.5 feet bgs in the push hole located closest to the northernmost hydraulic lift. Naphthalene, phenanthrene, and pyrene were also detected in this sample at 10 mg/kg, 1.3 mg/kg, and 1.9 mg/kg, respectively. Naphthalene was reported at a concentration of 4.2 mg/kg at 4.5 to 5.5 feet bgs in the second push, located further downgradient of the lift. The groundwater samples collected from the Geoprobe pushes located approximately 25 feet and 50 feet downgradient of the northernmost hydraulic lift reportedly contained TPH-MO at 5.6 mg/L and 5.4 mg/L, respectively. The sampling results indicate that some volume of TPH-impacted soil remains adjacent to the hydraulic lifts.

In March 2000, the DoN prepared a work plan for removal of the hydraulic lifts and oil water separators from Building 970. DoN reports that removal activities began on April 17, 2000. During excavation of the hydraulic lifts and oil water separator, unexpected subsurface piping and features (i.e., an additional oil/water separator) were encountered resulting in the expansion of the field excavation activities. Preliminary findings indicate that TPH-impacted soils left in place after completion of the excavation are limited both

in horizontal and vertical extent and are primarily associated with a gravelly layer along the footer of the building. DoN reports that they are currently assessing strategies for dealing with the TPH-impacted footing area. DoN plans to prepare a report documenting the activities and observations noted during the removal of the hydraulic lifts and oil water separators and associated lines.

d. MTBE Plume Delineation:

Three investigations were performed in 1998 to delineate the northern extent of the MTBE plume. Current Site characterization data suggest that the MTBE plume extends approximately 2,800 feet north, downgradient of the NEX site, and the plume is approximately 600 feet wide (see Attachment A). November 1999 groundwater data for the Site shows that MTBE concentrations in groundwater in the vicinity of the UST-970 source area vary from about 10,000 µg/L to 82,000 µg/L in a plume that extends a distance of approximately 1,200 feet downgradient of the UST–970 source area and onto the former HAAF, portions of which are currently owned by the City of Novato and Shea Homes. The Shea Homes-owned portion of the former HAAF is currently undergoing a phased redevelopment into single-family residences.

Predictive numerical modeling was performed by the Navy to simulate the fate and transport of the MTBE groundwater plume at the Site. The model and input parameters were presented to the Regional Board in the Navy's January 2000 "Draft Final Corrective Action Plan for the Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California." Predictive numerical modeling of the MTBE plume indicates that with a decay rate of zero, the MTBE plume will move through the aquifer as a slug with no reduction in MTBE concentrations using representative aquifer parameters. The maximum MTBE concentration is modeled to occur at about 2,230 feet downgradient after 20 years and at about 3,937 feet downgradient after 40 years from the UST-970 source.

7. **Interim Remedial Measures**: Between June 1998 and early October 1999, air-sparging and soil vapor extraction (SVE) were implemented in areas where the highest hydrocarbon concentrations were detected in groundwater. Significant mass removal was achieved through the operation of the air-sparging/SVE system. An estimated 23,000 pounds of gasoline were removed by the system over approximately one (1) year of operation. During the course of system operation, it was determined that additional extraction wells would be required to achieve significant additional hydrocarbon removal. Therefore, the Navy discontinued interim remedial measures at the Site in early October 1999. DoN reports that the cumulative cost incurred for the removal of the 23,000 pounds of hydrocarbons is estimated at $400,000.

8. **Adjacent Sites**: MTBE-impacted ground water extends approximately 2,800 feet downgradient of the former UST970 tank complex and impinges on the western boundary of the Hamilton Army Landfill 26 (LF-26). While there are no current plans to do so, the potential exists for LF-26 to pump groundwater in the future and thereby capture the MTBE plume, which originates upgradient of LF-26.

9. **Basin Plan**: The Board adopted a revised Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan) on June 21, 1995. This updated and consolidated plan represents the Board's master water quality control planning document. The revised Basin Plan was approved by the State Water Resources Control Board and the Office of Administrative Law on July 20, 1995, and November 13, 1995, respectively. A summary of regulatory provisions is contained in 23 CCR 3912. The Basin Plan defines beneficial uses and water quality objectives for waters of the State, including surface waters and groundwaters.

   The potential beneficial uses of groundwater underlying and adjacent to the site include:

   a. Municipal and domestic water supply.
   b. Industrial process water supply.
   c. Industrial service water supply.
   d. Agricultural water supply.
   e. Freshwater replenishment to surface waters.

   At present, there is no known use of groundwater underlying the Site for the above purposes.

   Pacheco Creek is an intermittent creek that feeds into Novato Creek. The existing and potential beneficial uses of Pacheco Creek and Novato Creek include:

   a. Cold freshwater habitat.
   b. Fish migration.
   c. Municipal and domestic supply.
   d. Preservation of rare and endangered species.
   e. Water contact recreation.
   f. Water non-contact recreation.
   g. Fish spawning.
   h. Warm freshwater habitat.
   i. Wildlife habitat.

10. **Other Regional Board Policies**: Board Resolution No. 88-160 allows discharges of extracted, treated groundwater from site cleanups to surface waters only if it has been demonstrated that neither reclamation nor discharge to the sanitary sewer is technically and economically feasible.

    Board Resolution No. 89-39, "Sources of Drinking Water," defines potential sources of drinking water to include all groundwater in the region, with limited exceptions for areas of high TDS, low yield, or naturally occurring high contaminant levels.

11. **State Water Board Policies**: State Water Board Resolution No. 68-16, "Statement of Policy with Respect to Maintaining High Quality of Waters in California," applies to this discharge and requires attainment of background levels of water quality, or the highest level of water quality which is reasonable if background levels of water quality cannot be

restored. Cleanup levels other than background must be consistent with the maximum benefit to the people of the State, not unreasonably affect present and anticipated beneficial uses of such water, and not result in exceedance of applicable water quality objectives. This Order and its requirements are consistent with Resolution No. 68-16.

State Water Board Resolution No. 92-49, "Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304," applies to this discharge. This Order and its requirements are consistent with the provisions of Resolution No. 92-49, as amended.

12. **Preliminary Cleanup Goals**: The discharger will need to make assumptions about future cleanup standards for soil and groundwater, in order to determine the necessary extent of remedial investigation, interim remedial actions, and the draft cleanup plan. Pending the establishment of site-specific cleanup standards, the following preliminary cleanup goals should be used for these purposes:

    a. Groundwater: Applicable water quality objectives (e.g. maximum contaminant levels, or MCLs) or, in the absence of a chemical-specific objective, risk-based levels (e.g. drinking water equivalent levels).

    b. Soil: 1 mg/kg total volatile organic compounds (VOCs), 10 mg/kg total semi-volatile organic compounds (SVOCs), and background concentrations of metals.

13. **Basis for 13304 Order**: The discharger has caused or permitted waste to be discharged or deposited where it is or probably will be discharged into waters of the State and creates or threatens to create a condition of pollution or nuisance.

14. **Federal Waiver of Sovereign Immunity**: The Federal government has waived its sovereign immunity for this Order under Title 42, Section 6991f, of the United States Code.

15. **Cost Recovery**: Pursuant to California Water Code Section 13304, the discharger is hereby notified that the Board is entitled to, and may seek reimbursement for, all reasonable costs actually incurred by the Board to investigate unauthorized discharges of waste and to oversee cleanup of such waste, abatement of the effects thereof, or other remedial action, required by this Order.

16. **CEQA**: This action is an order to enforce the laws and regulations administered by the Board. As such, this action is categorically exempt from the provisions of the California Environmental Quality Act (CEQA) pursuant to Section 15321 of the Resources Agency Guidelines.

17. **Notification**: The Board has notified the discharger and all interested agencies and persons of its intent under California Water Code Section 13304 to prescribe site cleanup requirements for the discharge, and has provided them with an opportunity to submit their written comments.

18. **Public Hearing**: The Board, at a public meeting, heard and considered all comments pertaining to this discharge.

IT IS HEREBY ORDERED, pursuant to Section 13304 of the California Water Code, that the discharger (or its agents, successors, or assigns) shall cleanup and abate the effects described in the above findings as follows:

A. **PROHIBITIONS**

1. **DISCHARGE OF WASTE:** The discharge of wastes or hazardous substances in a manner which will degrade water quality or adversely affect beneficial uses of waters of the State is prohibited.

2. **POLLUTION MIGRATION:** Further significant migration of wastes or hazardous substances through subsurface transport to waters of the State is prohibited.

3. **POLLUTION MIGRATION CAUSED BY INVESTIGATION AND REMEDIATION:** Activities associated with the subsurface investigation and cleanup, which will cause significant adverse migration of wastes or hazardous substances, are prohibited.

B. **TASKS**

1. **WORKPLAN FOR REMEDIAL INVESTIGATION**

COMPLIANCE DATE: September 1, 2000

Submit a workplan acceptable to the Executive Officer to define the vertical and horizontal extent of soil and groundwater contamination at the Site, specifically in the vicinity of the NEX UST970-complex and NEX hydraulic lifts. The workplan at a minimum shall include:

a. Plans for investigating soil and groundwater in the vicinity of the former UST970 complex.
b. An evaluation of the impacts and potential impacts to groundwater in the fractured bedrock directly beneath the areas of highest hydrocarbon detections.
c. A determination of the volumes of unsaturated and saturated soil containing significant residual TPH, benzene, toluene, ethylbenzene, xylenes, and MTBE in the vicinity of Site "hot-spots" including the former UST970 complex and ancillary piping and pump islands, the former UST957 area, the former NEX waste oil tank, NEX hydraulic lifts, etc. Volume estimates will be based on

isoconcentration maps constructed from all soil chemical data collected throughout the investigative history of the Site. Isoconcentration maps will be constructed at 2 foot intervals, beginning at the ground surface through 12 feet below ground surface.

d. A determination of the horizontal and vertical extent of the separate phase hydrocarbons detected in the vicinity of monitoring well 970-MW-5.
e. An evaluation of the horizontal extent of the separate phase hydrocarbons detected in the vicinity of UST957 during the 1994-1995 Geoprobe sampling event.
f. A determination of the adequacy of the screen intervals for Site monitoring wells given documented seasonal variation in ground water elevation and nature of Site pollutants.
g. A plan to install a series of monitoring wells, properly located along the southern margin of the Site, parallel to the State Access Road and cross-gradient to the documented groundwater flow direction, designed to monitor the concentration of groundwater pollutants leaving the Site, so that any migration of the Site plume can be documented.
h. A plan to install a series of monitoring wells located downgradient of the former Site UST locations, cross-gradient to the documented groundwater flow direction, designed to monitor the movement of the existing groundwater plume and gauge plume stability.
i. A monitoring program for the above specified monitoring wells, which shall specify frequency of sampling, the proposed chemical analyses for ground water samples collected, and reporting schedule.

2. **COMPLETION OF REMEDIAL INVESTIGATION**

COMPLIANCE DATE: November 17, 2000

Submit a technical report acceptable to the Executive Officer documenting completion of the tasks identified in Task 1 workplan. The technical report shall define the horizontal and vertical extent of pollution in soil and groundwater at the Site.

3. **INTERIM REMEDIAL ACTION WORKPLAN FOR SOIL**

COMPLIANCE DATE: January 5, 2001

Submit a workplan acceptable to the Executive Officer evaluating interim remedial action alternatives for hydrocarbon-impacted soil of significant concentration, identified in Task No. 1 and in the vicinity of the former Site USTs, ancillary piping, and hydraulic lifts, as appropriate. The work plan should:

a. Recommend one or more alternatives for implementation.

b. Provide a time schedule for completing each task in the workplan that includes notifying the Regional Board 3-business days prior to the start date of any interim remedial actions.
c. Include a report on how the Navy will require and assure that onsite workers (i.e., construction workers and maintenance personnel) work under a Health and Safety Plan and are adequately protected from exposure to contaminated soil and groundwater during Site remedial actions.

4. **COMPLETION OF INTERIM REMEDIAL ACTION FOR SOIL**

COMPLIANCE DATE: Within 21-days of the date for completion of each task in the accepted time schedule (B.4.c.) above.

Complete the work and submit a technical report acceptable to the Executive Officer documenting completion of each of the tasks identified in the Task B.4. workplan.

5. **MONITORING WELL PROTECTION PLAN**

COMPLIANCE DATE: September 15, 2000

Submit a workplan acceptable to the Executive Officer that presents a monitoring well protection and management strategy/plan given the nature and magnitude of proposed site redevelopment/construction activities. The workplan should include plans for GIS-location of wells and include a provision for notifying the RWQCB 60-days prior to any well modification.

The workplan shall also include a plan that is acceptable to the Executive Officer, for replacing monitoring wells destroyed in 1999 due to HAAF site redevelopment activities. The workplan shall specify investigation methods for finding the locations of the destroyed wells and present a time schedule for the investigation and monitoring well installations.

6. **PROPOSED FINAL CORRECTIVE ACTION PLAN FOR GROUNDWATER**

COMPLIANCE DATE: February 28, 2001

Submit a workplan acceptable to the Executive Officer that includes:

a. A feasibility study (FS) to:

1. Stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site.
2. Remediate the highest concentrations of soil pollution detected in Task B.1.
3. Reduce and remediate the concentrations of MTBE in Site groundwater.
4. Reduce and remediate the concentrations of benzene in Site groundwater which exceed applicable risk based screening levels (RBSLs).

b. The FS shall contain:

1. The results of all Site remedial investigations.
2. An evaluation of interim remedial actions.
3. An analysis and comparison of alternative final remedial actions.
4. Recommendation of final remedial actions and cleanup standards.
5. If any of the recommended final cleanup standards are less than background levels, the proposed standards must achieve the best water quality reasonably possible, be consistent with the maximum benefit to the people of the state, not unreasonably affect beneficial uses, and may not be set below those set by the Basin Plan and applicable Policies. Further, if the recommended final cleanup standards are less than background levels, provide evidence and analysis showing that it is a) technologically or economically infeasible to achieve background levels, and b) that the constituent will not pose a substantial present or potential hazard to human health or the environment for the duration of the exceedence of background levels.
6. Time schedule for implementation of the recommended alternative.

Item B.6.b.3 should include projections of cost, effectiveness, benefits, and impact on public health, welfare, and the environment of each alternative action.
Items B.6.b.1 through B.6.b.3 should be consistent with the guidance provided by Subpart F of the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), CERCLA guidance documents with respect to remedial investigations and feasibility studies, Health and Safety Code Section 25356.1(c), and State Board Resolution No. 92-49 as amended ("Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304"), and all other applicable State Board Policies.

7. INTERIM SITE CONTROLS ON EXCAVATION OF POLLUTED SITE SOILS AND DISCHARGE OF POLLUTED SITE GROUNDWATER

COMPLIANCE DATE: September 29, 2000

After consulting with interested parties, prepare and submit a report, acceptable to the Executive Officer, of interim controls to be placed on the excavation of polluted Site soils and extraction and discharge of polluted Site groundwater in

order to protect human health and the environment prior to the completion of a final remedial action at the Site pursuant to Task 6. The report shall include:

1. Requirements to ensure that any excavated, polluted Site soil will be handled and disposed of properly (e.g., bioremediate polluted soil before backfilling Site excavations, or backfill with clean backfill, and polluted excavated Site soils will be tested and disposed of at a permitted disposal facility);
2. Requirements to ensure that the discharge of polluted Site groundwater will be handled and disposed of properly (e.g., tested and hauled to a permitted disposal facility, or treated and discharged under an NPDES permit);
3. Requirements to ensure that on-Site workers who are involved in activities that can expose them to polluted Site soils and/or groundwater be notified of the location and depth to polluted Site soils and groundwater, and be informed that a Health and Safety Plan is required before the activity begins;
4. Requirements to ensure that the portion of the Site which is currently surrounded by chain-link fence and locked gates be kept secure, and the remainder of the polluted soil and groundwater impacted Site, which is currently not secured by fence and gate, be surveyed (policed) periodically to verify that the controls identified in the report required by the Task are complied with;
5. Requirements to ensure that a person will be designated, who will serve as the point of contact for any entity wanting to excavate polluted Site soil and who will distribute copies of the controls identified in the report required by this Task and maps of the Site pollution to any inquiring entity and all agencies, such as water, electric and gas agencies, that the Navy has reason to believe may be excavating polluted soil at the Site; and,
6. Requirements to ensure that any parties negotiating for the transfer of any Site parcel containing polluted soil and groundwater be made aware of these interim Site controls and informed that these controls will be continued by Deed Restriction or equivalent alternative type of institutional control, acceptable to the Executive Officer, if any Site parcel containing polluted soil and groundwater is transferred prior to completion of the a final remedial action at the Site pursuant to Task 6.

The above report and controls are intended to serve as interim measures to ensure protection of human health and the environment pending completion of a final remedial action and are not intended to be construed as a substitute for the Navy's compliance with any requirements in Task 6.

8. GROUNDWATER MONITORING PLAN

COMPLIANCE DATE: September 15, 2000

Submit a Groundwater Monitoring Plan, acceptable to the Executive Officer, that describes the procedures for conducting quarterly groundwater elevation measurements and quarterly sampling of existing and proposed wells located on Site 957/970 and the adjoining Army property (HAAF) to the north. The Groundwater Monitoring Plan shall include provisions for measuring surface water elevations and collecting and analyzing surface water samples from Pacheco Creek. The Groundwater Monitoring Plan shall describe methods, procedures, and materials to be used in the performance of the groundwater sample collection and analysis. The collection methods, preservation methods, and holding times for all samples will be in accordance with U.S. Environmental Protection Agency approved procedures. A California State certified analytical laboratory will conduct all analyses.

9. **SITE STATUS REPORTS**

COMPLIANCE DATE: Quarterly reports beginning November 1, 2000

Submit Quarterly Site Status Reports, acceptable to the Executive Officer that present the results of each quarterly groundwater/surface water monitoring event. The reports shall include <u>all</u> data gathered and observations made during each sampling event, a summary of findings, potentiometric maps, and tabulated groundwater level measurements and groundwater analytical reports for all pollutants analyzed. The reports shall be signed under penalty of perjury.

Additionally, the Quarterly Site Status Report shall include a discussion of the work completed in that quarter towards compliance with this Order, and the work planned for the next quarter.

10. **DELAYED COMPLIANCE**: If the discharger may be delayed, interrupted or prevented from meeting one or more of the completion dates specified in this Order, the discharger shall promptly notify the Executive Officer. If, for any reason, the discharger is unable to perform any activity or submit any document within the time required under this Order, the discharger shall make a written request for a specified extension of time. The extension request shall include a justification for the delay, and shall be submitted in advance of the date on which the activity is to be performed or the document is due.

11. **COSTS**: The discharger will pay the full costs incurred by the Regional Board in monitoring and enforcing cleanup at this site and for oversight of this order.

C. **PROVISIONS**

1. **No Nuisance**: The storage, handling, treatment, or disposal of polluted soil or groundwater shall be conducted in a manner such that would not create a nuisance as defined in California Water Code Section 13050(m).

2. **Good Operation and Maintenance (O&M)**: The discharger shall maintain in good working order and operate as efficiently as possible any facility or control system installed to achieve compliance with the requirements of this Order.

3. **Access to Site and Records**: In accordance with California Water Code Section 13267(c), the discharger shall permit the Board or its authorized representative:

   a. Entry upon premises in which any pollution source exists, or may potentially exist, or in which any required records are kept, which are relevant to this Order.

   b. Access to copy any records required to be kept under the requirements of this Order.

   c. Inspection of any monitoring or remediation facilities installed in response to this Order.

   d. Sampling of any groundwater or soil which is accessible, or may become accessible, as part of any investigation or remedial action program undertaken by the discharger.

4. **Lab Qualifications**: State-certified laboratories, or laboratories accepted by the Board using approved EPA methods for the type of analysis to be performed, shall analyze all samples. All laboratories shall maintain quality assurance/quality control (QA/QC) records for Board review. This provision does not apply to analyses that can only reasonably be performed on-site (e.g. temperature).

5. **Document Distribution**: Copies of all correspondence, technical reports, and other documents pertaining to compliance with this Order shall be provided to the following agencies:

   a. City of Novato, Department of Community Development, 900 Sherman Avenue, Novato, California 94945
   b. Cal/EPA-Department of Toxic Substances Control, 19151 Croydon Way, Suite 3, Office of Military Facilities, Sacramento, California 95827.
   c. U.S. Environmental Protection Agency, Region 9.
   d. California Regional Water Quality Control Board, Region 2.

The Executive Officer may modify this distribution list as needed.

6. **Reporting of Changed Owner or Operator**: The discharger shall file a technical report on any changes in site occupancy or ownership associated with the property described in this Order.

7. **Reporting of Hazardous Substance Release**: If any hazardous substance is discharged in or on any waters of the State, or discharged or deposited where it is, or probably will be, discharged in or on any waters of the State, the discharger shall report such discharge to the Regional Board by calling (510) 622-2300 during regular office hours (Monday through Friday, 8:00 AM to 5:00 PM).

   A written report shall be filed with the Board within five working days. The report shall describe: the nature of the hazardous substance, estimated quantity involved, duration of incident, cause of release, estimated size of affected area, nature of effect, corrective actions taken or planned, schedule of corrective actions planned, and persons/agencies notified.

   This reporting is in addition to reporting to the Office of Emergency Services required pursuant to the Health and Safety Code.

8. **Periodic SCR Review**: The Board will review this Order periodically and may revise it when necessary. The discharger may request revisions and upon review, the Executive Officer may recommend that the Board revise these requirements.

I, Lawrence P. Kolb, Acting Executive Officer, do hereby certify that the foregoing is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, San Francisco Bay Region, on July 19, 2000.

_____

Lawrence P. Kolb
Acting Executive Officer

==========

FAILURE TO COMPLY WITH THE REQUIREMENTS OF THIS ORDER MAY SUBJECT YOU TO ENFORCEMENT ACTION, INCLUDING BUT NOT LIMITED TO: IMPOSITION OF ADMINISTRATIVE CIVIL LIABILITY UNDER WATER CODE SECTIONS 13268 OR 13350, OR REFERRAL TO THE ATTORNEY GENERAL FOR INJUNCTIVE RELIEF OR CIVIL OR CRIMINAL LIABILITY

==========

Attachment A: DoD-Housing Facility and Vicinity Site Map, Marin County, Novato, California

ATTACHMENT 2

DTSC Approval Letter of July 13, 2001

on

Draft Revised Risk Assessment for Former UST Site 957/970, Department of Defense Housing Facility, Novato, California, dated June 8, 2001

Department of Toxic Substances Control

Edwin F. Lowry, Director
8800 Cal Center Drive
Sacramento, California 95826-3200

Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

July 13, 2001

Mr. Thomas L. Macchiarella
BRAC Environmental Coordinator
Department of the Navy
Naval Facilities Engineering Command
1220 Pacific Highway
San Diego, California 92132-5190

REVIEW OF THE DRAFT REVISED RISK ASSESSMENT FOR FORMER UNDERGROUND STORAGE SITE 957/970, DEPARTMENT OF DEFENSE HOUSING FACILITY, NOVATO, CALIFORNIA DATED JUNE 2001

Dear Mr. Macchiarella:

The Department of Toxic Substances Control (DTSC) has reviewed the Navy's Draft Risk Assessment for the subject site, and concurs with its findings. Please find specific suggestions from DTSC's risk assessor regarding the report enclosed.

Previously, the Navy completed a *Tier 3 Risk-Based Corrective Action (RBCA) Assessment for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility Novato, California and Adjoining Property on Hamilton Army Airfield* (Batelle, November 24, 1999) in consultation with the San Francisco Bay Regional Water Quality Control Board. A school site was proposed for location on a portion of the Navy Property by the Novato Unified School District (NUSD). DTSC is required pursuant to Section 17213 of the California Education Code, to approve the environmental review and cleanup process for the proposed acquisition and/or construction of school properties utilizing State funding. While the NUSD did not use State funding to acquire the property or make the initial improvements, the NUSD would like to be eligible for State funding in the future for additional projects. In order to be eligible, NUSD would have to complete all statutory requirements. Therefore, DTSC requested the Navy perform additional risk analysis consistent with DTSC risk models.

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Web-site at www.dtsc.ca.gov.

Printed on Recycled Paper

When contamination remains in place greater than what is allowed for unrestricted use, or the selected remedy requires protection, institutional controls including use restrictions will be required as part of the remedy. DTSC expects the Navy to work with the BRAC Cleanup Team to identify any necessary institutional controls required to protect public health and the environment in the Corrective Action Plan for Site 957/970.

This determination is based upon the information submitted by the Navy. We expressly reserve all rights and authorities relating to information not contained in Navy documents, whether such information is known as of this date or is discovered in the future.

If you have any questions, please contact me at (916) 255-3664.

Sincerely,

Theresa McGarry
Project Manager
Office of Military Facilities

Enclosure

cc: Mr. Jim Davies
Harding ESE, Inc.
90 Digital Drive
Novato, California 94949

Mr. Ken Bell
RBF Associates
14725 Alton Parkway
Irvine, California 92718-9739

Mr. Ray Seid
United States Environmental Protection Agency
75 Hawthorne Street
San Francisco, California 94105

cc: Mr. James Ponton
California Regional Water Quality Control Board
San Francisco Bay Region
1515 Clay Street, #1400
Oakland, California 94612

Department of Toxic Substances Control

Edwin F. Lowry, Director
2878 Camino Del Rio South, Suite 402
San Diego, California 92108

Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

MEMORANDUM

TO: Theresa McGarry
Office of Military Facilities
8800 Cal Center Drive
Sacramento, CA 95826-3746

FROM: Michael Schum, Ph.D.
Staff Toxicologist
Human and Ecological Risk Division (HERD)

DATE: July 6, 2001

SUBJECT: Department of Defense Housing Facility, Novato
Review of Revised Health Risk Assessment for Former UST Site 957/970
PCA: 14740 Site: 200529-47

Background

Per your technical services request, the Human and Ecological Risk Division (HERD) has reviewed a revised health risk assessment (HRA) submitted by the Navy for the DoD Housing Facility UST Site 957/970 in Novato (DoDHS). The site has undergone substantial remediation to reduce contamination associated with gasoline from leaking underground storage tanks under the jurisdiction of San Francisco Regional Water Quality Control Board. The site borders the former Hamilton Army Airfield (HAAF), a DTSC / RWQCB joint lead site. Contaminated groundwater has migrated onto the HAAF property. This revision was prepared to address comments DTSC provided on a risk assessment submitted to the RWQCB in preparation for transfer of portions of the DoDHS property to the Novato School District and the City of Novato (memo from DTSC dated 6/25/00). The HRA also includes additional site investigation work, specifically additional soil gas sampling, recommended by DTSC in meetings held with the Navy and their contractors.

Document Reviewed

"Draft Revised Risk Assessment for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California," prepared for Naval Facilities Engineering Command, Southwest Division by Battelle, dated June 8, 2001. Received by HERD on 6/12/01.

Comments

The Navy and Battelle have gone to great lengths to accommodate the recommendations DTSC has provided. The revision is well done and acceptable subject to the following caveats.

Specific Comments

1. Evaluation of the indoor air exposure pathway. As requested by DTSC, the Navy conducted soil gas sampling in both the Sale and PBC Areas. This data was used as input to USEPA recommended exposure models for evaluating potential migration of volatile organic chemicals in subsurface soil to indoor air. For modeling purposes, Battelle used the soil gas data to estimate an "equivalent soil concentration" based on equilibrium partitioning between soil, soil water and soil vapor. The model calculations use this equilibrium partitioning approach to estimate the indoor air concentrations to calculate risks. The advantage to this approach vs. using concentrations in groundwater to estimate indoor air risks is that the measured soil gas term includes the total contribution to soil gas from groundwater volatilization as well as that from contaminants bound in the vadose zone soil. It should be noted that the "equivalent soil concentration" used as input to the models shown in Appendix H is not the actual soil concentration that would be measured in the field. It is an artificial term that leads to a model calculated soil gas concentration term identical to the measured soil gas concentration.

HERD recommends that the HRA include the laboratory chemical data analytical sheets. Although soil gas data is summarized in Appendix H, evaluation of indoor air risks, the raw data sheets should be included to show which chemicals were included in the list of analytes as well as the appropriate method detection limits. The HRA should contain at the very least, a complete set of analytical data sheets from the most recent sampling events in all media (soil, groundwater and soil gas).

Appendix H shows a significant increase in toluene reported in soil gas collected during sampling events last fall at off-site monitoring well MP 7/8 (adjacent to the Hamilton Meadows subdivision). Toluene was not detected at a detection limit of 0.0075 ug/l on 9/22/00. A sample collected at the same location on 12/16/00 reported a concentration of 3.54 ug/l. The table labeled "Indoor Air Risks from Toluene" in Appendix H appears to have a units conversion error for the 12/16/00 sampling date between ug/l and ppbv. Lacking the original data sheets, it is not known which value is correct, so we cannot verify the risk calculations.

2. Soil gas. Several sections of the report, including the Executive Summary, note that no BTEX (benzene, toluene, ethylbenzene, xylene) compounds have been detected in "soil or groundwater" on the HAAF portion of the groundwater plume (e.g. Hamilton Meadows). MTBE has migrated with the plume over a large area of the Hamilton

Meadows subdivision and is present in groundwater. In addition, some gasoline-related VOCs (e.g. toluene, xylene) have been detected in soil gas at two monitoring well locations near the Hamilton Meadows subdivision, although the same chemicals have apparently not been detected in groundwater in these wells. This subdivision is also bordered on the north by Landfill 26 which is known to have high concentrations of methane gas that may facilitate migration of landfill gases including possible BTEX compounds onto the Hamilton Meadows property. At this point, it cannot be determined whether the BTEX compounds detected in soil gas result from vapor migration from the DoDHS site or the landfill. Regardless of the source of contamination, the HRA evaluated potential risks at location MP 7/8 from measured soil gas for the indoor air pathway and concluded that the risks are less than 1×10^{-6}.

3. Excavation Worker Risks/Hazards. DTSC had specifically requested that the HRA evaluate a future land use exposure scenario for a construction excavation worker, and recommended a specific exposure model developed by the USEPA for CERCLA activities. This exposure model uses a mathematical model and numerous generic assumptions about potential emission and contact rates to estimate ambient air concentrations to which workers using heavy construction equipment to excavate soil may be exposed. Using this highly conservative model, cancer risks were not considered to be a significant threat and HERD concurs. The predicted noncancer risks (Hazard Index) were well above an acceptable level of one for both the Sale and PBC Areas. HERD has examined these results in greater detail and we believe the noncancer hazard is likely less than reported, although the magnitude of the difference cannot be determined. Our conclusion is based on: 1) the exposure model is used to calculate a one-hour average air concentration using very conservative exposure factors (e.g. cubic yards of soil manipulated per day, volume of equipment loader bins, etc.); and 2) comparison to toxicity factors based on chronic, long-term exposure levels, which are typically much lower than those used to evaluate acute or subchronic health effects. It is more appropriate to compare estimated short term average concentration values to subchronic toxicity factors. This would lead to a lower estimated hazard index.

Noncancer health effects for the excavation scenario are attributed mostly to trimethylbenzene (1,2,4-TMB and 1,3,5-TMB ~90%) and to a lesser degree, naphthalene. No generally accepted regulatory toxicity factors are available for these compounds for short-term exposures for the general public. There are worker protection standards but these are not generally appropriate for risk assessment purposes. For comparison though, the exposure model predicted one-hour average outdoor air concentrations during excavation activities in the Sale Area to be 5.3 mg/m^3 (1,2,4-TMB); 2.4 mg/m^3 (1,3,5-TMB); 1.87 mg/m^3 (naphthalene). For the PBC Area, the model predicted 2.19, 1.03 and 0.14 mg/m^3. OSHA regulated worker protection standards are 50 mg/m^3 for naphthalene and 123 mg/m^3 for trimethylbenzene (ACGIH TLV/TWA). Please note that HERD does not recommend that these OSHA standards be used for risk assessment purposes. They are presented here strictly as a basis for comparison. The OSHA standards apply only for industrial hygiene limits for workers in

closely regulated and monitored environments (appropriate on-site monitoring, worker protection requirements, and medical monitoring and surveillance requirements). Since there is no guarantee that these types of OSHA industrial hygiene requirements will always be enforced, HERD recommends that appropriate institutional controls be implemented to insure that construction / excavation workers are not unwillingly exposed to potentially harmful soil gas vapors

4. Noncancer indoor air risks. The HRA used the spreadsheet models developed by the USEPA for CERCLA as modified by DTSC to use CalEPA recommended cancer potency factors. The version of the spreadsheet models used by Battelle did not contain toxicity reference values for noncancer effects from benzene, and therefore the hazard index (sum of hazard quotients of individual chemicals) calculated by Battelle did not include cumulative noncancer effects from benzene. DTSC has recently modified the USEPA spreadsheets to include the CalEPA OEHHA chronic noncancer Relative Effects Levels (RELs) used for the Air Toxics Hot Spots Program. HERD has examined the spreadsheets used for this HRA, and using the maximum reported soil gas concentration (Sample location SG-16; Appendix H) determined that the HI will not be significantly affected by the inclusion of benzene (increase in HI < 0.01). Even with the inclusion of the noncancer hazards from benzene, the noncancer residential HI for the indoor air pathway is well below one in both the Sale and PBC Areas.

5. Soil Gas Monitoring. Tables 3-2 and 3-3 tables summarize the predicted indoor air risks for the Sale Area and PBC Area respectively. Cancer risks in the PBC Area are estimated to be less than 1×10^{-6} using the maximum reported soil gas concentration at location SG-17. Risks inside the Sale Area are estimated to be less than 1.3×10^{-5} for a hypothetical residential exposure scenario, or 8×10^{-6} for an occupational exposure scenario at location SG-16 (maximum soil gas location in Sale Area). While we agree that a commercial/industrial exposure scenario in the Sale Area is most likely, we note that risks estimated from soil gas measurements vary substantially in a short distance between monitoring locations bordering the boundary of the Sale and PBC area. The Navy has indicated that the higher risks calculated for the Sale property can be attributed more to soil gas emanating from benzene bound in vadose zone soil rather than emissions from groundwater. This interpretation is based in part on the observation that the maximum measured soil gas concentrations generally do not occur at the locations of maximum groundwater concentrations. It is our understanding that the RWQCB intends to continue to monitor groundwater concentrations on both the Sale and PBC Areas. We also note that groundwater concentrations in the vicinity of SG-16 and SG-17 have decreased substantially over time. We recommend that the RWQCB also continue to monitor soil gas profiles at these locations to assist in evaluating if the decrease in groundwater concentrations is related to biodegradation vs. dilution related to migration of contaminants in the groundwater plume. If biodegradation is the primary process of removal as suggested by the Navy and Battelle, we would expect the soil gas concentrations to decrease significantly over time. If groundwater concentrations continue to decrease with little change in soil gas

concentrations, it would suggest that biodegradation may not be as significant as hypothesized. This may impact future decisions on development primarily in the Sale Area if a reservoir of soil-bound contaminants is to be left in place.

Summary

The methodology and risk calculations and overall risk assessment report is generally acceptable for release to the public, but we suggest that an additional appendix be made available for public review as soon as possible to accompany the HRA showing the actual laboratory data reports. HERD believes that the HRA would benefit greatly by including the analytical data sheets for the most recent sampling events for groundwater, soil gas and bulk soil measurements. Much of this data is already included in the Figures in the HRA and other reports submitted to the RWQCB. We feel it is useful to provide the original results (laboratory data sheets) for the most recent sampling events in the HRA report as well, showing which chemicals were analyzed for but not detected in the different media, as well as method detection limits.

For risk management purposes, Regional personnel should evaluate the following limitations on the risk assessment.

1. Groundwater Exposure Pathways. The HRA did not estimate health risks from potential ingestion of groundwater or residential use of groundwater (showering, gardening, swimming pools, etc). If the Regional Water Board has determined that the contaminated groundwater under the site will not be pumped and used for these purposes by whatever regulatory restrictions they have the authority to impose, HERD concurs that this pathway need not be evaluated for potential health risks

2. Ecological Assessment. Numerous concerns have been raised in the community about the potential for site-related contaminants to migrate off-site into Pacheco Creek on the HAAF property. The HRA prepared by Battelle evaluates only potential human health exposures on the Navy property (Sale and PBC Areas) from exposures by inhalation or direct soil contact. The HRA should not be used to make any decisions regarding potential ecological impacts from off-site migration of contaminated groundwater.

3. Secondary Exposure Pathways. The HRA did not evaluate potential secondary exposure pathways (e.g. consumption of food items grown in contaminated media) that might occur in a residential exposure scenario. Some concerns were raised about this possibility at a recent Restoration Advisory Board meeting. HERD feels that the risks from this pathway are negligible since: 1) volatile organic chemicals such as benzene, MTBE and toluene have not been shown to bioaccumulate in the types of garden crops which could potentially be grown in the PBC Area; and 2) uptake of these types of highly volatile chemicals by plants from groundwater would be rapidly lost by photosynthetic plants by the process of transpiration / evaporation to the atmosphere.

4. Invasive Construction Worker. As noted above, the HRA did evaluate potential inhalation exposures for future excavation / construction workers in the Sale and PBC Areas. The HRA concluded that there could be a potential noncancer health threat for this scenario. As such, the HRA should not be interpreted to mean that no land use restrictions are necessary. Although future occupational type exposures may be monitored and/or controlled by regulatory industrial hygiene requirements, it has been HERD's experience that these requirements are not always met in real life situations, especially for short-term invasive earth moving type of construction activities. Some type of enforceable institutional controls need to be included in a final risk management decision before any property transfers take place between the Navy and/or the City of Novato and the Novato School District.

The comments we have provided are meant to be constructive and we hope they are useful. If you have any questions please call me at (619) 278-3743 or the Human and Ecological Risk Division at (916) 255-6640.

Reviewed by: Michael Wade, Ph.D. MTW
Senior Toxicologist

Cc: Charles Miller, DVM, Ph.D.
Senior Toxicologist

c:\dtsc\region1\dodhs2.doc.36hz

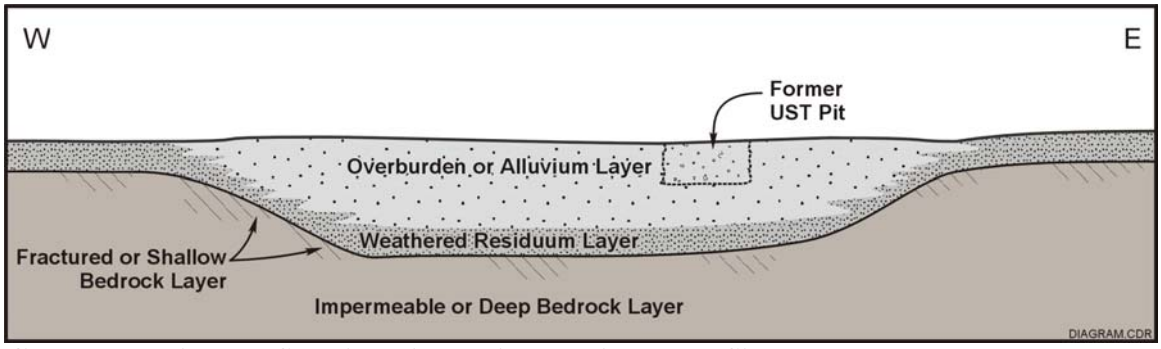
ATTACHMENT 3

US Navy Summary Findings on Bedrock Groundwater Conditions at the Former Underground Storage Tank Site 957/70 Department of Defense Housing Facility Novato, California

US Navy Summary Findings on Bedrock Groundwater Conditions at the Former Underground Storage Tank Site 957/70, Department of Defense Housing Facility (DoDHF), Novato, California

January 11, 2002

This document is a briefing on key facts, interpretations, and conclusions regarding the Franciscan Bedrock Complex at former Underground Storage Tank (UST) Site 957/970 at the Department of Defense Housing Facility (DoDHF) Novato, California and the adjoining former Hamilton Army Airfield (HAAF). This information was gathered during remedial investigation efforts and other subsurface characterization and remedial actions performed by the Navy and the U.S. Army Corps of Engineers (USACE). The primary issues of concern, expressed by the California Department of Toxic Substance Control (DTSC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB), are the potential for storage or transport of MTBE in bedrock at the site. Presented here is an evaluation of the likelihood that significant MTBE or other fuel constituents have impacted bedrock across the site, and the likelihood that significant downgradient or cross-gradient transport of MTBE or other fuel constituents from the UST sites has occurred within bedrock. The evaluation is based on results obtained during the following five types of activities performed at the site: 1) bedrock drilling and sampling already completed at the site, 2) bedrock characterization performed by USACE in the adjacent Area 800/Ammo Hill and Petroleum, Lubricants and Oil (POL) Hill, 3) characterization and monitoring of the MTBE plume located in the overburden aquifer, 4) risk assessments that have evaluated likely exposure pathways, and 5) review of aerial photographs, geologic maps and geologic reports of the Novato area. The conceptual diagram presented below identifies each lithologic layer that is discussed throughout this summary write-up.



Conceptual Diagram Showing Lithologic Layering at the Site

Based on the results of the activities mentioned above, the Navy believes it is unlikely that MTBE has directly impacted bedrock at the site, and there is no evidence of significant storage or transport of MTBE in bedrock under the site. The Navy understands there is uncertainty associated with the existing conditions in bedrock, and that there are many possible scenarios. However, based on the preponderance of the available data, the Navy believes the most likely explanations for observations of hydrocarbons in bedrock wells include: 1) a faulty seal around the conductor casing or completed well, or 2) bedrock wells were not installed such that their screens are hydraulically separated from the aquifer that exists in overlying alluvium, residuum, and potential fractures in the shallow bedrock layer. Both of these scenarios allow direct communication between the screens of the bedrock wells and the overlying aquifer through fractures that exist in the shallow bedrock. This direct communication could result in the

accumulation of groundwater in the bedrock wells that originates from the overlying aquifer. Primary porosity in bedrock may also at most play a minor role in downward migration of shallow groundwater into the bedrock wells. However, the core samples collected during bedrock drilling indicated that the bedrock is nearly impermeable and has very little primary porosity, unless fractures are present. Few fractures were observed during bedrock drilling and those fractures in impermeable bedrock (2 to 3 ft below shallow bedrock) were infilled with secondary minerals (calcite and silica).

It is unlikely that MTBE is being transported cross-gradient to the east within fractured bedrock and impacting shallow soil-gas in the area because generally non-detect concentrations of MTBE (1.6 µg/L of MTBE in MW-3B during the fourth quarter 1999) have existed in two groundwater monitoring wells located west of the bedrock high and east of C Street during twelve consecutive quarterly monitoring events. These data indicate that clean groundwater exists between the MTBE plume and the bedrock high in the area of the two monitoring wells east of C Street. Therefore, the bedrock high appears to be restricting the lateral extent of the alluvial aquifer, indirectly confining the MTBE plume in the area of the two monitoring wells east of C Street.

The Navy evaluation reached the following conclusions regarding the storage and transport of hydrocarbons in bedrock at the site:

1) Conditions are not favorable to enable migration of MTBE from the overburden into bedrock

Supporting evidence:

- The tank pit excavations are not in direct contact with and are not thought to communicate directly with any fractured bedrock that may be present. The pits were dug to depths that are about 6 to 8 ft. above the top of bedrock; therefore, any existing fractures in bedrock were insulated from the former tank sources by approximately 6 to 8 ft of the alluvium overburden.

- The split spoon soil and bedrock cores indicate that overburden directly above bedrock is weathered residuum. This residuum appears to be clayey and generally impermeable. Overburden split spoon samples, collected from a number of well locations across the site, indicate that clayey zones are generally present above bedrock and they generally range between 2 and 4 ft in thickness. **Figure 1** contains example boring logs collected from overburden wells in the vicinity of the former USTs.

2) MTBE has not systemically entered bedrock, and no appreciable mass of MTBE is present in storage in bedrock.

Supporting evidence:

- Rock core was collected, observed, and visually logged during the drilling of two bedrock wells. **Figure 2** is a display of the geologic logs from bedrock cores collected during drilling. There was no indication of MTBE observed in the cores during the field effort. Lithologically, these cores indicate a thin bedrock fracture zone may be present, (~2 ft thick), above underlying impermeable bedrock, which consists of slightly metamorphosed quartzic sandstone. The few fractures observed at depths greater than 2 ft below top of bedrock were infilled with secondary minerals (calcite and silica). Additionally, these rock core logs are consistent with the similar logs collected from bedrock wells drilled at the USACE POL Hill

site. Overall, core samples from both investigations indicated there were no bedrock intervals that appear to be capable of storing and transmitting significant volumes of groundwater.

- On-going quarterly groundwater sampling results indicate that concentrations of fuel constituents in the two completed bedrock wells closely match concentrations detected in the overburden above the bedrock wells (see **Table 1**). These results, along with other information, imply that the overburden contains the sole aquifer at the site. The overburden aquifer is underlain by impermeable bedrock. Sample results collected from the bedrock wells should not match those collected from the overburden if a permeable fractured bedrock interval was present below the overburden and if significant mass is being stored in bedrock. The fact that samples collected from the bedrock wells are similar to concentrations measured in the overburden, imply that the groundwater collected in the bedrock wells was pulled down to the screen interval from the overburden, through either primary porosity and/or localized fractures. An alternate scenario is that MTBE is present in these bedrock wells because the completions are leaking groundwater from the overlying aquifer.

3) Preferential fracture pathways are not present within bedrock, or if they are present, they are unlikely to be transmitting MTBE.

Supporting evidence:

- A review of aerial photographs showed no evidence of a large-scale bedrock fracture system or pattern in the site vicinity. According to information presented in the California Division of Mines and Geology (DMG) report (1975) and the bedrock logs from site investigations, the bedrock beneath the site is most similar to the graywacke-type sandstone of the Franciscan Melange geologic unit. The graywacke is characterized by "tough, fine- to coarse-grained, thick bedded, gray to dark gray at depth, but normally weathered near the surface to brown or pale buff color. Sheared in many places. Has no interangular permeability; thus permeability determined by joints or fracture density and spacing. 'Permeability' generally low because of clay filled in joints." (DMG, 1975). Based on this description and the lack of large-scale faulting or fracture systems, as a unit, the graywacke bedrock beneath the site is likely to exist as the impermeable base of the overlying alluvial aquifer.

- The two completed bedrock wells at the UST site both yield low quantities of groundwater and recover very slowly when they are bailed or pumped. Typically, about 3 and 5 gallons of groundwater are purged from bedrock wells MW-3D and MW-9A, respectively, before they go dry. The fact that the bedrock wells are slow to recover implies that no significantly permeable interval is present below the overburden.

- Taking a more regional perspective, the USGS topographic map (see **Figure 3**) shows that outcropping bedrock highlands surround the site. Bedrock highlands are present in all directions except to the north. North (downgradient) of the site, Ammo Hill projects upward through the overburden aquifer, diverting groundwater flow. Because Former UST Site 957/970 is situated in a bedrock valley, flow would occur in a direction that is away from highland areas, toward bedrock and surface topographic lows. At this former UST site, flow can only take a generally northward direction. As a consequence, regardless of fracture orientation, groundwater flow in bedrock would be forced to flow is the same direction that groundwaters flows in the overburden. If an isolated, transmissive bedrock zone or discrete fractures were present, recharge would occur in the outcropping bedrock highs surrounding

the site and an upward vertical gradient would be present beneath the site such that overburden groundwater would not enter bedrock.

- The Ammo Hill site, as depicted on **Figure 3**, is located immediately downgradient of Former UST Site 957/907. USACE performed soil and rock coring at Ammo Hill, in addition to hydraulic slug testing. Results from these efforts show that shallow bedrock permeability is less than or equal to permeabilities measured in the overburden, and that deep bedrock is impermeable. Based on these findings, USACE concluded that there in only one aquifer at the site. Any permeable areas of bedrock behave as an extension to the overlying overburden aquifer. No separate zone of transmissive bedrock is known to be present. (IT Corporation, 1998).

> "The bedrock of the Franciscan Formation underlies the alluvium throughout the site and is exposed at Ammo Hill and Reservoir Hill. It is largely composed of a fine to medium grained sandstone that has been slightly altered by metamorphism. This has effectively sealed the primary porosity of the bedrock. The bedrock has been fractured to create a degree of secondary porosity. This secondary porosity has been in turn locally healed by calcite mineralization. Observation of bedrock core indicates that the degree of fracturing decreases with depth. Minor amounts of groundwater are present in bedrock fractures. An average hydraulic conductivity value of $1.2x10^{-4}$ ft per minute was calculated from four slug tests conducted in monitoring well 1MW-08, screened in bedrock on the south side of Ammo Hill. Given that fractured bedrock porosities are on the order of 0-10 percent (Freeze and Cherry, 1979), the bedrock is considered to be a subordinate unit in terms of groundwater transport (with respect to the alluvium)."
>
> (IT Corporation, 1998; pg 6-3)
>
> "For the purposes of this investigation, zones of intensely weathered bedrock in contact with alluvium are considered part of the alluvial aquifer, and unweathered bedrock is considered to be the impermeable base of the groundwater system, although minor amounts of water may be present in fractures in the unweathered bedrock."
>
> (IT Corporation, 1998; pg 6-24)

- The Navy's on-going groundwater quality monitoring program results indicate that the MTBE plume is contained only within the overburden. As depicted in **Figure 4**, there are no plume features implying that preferential pathways in the bedrock are present across the plume area. No anomalous hot spots have been detected either along the downgradient plume margin or along the lateral margins of the plume. The plume "tapers" evenly along all of its margins. If fractured bedrock preferential pathways were present, it is likely that the plume shape would be more erratic and exhibit spatial anomalies.

4) Observations of hydrocarbons in water collected from bedrock wells do not change the conclusions of the Revised Risk Assessment (Battelle, 2001).

Supporting evidence:

- MTBE concentrations in the Navy's two bedrock wells were equivalent to concentrations measured in proximal overburden wells. The Revised Risk Assessment (Battelle, 2001) concluded that observed concentrations were acceptable for unrestricted land use. In **Table 2**, are the concentrations in groundwater evaluated in the Revised Risk Assessment.

- In the event that MTBE were present in bedrock fractures, the closely monitored overburden aquifer would insulate the accessible environment from any MTBE in bedrock.

- Exposure pathways from bedrock fractures (if present) and receptors include media (groundwater and soil gas) that were evaluated in the Revised Risk Assessment (Battelle, 2001).

SUMMARY

The Navy has performed bedrock drilling, collected bedrock and considerable overburden data, has reviewed aerial photographs of the site, previous characterization , and regional geologic information, and has performed a Revised Risk Assessment for the site. Based on results from these efforts, there is no evidence of significant storage or transport of MTBE in bedrock under the site, and any undetected potential bedrock pathways pose no additional threat to human health and the environment at this site.

Although it is recognized that other possibilities exist, the Navy believes the likely explanations for observations of hydrocarbons in bedrock wells include a) a faulty seal around the conductor casing, or b) conductor casing was not installed at an adequate depth to ensure it extended completely into the impermeable bedrock. The residuum layer is essentially hydraulically continuous with the alluvial overburden and does not warrant a significant distinction that would affect the remediation, MTBE plume control, risk assessment, or risk management decisions.

Proposed Future Activity:

The Navy will continue to monitor the MTBE plume and the bedrock wells and will report enhancements of the bedrock interpretation in future quarterly site status reports. Careful consideration will be given to the appearance of any anomalies that may develop in the future that may indicate that bedrock may be playing a role in the storage, release, or transport of MTBE from Former UST Site 957/970. The Navy will present any anomalies to the regulatory agencies as they arise and discuss their implications at the site. If the expected performance of the chosen remedial action for the site appears to be affected by bedrock conditions, the Navy will consult with the agencies and decide how to appropriately adjust the remedy. All future activities pertaining to bedrock at the site will be addressed in the final corrective action plan.

REFERENCES

Battelle. 2001. *Final Revised Risk Assessment for Former UST Site 957/970 at Department of Defense Housing Facility, Novato, California*. Prepared for the Southwest Division, Naval Facilities Engineering Command under NFESC Contract No. N47408-95-D-0730. June 8.

IT Corporation. 1998. *Site Investigation Report 800-B and Ammo Hill Parcels GSA Phase II Sale Area Hamilton Army Airfield, Novato, California, Final Report*. Prepared by IT Corporation, Martinez, California.

DMG. 1975. *Geology for Planning, Novato Area, Marin County, California*. Open-File Report 75-1. Prepared by Salem J. Rice, assisted in geophysical studies by Gordon W. Chase.

Table 1. Bedrock Well and Nearby Overburden Monitoring Well Sampling Results

Bedrock Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Nearby Monitoring Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)
MW-9A	10/21/00	220	<2.0	MW-5A	NS	NS	NS
	11/17/00[a]	120/120	<2.0/<2.0		11/13/00	2,300	2.0
	3/1/01	600	16		2/25/01	1,100	<1.0
	5/22/01	350	<1.3		5/16/01	380	0.57
	8/19/01	310	<0.5		8/14/01	330	<0.5
MW-3D	10/21/00	25,000	<10	957-MW4	NS	NS	NS
	11/17/00	34,000	<10		11/15/00	34,000	2.7
	2/28/01	43,000	<20		2/25/01	10,000	<1.0
	5/22/01	28,000	<2.5		5/14/01	30,000	<0.5
	8/19/01[a]	31,000/34,000	<2.5/<2.5		8/14/01	39,000	<6.3

(a) Results of duplicate sample are shown.
NS = not sampled.

Table 2. Groundwater Concentrations Evaluated in the Revised Risk Assessment (Battelle, 2001)

Chemical	Groundwater Concentration[a] (µg/L)
Benzene	1,600
Ethylbenzene	900
MTBE	35,000
Toluene	380
Xylenes (mixed)	2,160

(a) Maximum groundwater concentrations from the November 2000 quarterly monitoring event that were used in the Revised Risk Assessment (Battelle, 2001).

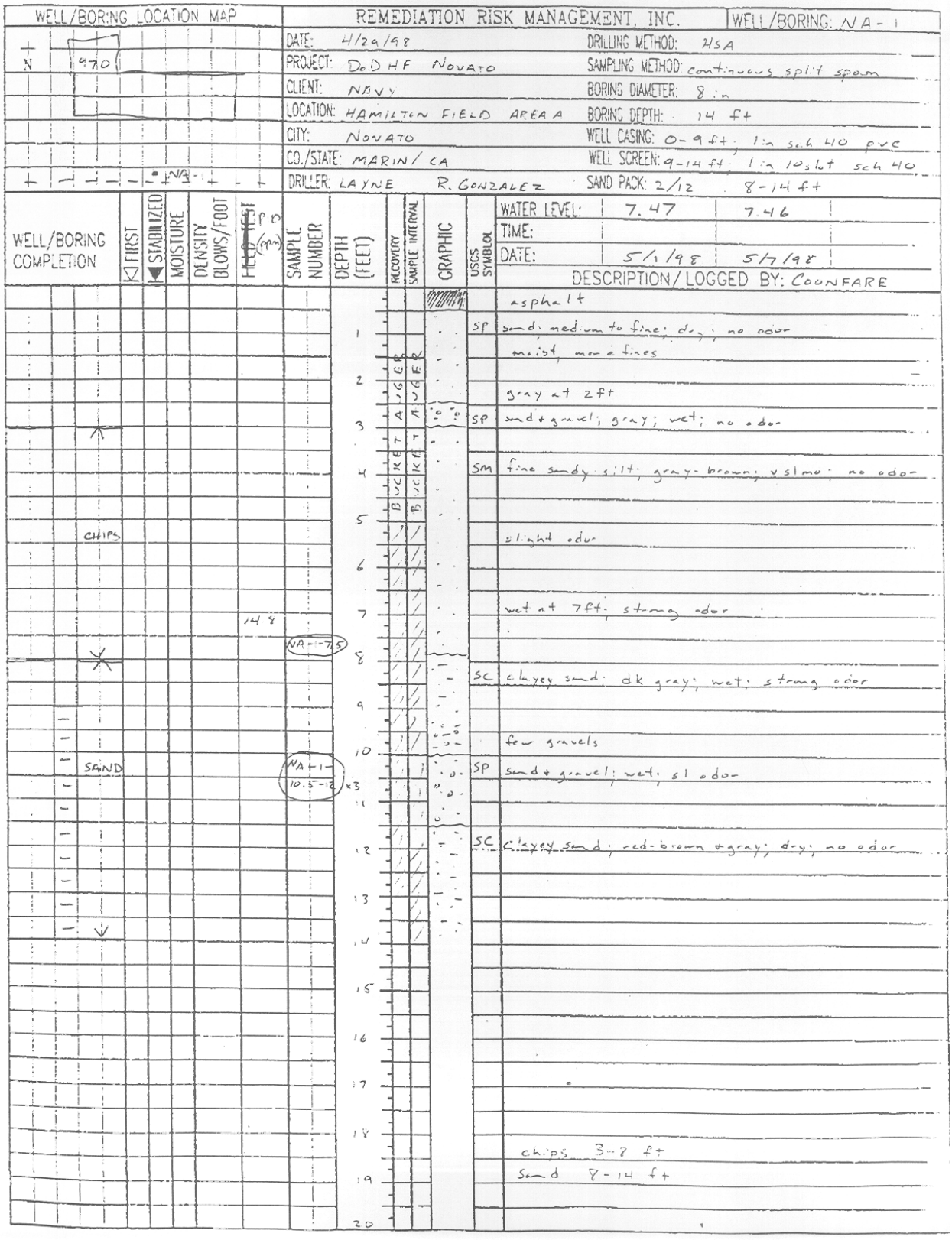


Figure 1. Boring Logs Collected from Overburden Wells (NA-1) in the Vicinity of the Former USTs

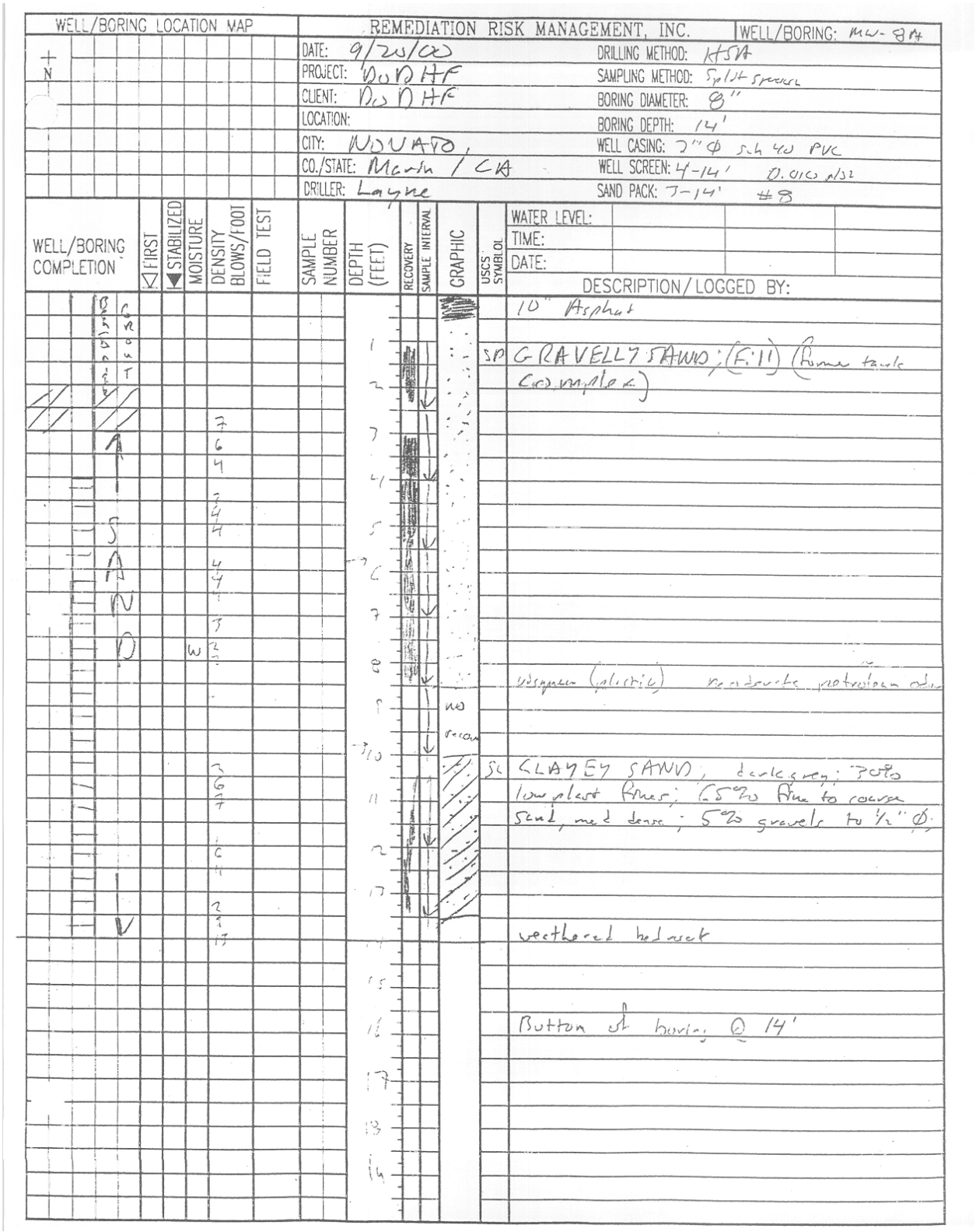


Figure 1 (continued). Boring Logs Collected from Overburden Wells (MW-8A) in the Vicinity of the Former USTs

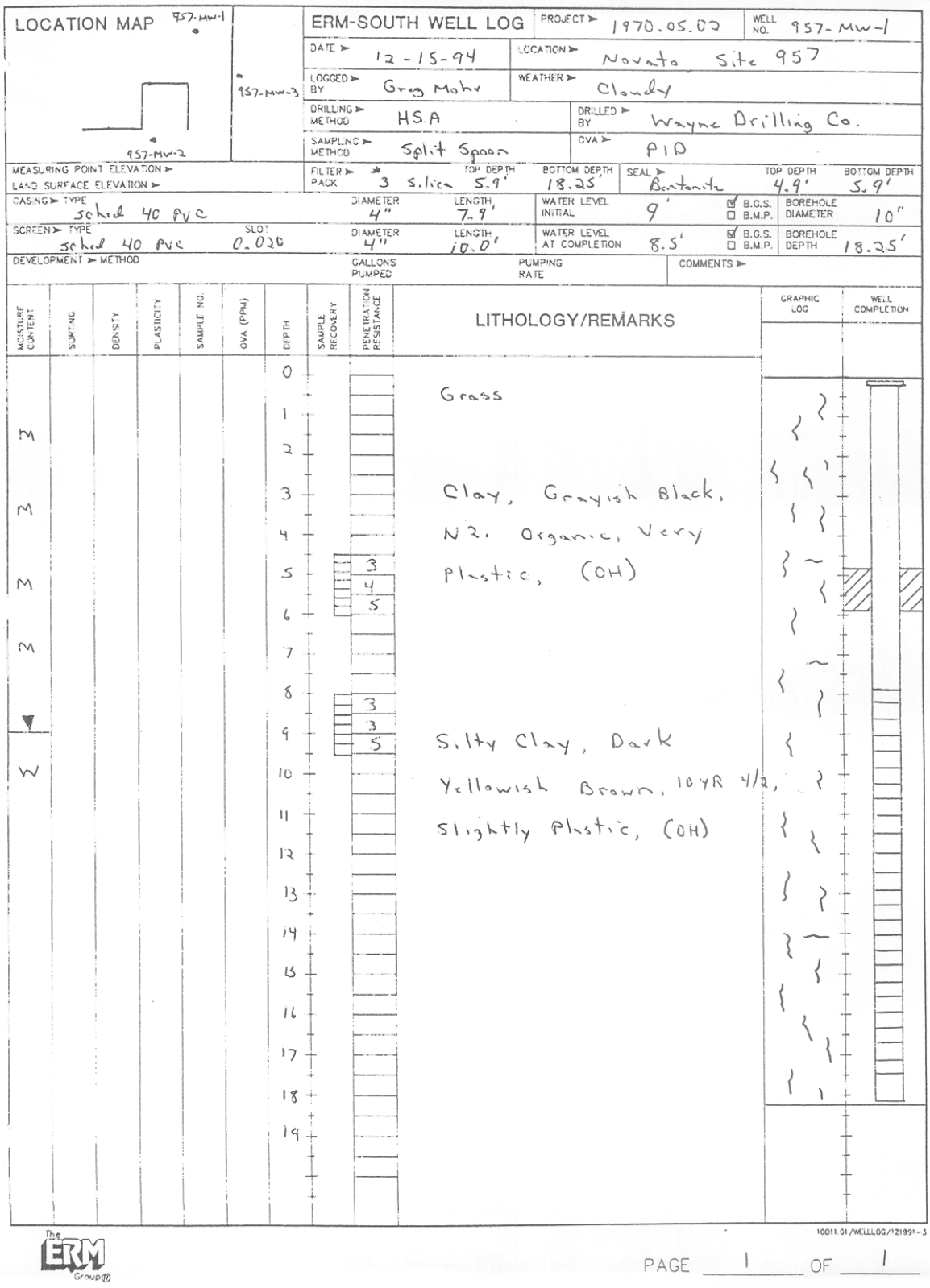


Figure 1 (continued). Boring Logs Collected from Overburden Wells (957-MW1) in the Vicinity of the Former USTs

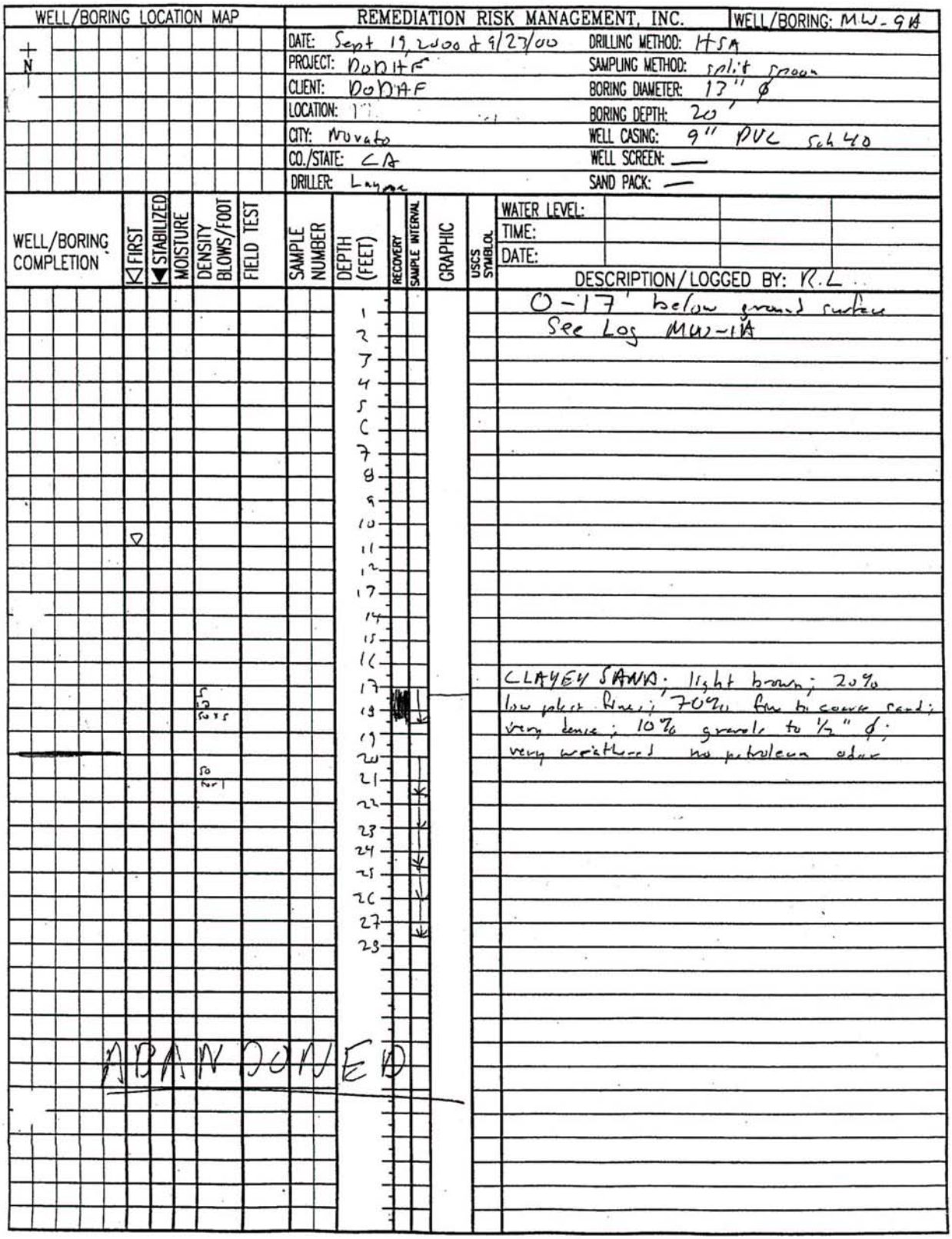


Figure 2. Boring Logs from Bedrock Wells (MW-9A)

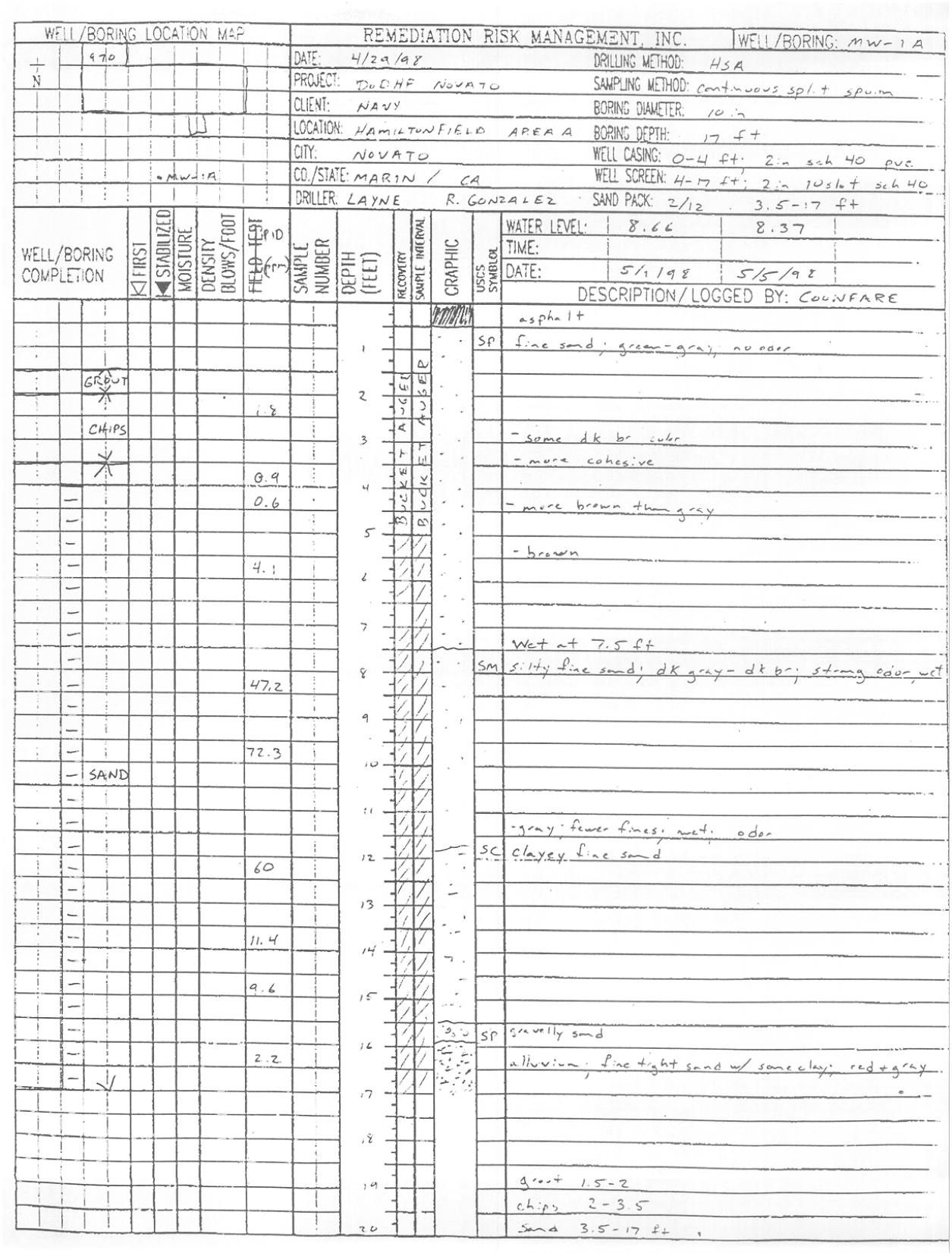
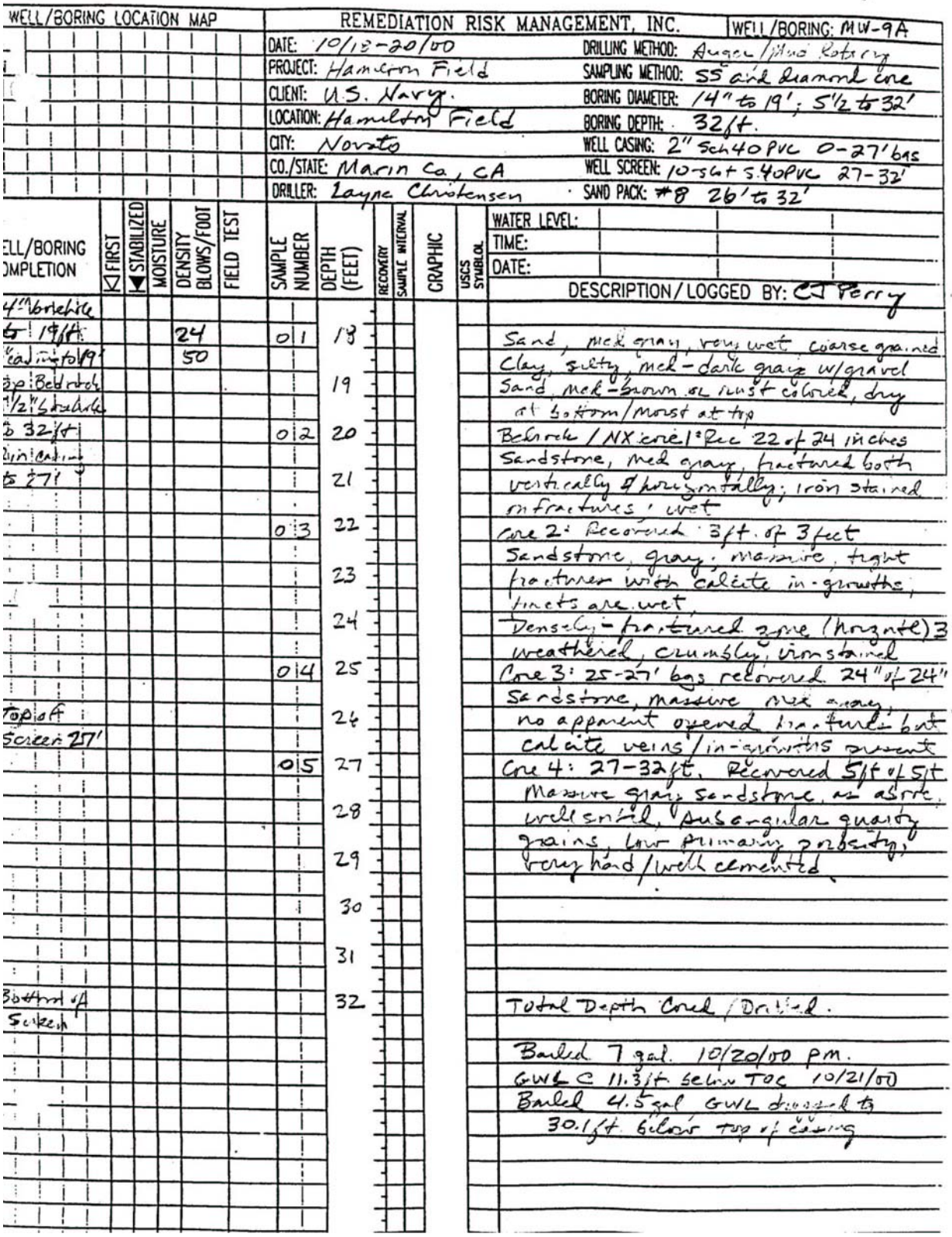


Figure 2 (continued). Boring Logs from Bedrock Wells (MW-9A)



WELL/BORING LOCATION MAP

REMEDIATION RISK MANAGEMENT, INC.

WELL/BORING: MW-9A

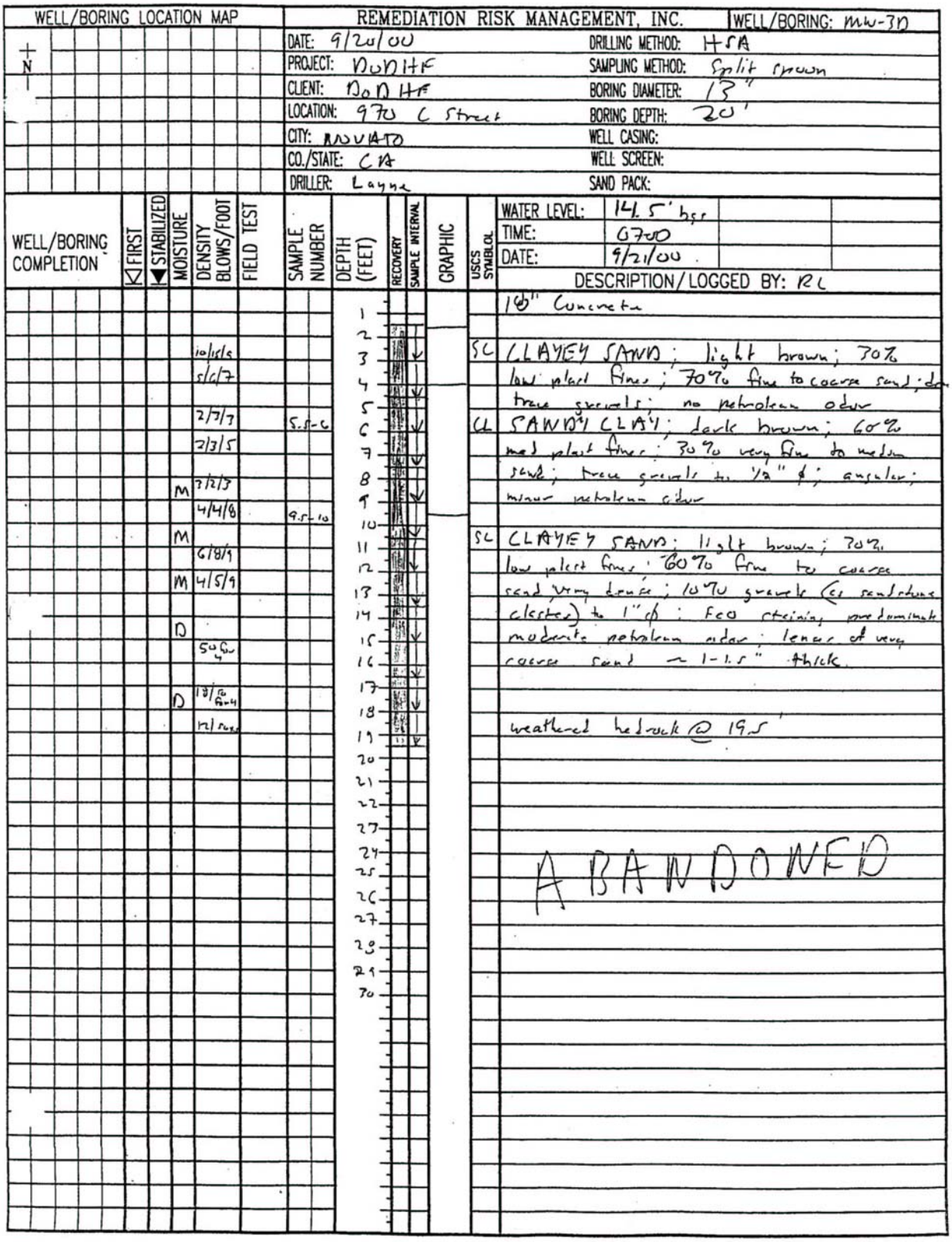
DATE: 10/18-20/00
PROJECT: Hamilton Field
CLIENT: U.S. Navy.
LOCATION: Hamilton Field
CITY: Novato
CO./STATE: Marin Co, CA
DRILLER: Layne Christensen

DRILLING METHOD: Auger / Mud Rotary
SAMPLING METHOD: SS and diamond core
BORING DIAMETER: 14" to 19'; 5 1/2 to 32'
BORING DEPTH: 32 ft.
WELL CASING: 2" Sch 40 PVC 0-27' bgs
WELL SCREEN: 10-slot S.40 PVC 27-32'
SAND PACK: #8 26' to 32'

WATER LEVEL:
TIME:
DATE:

ELL/BORING OMPLETION	FIRST	STABILIZED	MOISTURE	DENSITY BLOWS/FOOT	FIELD TEST	SAMPLE NUMBER	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	GRAPHIC	USCS SYMBOL	DESCRIPTION / LOGGED BY: CJ Perry
4" borehole												
to 19 ft				24		01	18					Sand, med gray, very wet, coarse grained
ead in to 19'				50								Clay, silty, med - dark gray w/ gravel
op Bedrock							19					Sand, med - brown at first colored, dry
1/2" borehole												at bottom / moist at top
to 32 ft						02	20					Bedrock / NX core / Rec 22 of 24 inches
in casing												Sandstone, med gray, fractured both
to 27'							21					vertically & horizontally; iron stained
												on fractures, wet
						03	22					Core 2: Recovered 3 ft. of 3 feet
												Sandstone, gray, massive, tight
							23					fractures with calcite in-growths,
												fracts are wet
							24					Density - fractured zone (horizntl) 3'
												weathered, crumbly, iron stained
						04	25					Core 3: 25-27' bgs recovered 24" of 24"
												Sandstone, massive med gray,
top of							26					no apparent opened fractures but
Screen 27'												calcite veins / in-growths present
						05	27					Core 4: 27-32 ft. Recovered 5 ft of 5 ft
												Massive gray, sandstone, as above,
							28					well sorted, sub angular quartz
												grains, low primary porosity,
							29					very hard / well cemented.
							30					
							31					
Bottom of							32					Total Depth Cored / Drilled.
Screen												
												Bailed 7 gal. 10/20/00 pm.
												GWL @ 11.3 ft below TOC 10/21/00
												Bailed 4.5 gal GWL dropped to
												30.1 ft. below top of casing

Figure 2 (continued). Boring Logs from Bedrock Wells (MW-9A)



WELL/BORING LOCATION MAP

REMEDIATION RISK MANAGEMENT, INC.

WELL/BORING: MW-3D

DATE: 9/20/00
PROJECT: NAVHF
CLIENT: NAVHF
LOCATION: 970 C Street
CITY: ALAMEDA
CO./STATE: CA
DRILLER: Layne

DRILLING METHOD: HSA
SAMPLING METHOD: Split spoon
BORING DIAMETER: 13"
BORING DEPTH: 20'
WELL CASING:
WELL SCREEN:
SAND PACK:

WATER LEVEL: 14.5' bgs
TIME: 0700
DATE: 9/21/00

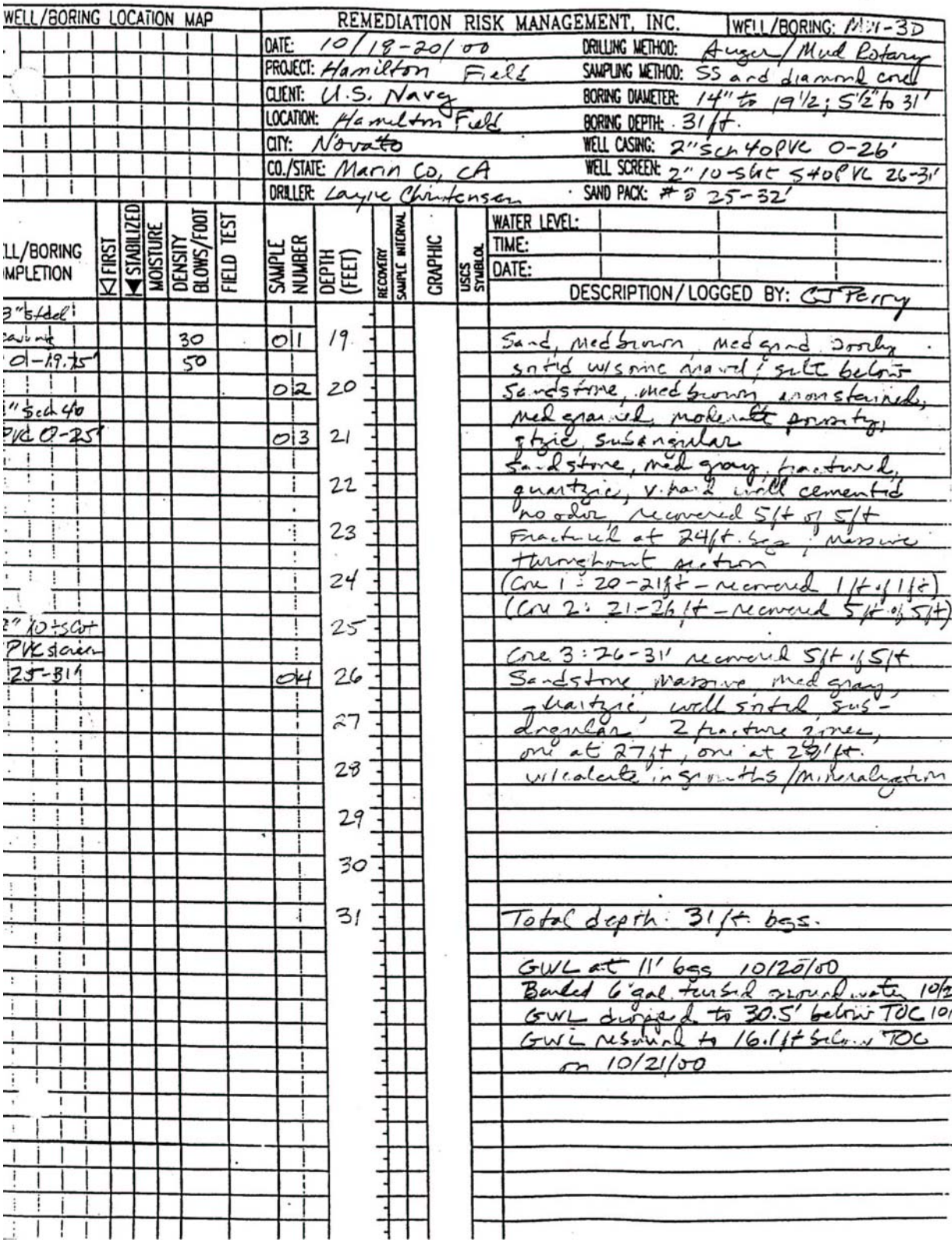
WELL/BORING COMPLETION | FIRST ☑ | STABILIZED ▼ | MOISTURE | DENSITY BLOWS/FOOT | FIELD TEST | SAMPLE NUMBER | DEPTH (FEET) | RECOVERY | SAMPLE INTERVAL | GRAPHIC | USCS SYMBOL

DESCRIPTION/LOGGED BY: RL

DEPTH (FEET)	SAMPLE NUMBER	MOISTURE	DENSITY BLOWS/FOOT	USCS SYMBOL	DESCRIPTION/LOGGED BY: RL
1					10" Concrete
2					
3			10/15/6	SC	CLAYEY SAND; light brown; 70% low plast fines; 70% fine to coarse sand; dr
4			5/6/7		trace gravels; no petroleum odor
5					
6	5.5-6		2/7/7	CL	SANDY CLAY; dark brown; 60% med plast fines; 30% very fine to medium sand; trace gravels to 1/2" ø; angular; minor petroleum odor
7			2/3/5		
8					
9		M	2/2/3		
10	9.5-10		4/4/6		
11		M		SC	CLAYEY SAND; light brown; 70% low plast fines; 60% fine to coarse sand, very dense; 10% gravels (cemented clasts) to 1" ø; FeO staining, predominate moderate petroleum odor; lenses of very coarse sand ~ 1-1.5" thick
12			6/8/9		
13		M	4/5/9		
14					
15		D			
16			50/6"		
17					
18		D	18/6" 6-4		
19			refusal		weathered bedrock @ 19.5'
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

ABANDONED

Figure 2 (continued). Boring Logs from Bedrock Wells (MW-3D)



WELL/BORING LOCATION MAP

REMEDIATION RISK MANAGEMENT, INC.

WELL/BORING: MW-3D

DATE: 10/19-20/00
PROJECT: Hamilton Field
CLIENT: U.S. Navy
LOCATION: Hamilton Field
CITY: Novato
CO./STATE: Marin Co, CA
DRILLER: Layne Christensen

DRILLING METHOD: Auger/Mud Rotary
SAMPLING METHOD: SS and diamond core
BORING DIAMETER: 14" to 19 1/2; 5 1/2" to 31'
BORING DEPTH: 31 ft.
WELL CASING: 2" Sch 40 PVC 0-26'
WELL SCREEN: 2" 10-slot Sch 40 PVC 26-31'
SAND PACK: #3 25-32'

WATER LEVEL:
TIME:
DATE:

DESCRIPTION/LOGGED BY: CJ Perry

LL/BORING MPLETION	FIRST ▽	STABILIZED ▼	MOISTURE	DENSITY BLOWS/FOOT	FIELD TEST	SAMPLE NUMBER	DEPTH (FEET)	RECOVERY	SAMPLE INTERVAL	GRAPHIC	USCS SYMBOL	
3" bldel												
				30		01	19					Sand, med brown, med grnd, poorly sorted w/some gravel; silt below
01-19.75'				50								
						02	20					Sandstone, med brown, iron stained, med grained, moderately porosity, clastic, subangular
1" Sch 40												
PVC 0-25'						03	21					Sandstone, med gray, fractured, quartzitic, v. hard, well cemented, no odor, recovered 5/t of 5/t
							22					
							23					Fractured at 24/t. bgs; massive throughout section
							24					(Core 1: 20-21/t - recovered 1/t of 1/t)
												(Core 2: 21-26/t - recovered 5/t of 5/t)
2" 10-slot							25					
PVC screen												Core 3: 26-31' recovered 5/t of 5/t
25-31'						04	26					Sandstone, massive, med gray, quartzitic, well sorted, sub-angular, 2 fracture zones, one at 27/t, one at 29/t. w/calcite in fractures/mineralization
							27					
							28					
							29					
							30					
							31					Total depth: 31/t bgs.

GWL at 11' bgs 10/20/00
Bailed 6 gal. turbid ground water 10/20
GWL dropped to 30.5' below TOC 10/2
GWL measured to 16.11 ft below TOC on 10/21/00

Figure 2 (continued). Boring Logs from Bedrock Wells (MW-3D)

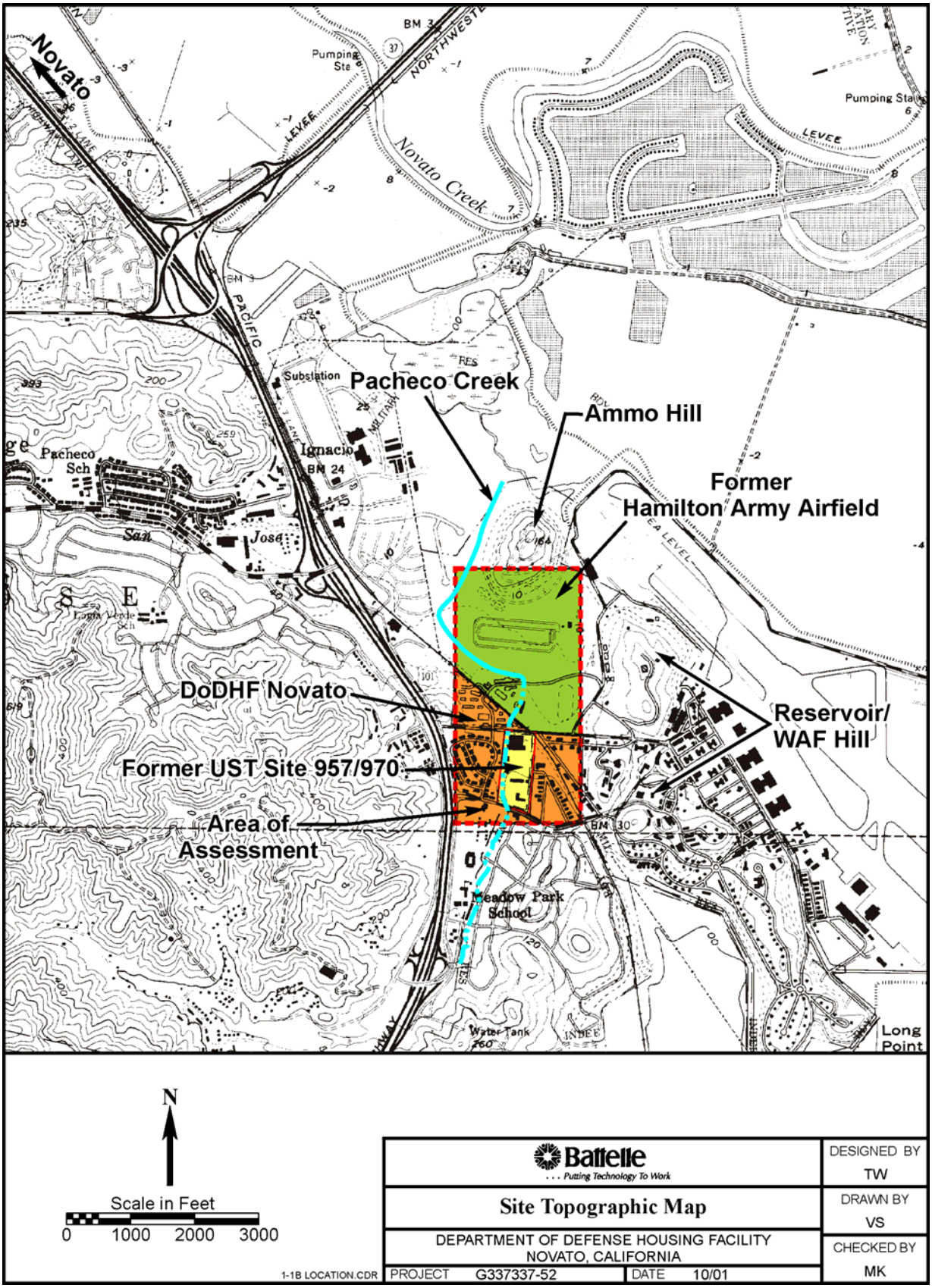


Figure 3. Topographic Map Showing DoDHF Novato

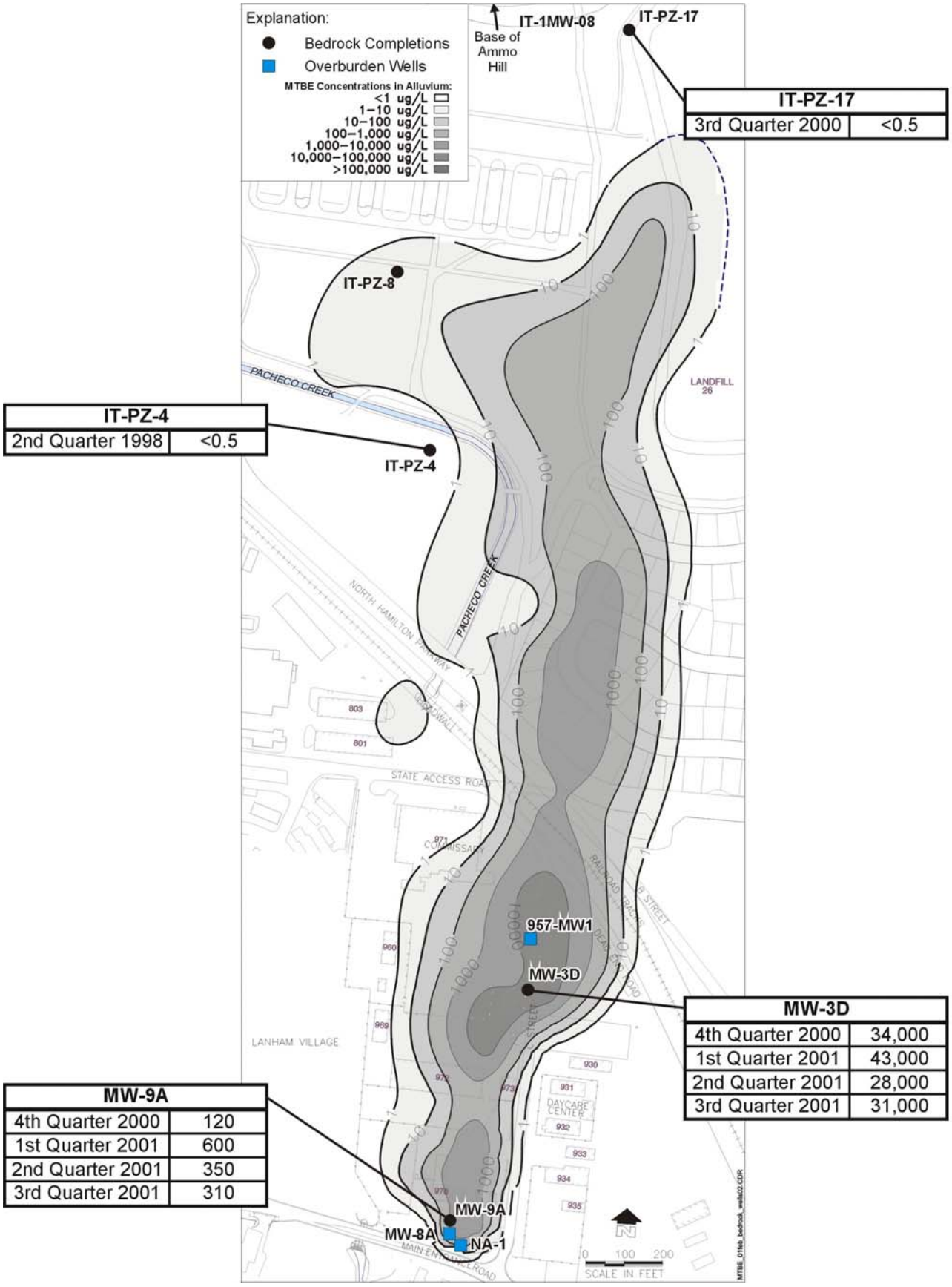


Figure 4. MTBE Plume Map with Concentrations of MTBE (µg/L) Detected in Bedrock Wells Posted

ATTACHMENT 4

Response to Comments Table [Dated November 30, 2001] for
Draft Proposed Final Revision 1.0 Corrective Action Plan For Groundwater For
Former UST Site 957/970 at Department of Defense Housing Facility Novato, California

General Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

The Navy has reviewed RWQCB Order No. 00-064 ("the Order") and the Draft Proposed Final Revision 1.0 CAP. We are satisfied that the Draft Proposed Final Revision 1.0 CAP satisfies the requirements in Task 6 of the Order. In preparation of the Draft Proposed Final Revision 1.0 CAP, the Navy reviewed Task 6 of the Order on an item-by-item basis. As part of our general response, we will address some of the broader concerns expressed by the RWQCB in the Draft Proposed Final Revision 1.0 CAP comment letter dated October 16, 2001. In addition, we respond individually to all the RWQCB specific comments in the table that follows.

The RWQCB seems to raise several general concerns regarding the Navy's proposed approach to contain and manage the MTBE plume on its property. While the Navy recognizes the sensitive nature of this problem and the heightened public interest in environmental issues on adjacent property, the Navy is fully confident that it has the planned and phased response to this problem that will ensure success. The RWQCB seems to feel that the proposed biosparging must achieve a performance goal of achieving MCL concentration limits immediately. Any remedy implemented to address an environmental problem must be brought to the point that it is operating effectively before its performance can be assessed. Once biosparging is installed and operating successfully, the Navy will monitor remedy performance and make any necessary changes or adjustments. The Navy is confident that its chosen remedial approach will succeed within a reasonable time but remains vigilant to monitoring performance and making changes to the remedial approach when warranted. The Navy further believes that based on the extensive analysis of the site, responses already taken at the site coupled with two focused risk assessments performed at the site, provide an excellent basis for conducting our response action which when complete should qualify the site for a "low risk" designation.

The Navy very much appreciates the extensive review and comment provided by the RWQCB. With this, the second round of draft changes, the Navy proposes to finalize the Corrective Action Plan that fully tracks with the Order and implement the remedy. Our thanks to all who made this possible.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

Comment Number	Comment	Response
Introduction	The following present Regional Board staff comments on the August 2001 internal Draft Corrective Action Plan for Tank Site 957/970 (the CAP), Department of Defense Housing Facility, Novato California (the Site). In general, Sections 1 through 4 of the draft CAP satisfy Order No. 00-064, Task 6.b.1 by providing a comprehensive overview of the site description, previous investigations, previous remedial actions, and nature and extent of the hydrocarbon contamination detected a the Site. With respect to feasibility study (FS) requirements of Order No. 00-064, the draft CAP does not adequately address MTBE plume containment at the Site. The discussion surrounding the proposed remedy of biosparging (Alternative 4) seems not to explain how the plume will be contained which is a required remedial action objective (RAO), an RAO critical to compliance with Site Cleanup Requirements Order No. 00-064. As we discussed in our CAP scoping meeting on July 10, 2001 and outlined in our July 16, 2001 follow-up letter to the scoping meeting, "if air-sparging will not immediately reduce the MTBE to MCLs at the area of the property line, the installation of an aeration trench should be included as one part of an alternative in the CAP to comply with Finding 12 (Order No. 00-064)."	Discussion of how the proposed remedy will contain the MTBE plume to Navy property is presented in the fourth paragraph of Section 7.2.1.4 on page 243 and fourth paragraph on page 244 of the Draft Proposed Final Revision 1.0 CAP among other places. It is stated, "to ensure containment of the MTBE plume on Navy property is achieved, MTBE concentrations will be reduced by multiple and overlapping sparging curtains. This will be accomplished by a much more dense well distribution in the region just south of the property boundary than was used in the IAS design for the interim remedial action. A less dense well distribution will be used upgradient of the sparging curtain or barrier to remove elevated concentrations of MTBE (and other hydrocarbons) at an accelerated rate." The fourth paragraph on page 244 goes on to say, "the effect of the active biosparging system barrier and other injection wells intended to reduce plume concentrations, coupled with natural attenuation mechanisms, the effects of which are already observable at the Site, will overcome the tendency of advection to carry MTBE off-site, and will eliminate flux at the property boundary. This effect is consistent with a stable and contained MTBE plume and will be confirmed by groundwater monitoring to demonstrate rapidly declining concentrations in wells near the property boundary." Regarding the quote of the July 16, 2001 follow-up letter, an aeration trench was explicitly included as an alternative in the Draft Proposed Final Revision 1.0 CAP, as requested by the RWQCB. Additionally, there is not a requirement in the Order to immediately reduce MTBE to MCLs in the area of the Navy property boundary. Task 6 of the Order includes the requirement to, "stabilize and contain the higher concentration MTBE groundwater plume on the currently Navy-owned portion of the Site." Furthermore, immediate achievement of MCLs is not an appropriate remedial action objective for this site because as discussed on page 186 in the CAP,

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
Introduction (continued)		"risk assessments performed at the Site indicate that an immediate threat to human health or the environment does not exist, (and) in compliance with Resolution 92-49, the proposed final cleanup standards must be achieved within a reasonable time that provides the maximum benefit to the people of the State of California." The feasibility study in Section 6 of the Draft Proposed Final Revision 1.0 CAP evaluates four different remedial alternatives and determines that biosparging (Alternative 4) is the preferred alternative because it has an established operational history at the Site and is the: 1. Most beneficial to the people of the state of California given the current site conditions. Results of two risk assessments have concluded that the current conditions at the site are suitable for the future intended use of the property. Furthermore, the Navy has demonstrated that the proposed remedial alternative has a "substantial likelihood to achieve compliance, within a reasonable time frame" as required by SWRCB Resolution No. 92-49, because: 1) the shallow aquifer conditions at the site, 2) low-yield, and 3) availability of a city water supply indicate that the alluvial aquifer at the site would not be used for its designated beneficial uses within the cleanup timeframe of the proposed remedy. 2. Least negatively impactful on public health and welfare and the environment 3. Most flexible and simplistic alternative to implement at the site, and 4. Most cost effective. Please note that Table 6-10 of the Draft Proposed Final Revision 1.0 CAP shows that the estimated time to reach MTBE plume stabilization at the Navy property boundary is the same for Alternative 2 (interception/aeration trench) as for Alternative 4 (biosparging). Due to the subsurface installation limitations associated with the railroad easement that exists just south of State Access Road and along the Navy property boundary, it is not

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
Introduction (continued)		logistically favorable to plan for the placement and installation of the treatment area within the railroad easement and directly along the Navy property boundary. Instead, the planned treatment areas for any of the remedial alternatives are forced to be located slightly upgradient of the Navy property boundary and treat groundwater before it travels through the railroad easement and across the Navy property boundary. The travel-time of groundwater from the treatment areas, through the railroad easement, and to the Navy property boundary is the limiting time factor of achieving stabilization and containment of the MTBE plume at the Navy property boundary. This travel-time is estimated to be approximately 1.5 years. Interim remedial action activities performed near the former source areas on Navy property in 1998 and 1999 have not affected any of the aquifer conditions on former HAAF property due to the delayed travel-time of groundwater flow at the site. Therefore, the 48% decrease in the estimated mass of MTBE dissolved in groundwater on former HAAF property from February 1999 to February 2001 (see Table 5-3 of the Draft Proposed Final Revision 1.0 CAP) is solely a result of natural attenuation mechanisms. No treatment alternative implemented at the Navy property boundary will have an immediate effect on MTBE concentrations located downgradient of Navy property due to this travel-time issue; however, natural attenuation mechanism are expected to continue to substantially reduce MTBE concentrations on former HAAF property.
1. Table 7-1 and Figure 7-1	A. Are the three monitoring wells depicted on Table 7-1 equivalent to the three performance monitoring wells depicted on Figure 7-1	A. Yes, the three monitoring wells depicted on Table 7-1 are equivalent to the three performance monitoring wells depicted on Figure 7-1.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
1. (continued)	B. The performance wells appear clustered together, located within approximately 15 ft of each other. This well cluster does very little to define the groundwater concentration parallel to State Access Road. Hot spot remediation is one performance goal of the proposed remedy, and plume containment is a second performance goal. Performance wells should be located along the downgradient NEX property line to verify that the entire plume is contained, down to MCLs, along a line parallel to State Access Road. As the Regional Board stated in letter dated 7/16/01, " if air sparging will not immediately reduce the MTBE to MCLs at the area of the property line, the installation of the aeration trench should be included as part of an alternative in the CAP to comply with Finding 12."	B. As stated in the first paragraph on page 245 of the Draft Proposed Final Revision 1.0 CAP: "the cluster of monitoring wells just south of the Navy property boundary are proposed to provide data regarding the quality of the groundwater that is about to cross the boundary in the permeable channel, whereas some existing monitoring wells are screened in tighter, less-permeable soils which may not represent the quality of groundwater leaving the Site. The current groundwater monitoring program will be continued to view changes in behavior of the MTBE plume as a result of biosparging operation. However, it is not reasonable to expect MTBE concentrations in all monitoring wells located near the Navy property boundary to rapidly decrease due to biosparging operation because some wells are placed in tighter, clayey soils that will release MTBE primarily by diffusion. The biosparging system will not directly treat the MTBE in clayey soils, but a concentration diffusion gradient will be established, causing an overall decrease in concentrations in all site wells." Wells have already been installed along the Navy property boundary (MW-M1, -M8, -M9, -M10, and –M16), outside the railroad easement; however, the soil conditions along the property boundary are tighter and less permeable than the sandy intervals suspected of transporting the majority groundwater across the property boundary. Therefore, as stated above, it is not reasonable to expect MTBE concentrations in these monitoring wells to rapidly decrease due to active remedial activities because they are not thought to be located within the preferential flowpath at the site where treated groundwater will be transported. The planned location of the proposed performance monitoring wells upgradient of the Navy property boundary (shown in Figure 7-1) is directly within the preferential flowpath, so monitoring of MTBE concentrations within the wells will be representative of treatment efficiency. Please note that as treated groundwater is monitored at the proposed performance monitoring well locations within the sandy channel upgradient of the Navy property boundary, MTBE is likely to diffuse into the treated channel water from the tighter deposits on the sides of the channel as the groundwater travels downgradient toward and across the Navy

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
1. (continued)		property boundary. This result can be expected equally with the aeration trench option due to the tighter deposits containing MTBE that exist along the sides of the permeable sand channel at the site.
	C. Expand Figure 7-1 to include the point of groundwater compliance specified in the Order, that is, State Access Road and outfalls to Pacheco Creek.	C. The requested change will be made. Figure 7-1 will be expanded to include the Navy property boundary, State Access Road, and outfalls of Pacheco Creek. However, please refer to the response of comment 1B on page 5 for a discussion of the limitations presented by tight soil conditions that exist along State Access Road and the Navy property boundary. A draft version of the revised Figure 7-1 is provided in Attachment 1.
	D. Why is only one soil gas monitoring probe collocated with the proposed contingency SVE well locations shown on Figure 7-1? Explain how you plan to determine when to start SVE, how to gauge the effectiveness of SVE, and when to stop SVE with no soil gas wells collocated near the proposed SVE points.	D. As indicated in the Draft Proposed Final Revision 1.0 CAP, Figure 7-1 is a "conceptual diagram" and is not meant to show the final design and installation locations of all system components. A Remedial Design Workplan that describes such details will be produced by the Navy and provided to the RWQCB and BRAC Cleanup Team (BCT) for review. Some number of shallow soil-gas monitoring points, determined during detailed design (three shown conceptually in plan view of Figure 7-1), will be installed between the treatment area and nearby receptors (i.e., daycare center, proposed charter school location and former commissary building 971). These newly installed soil-gas monitoring probes will be augmented by six soil-gas monitoring probes that already exist east of C Street. A subset of all these available soil-gas monitoring probes will be proposed for sampling during biosparging operation in the Remedial Design Workplan. The Navy proposes to sample the subset of shallow soil-gas monitoring points daily during the first two weeks of routine biosparging system operation, weekly for the following 2 months, and monthly thereafter. If anomalies are encountered during any stage of the shallow soil-gas monitoring, the sampling will occur more frequently to determine the cause of the anomaly. As discussed in Sections 7.2.1.4 and 7.2.1.5 of the Draft Proposed Final Revision 1.0 CAP, the objective of sampling shallow soil-gas will be to ensure that concentrations of hydrocarbons are not elevated beyond a safety threshold. The safety threshold hydrocarbon concentrations originate from the final revised risk assessment,

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
1. (continued)		with which the DTSC concurred, and are presented in Table 7-3 of the Draft Proposed Final Revision 1.0 CAP. If shallow soil-gas monitoring indicates that safety threshold hydrocarbon concentrations are exceeded, adjustments of biosparging system operating parameters, such as injection rate or cycling frequency, will be made to maintain the hydrocarbon concentrations below the safety threshold. If adjusting system operating parameters is unable to maintain shallow soil-gas concentrations below the safety threshold, the contingency SVE system will be initiated. The effectiveness of the SVE system will be gauged by regular monitoring to ensure that hydrocarbon concentrations are maintained below the safety threshold in shallow soil-gas points located between the treatment area and nearby receptors. In addition, the mass of hydrocarbons removed by the SVE system will be regularly monitored during operation. The SVE system operation would be terminated after demonstrating that hydrocarbon concentrations in the extracted air are decreased by an order of magnitude and the safety threshold hydrocarbon concentrations in shallow soil-gas can be maintained without SVE system operation.
	E. What steers the placement of the proposed SVE wells?	E. SVE wells will be installed in vadose zone soils having higher permeability. The SVE wells will be placed within the treatment area and along pathways to nearby receptors to extract hydrocarbons in soil-gas if the SVE contingency is required.
	F. Is one blower powerful enough to supply 40 sparge wells?	F. As discussed in the first paragraph on page 239 of the Draft Proposed Final Revision 1.0 CAP, one Quincy, 15-hp, 208V three-phase, oilless air compressor is located at the site along with a regenerative blower. This equipment may be used to inject air into the sparge wells or additional equipment may be required. These types of specific details do not effect the remedy selection process of the CAP and will be given further consideration during the planning and production of the Remedial Design Workplan.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
2. Section 7.2	The text states, "once the biosparging system has met its performance goals, the system will be shut down and groundwater monitoring will be performed to verify that concentrations do not rebound." A. State your performance goals. The Regional Board considers the MCL of 5 ppb MTBE groundwater concentration at State Access Road one of your performance goals. As the Regional Board stated in letter dated 7/16/01, " if air sparging will not immediately reduce the MTBE to MCLs at the area of the property line, the installation of the aeration trench should be included as part of an alternative in the CAP to comply with Finding 12."	A. Please refer to Section 7.2.1.4 of the Draft Proposed Final Revision 1.0 CAP, which is dedicated to the detailed description of Performance Goals. Furthermore, performance goals are established to track the progress of a specific technical remedy toward remedial action objectives at a specific site. Performance goals are not endpoints of remedial actions, as are remedial action objectives, nor are they long-term goals as are final cleanup levels. As discussed in the second paragraph on page 244 of the Draft Proposed Final Revision 1.0 CAP, the performance goals of the biosparging system are to decrease the concentration of MTBE in monitoring wells located within the preferential flow path near the Navy property boundary by 95% to 99%. Figure 7-6 of the Draft Proposed Final Revision 1.0 CAP provides a range of MTBE cleanup concentrations (1,398 to 302 ppb MTBE), based on the proposed performance goals of the biosparging system and an assumed initial MTBE concentration of 30,000 ppb in groundwater collected from the performance monitoring wells that are to be installed as discussed in response to comment 1B on page 5. If the MTBE concentration within the performance monitoring wells varies from the assumed value of 30,000 ppb, the range of MTBE concentrations associated with expected system performance will be adjusted accordingly. Regarding the quote of the July 16, 2001 follow-up letter and as discussed in the response to the RWQCBs introduction on page 2 of this table: 1) the Draft Proposed Final Revision 1.0 CAP does include an aeration trench as an alternative considered in detail in the feasibility study, as requested by the RWQCBs July 16, 2001 letter, 2) the requirement to immediately reduce MTBE to MCLs is not factually found in the Order, and 3) immediate achievement of MCLs is not an appropriate remedial action objective for this site because risk assessments have demonstrated that current concentrations are below acceptable risk levels at the site.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
2. (continued)	B. How many sampling events do you need to define a concentration rebound?	B. A complete annual cycle of groundwater sampling is required to define a concentration rebound. Currently, the fourth paragraph of page 245 in the Draft Proposed Final Revision 1.0 CAP proposes monthly monitoring for two quarters following cessation of biosparging system operation. The Navy's regular quarterly groundwater monitoring program will be continued during and after biosparging system operation; therefore, the regular monitoring program will evaluate whether any concentration rebound occurs during future quarters.
	C. What is the frequency of the sampling events?	C. Near the bottom of page 244 in the Draft Proposed Final Revision 1.0 CAP it is stated that monthly monitoring will be performed during system operation. As mentioned above, monthly monitoring would be performed for two quarters following biosparging system shutdown. Also, the regular quarterly groundwater monitoring program will be continued during and after the proposed monthly biosparging system groundwater monitoring.
3. Section 7.2.1	The text states "SVE wells will be installed with the biosparging system to collect vadose zone vapors in the event that the in-situ bioreactor is unable to sufficiently destroy the residual vapor stream." A. Explain how this (i.e., bioreactor is unable to destroy vapor stream) will be determined/measured.	A. As discussed in the response to comment 1D on page 6 of this table, some number of shallow soil-gas monitoring points, determined during detailed design (three shown conceptually in plan view of Figure 7-1), will be installed between the treatment area and nearby receptors (i.e., daycare center, proposed charter school location and former commissary building 971). If shallow soil-gas monitoring indicates that the safety threshold hydrocarbon concentrations are exceeded that would be an indication that the bioreactor is unable to sufficiently destroy the hydrocarbons in the vapor stream. Adjustments to biosparging system operating parameters, such as injection rate or cycling frequency, will be made to try and decrease the hydrocarbon concentrations below the safety threshold. However, if adjustment of system operating parameters is unable to maintain shallow soil-gas concentrations below the safety threshold, the contingency SVE system will be initiated.
	B. Specify the soil gas concentrations that trigger SVE.	B. Soil-gas concentrations that trigger SVE are specified in the Draft Proposed Final Revision 1.0 CAP in Table 7-3, which identifies the "safety threshold hydrocarbon soil-gas concentrations." Additional details are presented in Section 7.2.1.5 of the Draft Proposed Final Revision 1.0 CAP.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
4. Section 7.2.1.1.1 Design Objectives	In general, the CAP focuses more on MTBE plume concentration reductions resulting from short-term (1 to 2 years) biosparging within the 10,000+ ppb isocontour, and predicted plume collapse, rather than on plume containment. Furthermore, the width of the MTBE plume (as measured between the 5 ppb contours) as depicted on Figure 4, in a line parallel to State Access Road is approximately 400 ft. The proposed sparge curtain (as measured on Figure 7-1), is approximately 65 feet in length and also appears focused on the 10,000+ ppb contour.	The placement and dimensions of the sparge curtain are not being focused on the 10,000+ ppb contour of MTBE but on the more highly permeable, sand channels that transport majority of the groundwater downgradient, across the Navy property boundary. As reported on page 22 of the Final Remedial Investigation Report (Battelle, 2001), "MTBE concentrations are generally highest in the thickest, most sandy, most transmissive portion of the aquifer, running north-south, at the eastern half of the (CPT study) area…concentrations decrease substantially toward the western portion of the study area, where most of the soil is finer, and sand zones are not connected hydraulically as completely as in the eastern portion of the (CPT) study area." The recommendations on pages 25 and 26 of the Final Remedial Investigation Report (Battelle, 2001) go on to say how the CPT investigation data would be used in the future, "Finding the preferential pathway of groundwater flow during the CPT investigation will allow for a more focused and cost-effective design of treatment alternatives to be recommended in the proposed final CAP. Specific examples of the added benefit that the CPT investigation data could provide for future design of potential MTBE-containment alternative include: Aeration Trench – A trench design could be optimized by focusing on the preferential pathway of MTBE. This would allow for more efficient capture and control of MTBE-impacted groundwater, and ensure that the trench is of sufficient depth and width without over designing the system." The Navy acknowledges that the width of the MTBE plume is greater than the span of the proposed sparge curtain, but because the soils toward the lateral fringes of the plume are tighter and conduct very little groundwater flow relative to the sandier channels that the remedial alternative will focus on, the added advantage and treatment efficiency provided by installing the sparge curtain (or interception/aeration trench) across the entire extent of the plume would be minimal and not cost-effective. If sparge wells along the lateral fringes of the MTBE plume were included in the sparge curtain, they would not be effective at injecting air into the tight

Comment Number	Comment	Response
4. (continued)		soils, and an interception/aeration trench that spanned the entire lateral extent of the MTBE plume would not treat an appreciably greater volume of MTBE-impacted groundwater. This result is because groundwater flow being conducted through the tighter soils along the lateral fringes of the MTBE plume is low relative to the sandier channels identified during the CPT investigation of RI Order Task 2. Furthermore, the railroad easement limits the lateral span of the sparge curtain (or interception/aeration trench).
	A. How does the proposed sparge curtain design accommodate plume containment? Please remember as we have stated in earlier correspondence/comments, " if air sparging will not immediately reduce the MTBE to MCLs at the area of the property line, the installation of the aeration trench should be included as part of an alternative in the CAP to comply with Finding 12."	A. Please refer to the Navy's response to the RWQCBs introduction on page 2 of this table.
	B. It appears that operation of the proposed sparge curtain will need to be independent from the wells used for hot spot remediation. Plume migration control beyond State Access Road will need to continue as long as MTBE groundwater concentrations in the vicinity of the Site boundary exceed cleanup goals. Please explain how the system will be operated to achieve this RAO.	B. Plume migration control is an RAO that will be achieved by reducing MTBE concentrations and confirming that migration is not occurring. Monitoring of the groundwater conditions in the portion of the MTBE plume upgradient of the Navy property boundary is addressed in the second and third paragraphs on page 245 of the Draft Proposed Final Revision 1.0 CAP, "In addition to collecting groundwater from system monitoring wells for tracking biosparging system performance, groundwater samples will be collected from some existing monitoring wells located within the treatment area to track the behavior of the MTBE plume upgradient (south) of the sparging curtain. Biosparging system operation will focus on achieving a stable or decreasing MTBE plume on Navy property, which is considered the RAO that will dictate the duration of operations. It is expected that this objective will be achieved following approximately one year of biosparging system operation. The status of the MTBE plume on Navy property will be evaluated by analyzing the behavior and size of the MTBE plume during biosparging operation. When monitoring data from the well cluster near the property boundary and upgradient in areas with currently elevated MTBE concentrations indicate that the MTBE plume has been contained and stabilized, the biosparging system will be shut down. Groundwater monitoring will then be performed monthly in selected wells for two quarters to confirm that rebound does not occur and threaten compliance with RAOs."

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
5. Section 7.2.1.1.4, Vapor Migration Control/ Soil Vapor Extraction	The text states, "… in the event that residual vapors pose a potential risk to nearby receptors (i.e., day-car center), SVE will be initiated to manage the migration and emission of volatilized gasoline constituents." A. What defines/constitutes a "potential risk?" Prepare a flow chart depicting the series of events that trigger SVE and the series of steps taken to operate the SVE system.	A. Please refer to Section 7.2.1.5 and Table 7-3 of the Draft Proposed Final Revision 1.0 CAP, which defines a "potential risk" posed by residual hydrocarbon vapors. A flowchart outlining the initiation, operation, and shutdown of the SVE contingency will be produced and included in the next draft of the CAP. A draft version of the requested flowchart is provided in Attachment 1.
	B. What frequency of soil gas monitoring is proposed to ensure vapors do not pose a potential risk to receptors? Prepare and provide a soil gas-sampling schedule.	B. Please see response to comment 1D on page 6.
	C. RWQCB staff propose that the Navy install and test soil gas probes at the Day- Care Center and proposed Novato Charter School to ensure/verify no increases in ambient soil gas concentrations result from remediation.	C. Figure 7-1 "conceptually" shows three shallow soil-gas monitoring points are planned for installation between the treatment area and Daycare Center to ensure hydrocarbon safety threshold concentrations (see Table 7-3 in the Draft Proposed Final Revision 1.0 CAP) are not exceeded during active remedial activities. The Navy will also install a shallow soil-gas monitoring point in the immediate vicinity of the Novato Charter School. The exact location of soil-gas monitoring probe installations will be included in the Remedial Design Workplan, which will be provided to the RWQCB and other BCT members for review.
	D. The text is not clear whether SVE wells will be installed during the installation of the bio-sparging wells or at some late date when deemed necessary as the result of elevated soil gas concentrations. Do you expect delays in procuring the equipment (air water separator, extraction blower, GAC, etc.) that will be needed to treat the soil gas, or will the equipment be on standby.	D. The discussion of the SVE component of Alternative 4 will be expanded to state that the SVE wells and piping network for the SVE system will be installed while the biosparging system is installed. Treatment equipment such as carbon canisters for the SVE treatment system are readily available and will be purchased from local vendors as necessary.
6. Section 7.2.1.15 - Soil gas monitoring probes	Explain how the design of the deep soil gas monitoring probes accommodates seasonal variations in groundwater elevations.	The deep soil-gas monitoring probes that will be used to monitor the bioreactor and vadose zone within the treatment area can be installed in a series of multiple depths. For example, if the seasonal high and low water table elevations in the treatment area ranged from 9 to 12 ft bgs, respectively, soil-gas monitoring probes could be installed at discrete depths of 11, 9, 7, and 5 ft bgs within the same borehole.
	Please confirm that the design of the shallow soil gas probes meets the requirements of the DTSC risk assessors in terms of placement and construction.	All soil-gas monitoring points that will be installed during the remedial action will be constructed consistent to those used to collect data for the DTSC revised risk assessment.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
7. Section 7.2.1.1.6 - Groundwater monitoring wells	Regional Board staff suggest that Section 7.2.1.1.6 should more appropriately be titled Performance Goal Groundwater Monitoring Wells. As previously mentioned, a fundamental component of the proposed remedy is to include immediate plume containment to a 5 ppb MTBE concentration upgradient of State Access Road. Although plume containment is an RAO, the CAP only briefly addresses plume containment (mention of a "sparge curtain" or "barrier"). Therefore, please: A. Depict on a map and list on a table, the series of wells that will be used to monitor the performance of the proposed sparge curtain for the required plume containment portion of the proposed remedy.	The title of Section 7.2.1.1.6 will be changed to "Performance Goal Groundwater Monitoring Wells" as requested by the RWQCB. In no part of Order No. 00-064, the ruling guidance for the Former UST Site 957/970, or the Basin Plan does it state that "a fundamental component of the proposed remedy is to include immediate plume containment to a 5 ppb MTBE concentration upgradient of State Access Road." A. As discussed in the response to comment 1B on page 5 of this table, the proposed performance monitoring wells shown in Figure 7-1 of the Draft Proposed Final Revision 1.0 CAP will be located directly within the preferential flowpath. Monitoring of MTBE concentrations within these planned wells will be representative of the treatment efficiency of the biosparging system because groundwater emanating from the sparge curtain will likely travel within this sandy, more transmissive flowpath. The location of the planned performance goal monitoring wells will be further defined in the Remedial Design Workplan, but the exact locations will not be known until the CPT investigation is performed prior to biosparging system installation.
8. Section 7.2.1.3.2 – Routine Operations	Regional Board staff see two main objectives of the system monitoring. The first, and most important objective to monitor the site is for health and safety concerns. Along those lines; A. Please provide a map showing the locations of the sampling points proposed for health and safety compliance monitoring. In addition to the three points depicted on Figure 7-1, locate additional sampling points at the Daycare Center and Novato Charter School site. Please pay attention to underground utility lines that may potentially serve as preferential pathways for vapor transport.	A. All existing and proposed soil-gas monitoring points will be depicted on Figure 7-1 in the next draft of the CAP. Underground utilities near the treatment area will also be depicted on Figure 7-1 in the next draft of the CAP to determine if any additional monitoring locations should be considered. A subset of all the available soil-gas monitoring probes will be proposed for sampling during biosparging operation in the Remedial Design Workplan, which will be provided to the RWQCB and BCT for review. A draft of the revised Figure 7-1 is provided in Attachment 1.
	B. Please expand Table 7-3 so as to list each sampling points, the sampling frequency for each point, constituents of concern (COC), EPA-approved sampling methods, and detection limits proposed for ongoing monitoring of each COC.	B. Table 7-3 will be expanded to include constituents of concern that will be monitored, EPA-approved analytical methods, and detection limits. Please refer to the response to comment 1D on page 6 of this table for the proposed sampling schedule of shallow soil-gas monitoring points. A draft of the revised Figure 7-3 is provided in Attachment 1.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
8. (continued)	C. Turnaround time – what is the expected turnaround time for analysis of soil gas samples collected for health and safety monitoring purposes? Will a standard turnaround time provide (including internal data validation procedures, QA/QC, etc.) allow ample time to implement SVE? Furthermore, and as previously mentioned, will the remedial system incur significant downtime as the result of procurement/installation of the SVE equipment?	C. The standard turnaround time for analysis of soil-gas samples is expected to be two weeks from the day the laboratory receives the samples. Because the safety threshold values for hydrocarbons in soil-gas originated from the revised risk assessment, which assumed a 30-year exposure duration, exposure to levels above the threshold values in a two-week exposure period would not be expected to be associated with harmful health effects. Thus, the turnaround time for analytical results of soil-gas samples is not expected to affect implementation of the SVE contingency. Furthermore, field meters will be used to regularly monitor shallow soil-gas to ensure anomalies in hydrocarbon concentrations are not found. Before the SVE contingency is triggered, biosparging system parameters will be adjusted in an attempt to decrease hydrocarbon concentrations in shallow soil-gas below the safety threshold. As these adjustments will take some time, the standard turnaround time of analytical results should be sufficient to react to current site conditions within a timely manner. All materials associated with the SVE contingency will either be onsite or readily available from local vendors, therefore, the Navy does not anticipate any significant downtime for SVE treatment equipment procurement.
	D. Please create a flow chart, including a time line; depicting the steps (process) the Navy will go through in collecting and evaluating the data collected from the proposed health and safety monitoring and the steps that trigger SVE.	D. The requested change will be made. This flow chart will be combined with the flow chart requested in comment 5A. A draft version of the flowchart is provided in Attachment 1.
	The second soil gas-monitoring objective is designed for evaluating remedial system performance. A. Figure 7-1 shows four deep soil gas monitoring probes that are designed to monitor the vadose-zone component of the proposed "bioreactor." Why are no monitoring points installed upgradient or downgradient of the biosparging wells to monitor background soil gas composition before and after biosparging, respectively? It seems that this data is needed to fully access the effectiveness of the proposed remedy, including the downgradient/lateral extent of the oxygen enrichment zone.	A. The deep soil-gas monitoring probes are being installed to monitor the biodegradation potential of the bioreactor. Soil-gas samples and field measurements at the deep probes can be collected before, during, and after biosparging system operation to fulfill the data objective of these probes. Soil-gas monitoring probes outside of the treatment area are not required because radius of influence determination is not the objective of the sampling probes.

Specific Responses to Comments From Mr. James D. Ponton Dated October 16, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
8. (continued)	B. Overlay a utility map on Figure 7-1 and identify potential preferential pathways. Evaluate the placement of the probes in light of existing utility corridors.	B. Utility maps will be reviewed, and any existing underground utilities near the treatment area will be depicted on Figure 7-1 of the next draft of the CAP. The placement of additional soil-gas monitoring probes will be evaluated based on the updated figure. A draft of the revised Figure 7-1 is provided in Attachment 1.
	C. As described in Comment Nos. 7 and 11, the CAP does not adequately address how the groundwater plume will be contained on the site, nor does it describe/identify the monitoring well series necessary to confirm plume control. Please expand the discussion on this component of the proposed remedy.	C. Please refer to the Navy's response to the RWQCBs introduction on page 2 of this table. Also, please refer to the Navy's response to comments 1 and 7 on pages 4 and 13, respectively.
	D. Schedule for remediation: Regional Board staff does not agree with the estimated time frame of one year to 1.5 years for system operation and system performance monitoring before RAOs are met. Specifically, one of the RAOs is to contain the plume to the site. Plume containment will require operation, maintenance and monitoring of the sparge curtain, for as long as groundwater concentrations exceed cleanup goals (i.e., MCLs). Groundwater data collected to date suggest that this RAO will take longer than 1 year.	D. As mentioned in previous responses, the Navy contends that because there is no unacceptable risk associated with the current site concentrations, MCLs in groundwater at the property boundary are not an applicable RAO for the active remediation system, but are the final cleanup goals for the site, as stated in the Basin Plan. MCLs will be achieved by natural attenuation after the RAOs of the active remediation system are attained. Based on the discussion presented in Section 7.2.1.4 of the Draft Proposed Final Revision 1.0 CAP, MTBE concentrations in performance monitoring wells located within the permeable sand channel at the site and near the Navy property boundary will be decreased by 95% to 99% through biosparging system operation, at which point groundwater monitoring results will likely indicate a stable MTBE plume that is contained to the Navy property and RAOs will be achieved. The estimated treatment duration to achieve 95% to 99% removal is 1 to 1.5 years, as discussed in Section 7.2.1.4 of the Draft Proposed Final Revision 1.0 CAP and presented in Figure 7-6.

Responses to Comments From Ms. Theresa McGarry Dated November 9, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan and the US Navy Summary Findings on Bedrock Groundwater Conditions for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

Comment Number	Comment	Response
	General Comments	
1	DTSC's main concern is for the continued safety of occupants of the property on and adjacent to the Plumes. Therefore, we request the following two key issues be clearly stated in the CAP. 1. The Navy will issue a remedial design document for regulatory review and approval. The Design should include installation of additional monitoring points to confirm that the selected remedy does not impact migration of the contaminants of concern currently identified in groundwater, soils, soil gas, and potential fractures in bedrock. 2. As part of the Remedial Design process, the Navy will also modify, as necessary, and with regulatory approval, the current groundwater monitoring plan to ensure it addresses potential impacts from remediation activities. (For example, more frequency monitoring may be necessary due to remedial actions). If these measures are adequately described and required in the CAP, DTSC believes that both issues can be successfully addressed during the remedial design/remedial action phase of the project. With appropriate monitoring of groundwater (alluvium and bedrock) and soil gas during remediation, the Navy will be able to quickly evaluate any changes in risk and respond appropriately.	The Navy plans to produce a Remedial Design Workplan which will describe in more detail the planned installation, construction, and operation and maintenance of the remedial alternative after a final alternative has been agreed upon by the Navy, regulatory agencies, and future stakeholders of the property. The detailed workplan will address all facets of monitoring required to ensure the protection of nearby receptors and site workers during remedial system operation. Also, the existing groundwater monitoring plan for the site will be reevaluated and modified to address and track any potential impacts of the future remedial action. The production of a detailed Remedial Design Workplan and modification of the existing groundwater monitoring plan is already discussed in the Draft Proposed Final Revision 1.0 CAP, but the subjects will be further developed in the next draft of the CAP to fully address DTSC's concerns.
	Specific Comments on US Navy Summary Findings on Bedrock Groundwater Conditions	
1	Background: During the investigation, MTBE was observed in bedrock. The Navy believes that there is no significant storage or transport of MTBE in bedrock under the site. Instead, the Navy believes that the cause of MTBE in bedrock is either from existing wells in bedrock leaking or faulty installation. Please obtain information on the nearby Petroleum, Lubricants and Oil (POL) Hill Army investigation regarding the presence of petroleum hydrocarbons in fractured bedrock aquifer, and discuss its relevance to the Navy's position regarding the condition of bedrock at the Navy site.	The Navy has reviewed information pertaining to the presence of hydrocarbons in a fractured bedrock aquifer at the Army's nearby POL Hill. The Navy will address the relevance of the POL Hill site to the Former UST 957/970 site in a revised version of the bedrock summary write-up (dated October 15, 2001), which will be included as an attachment to the next version of the CAP.

Responses to Comments From Ms. Theresa McGarry Dated November 9, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan and the US Navy Summary Findings on Bedrock Groundwater Conditions for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

Comment Number	Comment	Response
2	The Navy should establish with regulatory agencies a mutually acceptable definition(s) of an anomaly in bedrock. An example of an anomaly could be if MTBE concentrations remain consistent or increase during remediation.	The Navy proposes to address the issue of listing and defining all possibly anomalies associated with bedrock conditions in the detailed Remedial Design Workplan, which will be provided to the regulatory agencies and BCT for review and approval.
3	Based on the Navy's statement that the bedrock wells may have leaked or been improperly installed, DTSC requests the Navy conduct testing to assess the theory that current bedrock wells are acting as conduits.	Currently, the Navy is collecting additional data in the area of existing bedrock wells while regular quarterly monitoring occurs to further substantiate the theory that existing bedrock wells may be acting as conduits from the overlying alluvial aquifer. If additional testing of the existing bedrock wells is required in the future to address DTSC's concerns, the Navy will address the nature and scope of the testing in the detailed Remedial Design Workplan.
Specific Comments on Corrective Action Plan		
1	The CAP should incorporate the Navy's Findings from the Bedrock Report as well as the revisions to it based on regulatory comments. The final report can be appended to the CAP.	The requested change will be made. The Navy's Summary Findings on Bedrock Groundwater Conditions will be revised based on regulatory comments and included as an attachment to the next version of the CAP.

Responses to Comments From Ms. Theresa McGarry Dated November 9, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan and the US Navy Summary Findings on Bedrock Groundwater Conditions for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

Comment Number	Comment	Response
2	Although the Navy believes that the information collected to date indicates contaminants in bedrock are localized, the Navy states in the CAP that further field tests will be conducted. Please provide more specific details regarding the field tests. These tests should include at least the following: A. Installation and continuous monitoring of additional groundwater monitoring wells (screened in bedrock) to assure that air sparging is not mobilizing contaminants through a potential bedrock aquifer. These wells can be installed during the Remedial Design and Remedial Action phases. B. Summary of all information pertaining to fractured flow in bedrock underlying the Hamilton Army Airfield Site (i.e., POL Hill area and others). In addition, if any evidence is found that bedrock is already impacted or being impacted by the remediation system, the CAP should state that the Navy will submit a workplan (with a time schedule) to the agencies to fully characterize the contaminants in bedrock.	The Navy will provide more specific details regarding the planned field tests of bedrock in the detailed Remedial Design Workplan, which will be provided to the regulatory agencies and BCT for review and approval. A. The installation and monitoring of additional bedrock wells and specifics regarding the number and location of additional bedrock wells will be presented in the detailed Remedial Design Workplan. B. All existing regional information pertaining to fractured flow in bedrock around Hamilton will be discussed in the revised summary findings, which will be included as an attachment to the next version of the CAP. If any evidence is found that bedrock is impacted or being impacted during remediation, the Navy will produce a workplan to characterize the gasoline constituents in the bedrock for regulatory review and approval.
3	Due to DTSC's main concern for continued safety of occupants, DTSC requests the Navy continue monitoring soil gas at the Day Care Center and proposed Charter School to ensure that no increases in ambient soil gas concentrations results from remediation activities.	Currently, six shallow soil-gas monitoring points exist on PBC Parcel 2 east of C Street. Some number of shallow soil-gas monitoring points, determined during detailed design (three shown conceptually in plan view of Figure 7-1), will be installed between the treatment area and nearby receptors (i.e., daycare center, proposed charter school location and former commissary building 971). A subset of all these available soil-gas monitoring probes will be proposed for sampling during biosparging operation in the Remedial Design Workplan. As discussed in Sections 7.2.1.4 and 7.2.1.5 of the Draft Proposed Final Revision 1.0 CAP, the objective of sampling shallow soil-gas will be to ensure that concentrations of hydrocarbons are not elevated beyond a safety threshold. The safety threshold hydrocarbon concentrations originate from the final revised risk assessment, with which the DTSC concurred, and are presented in Table 7-3 of the Draft Proposed Final Revision 1.0 CAP.

Responses to Comments From Mr. James C. Davies Dated October 19, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California

Comment Number	Comment	Response
	General Comments	
1	**Glossary.** This report has numerous technical terms and acronyms that can make reading and understanding the document difficult for the public. Therefore, it is recommended that a glossary be added at the beginning of the report. The Army has added this feature to their reports and it has been very well received by the public and others.	Comment noted. A glossary will be added to the beginning of the CAP if time and resources are available.
2	**RWQCB Order 00-064.** This report would be much more reader friendly if a copy of RWQCB Order 00-064 were included as a table, attachment (as was done for the DTSC letter) or an appendix. Please include the Order in the CAP.	The requested change will be made. A copy of Order No. 00-064 will be included as an attachment to the next draft of the CAP.
3	**Cleanup Goals.** Throughout the CAP there are references that the groundwater will have to be cleaned up to meet the RWQCB Basin Plan requirements, which is background concentrations. However, background is never defined nor are specific concentrations provided for MTBE, benzene or any of the other hydrocarbon constituents. Please add the numerical background cleanup goal concentrations and detection limits to the CAP.	The requested change will be made. Numerical background goals consistent with MCLs will be added as cleanup goal concentrations in the next revision of the CAP.
4	**The Offsite MTBE Plume Remediation.** The offsite portion of the MTBE plume north of the Navy property is mentioned sporadically in the CAP. While the report is correctly focused on the onsite plume, the offsite portion must be clearly addressed also. In order to clearly identify the offsite plume discussions, please insert subsections under each of the main CAP sections, as appropriate, specifically addressing the offsite portion of the plume.	Throughout the discussion of monitored natural attenuation (MNA) in Sections 6 and 7 of the Draft Proposed Final Revision 1.0 CAP, it is explicitly stated that MNA has been selected to reach background concentrations (MCLs) on the Navy portion of the site and on former HAAF property. Please refer to the last paragraph of Section 6.2.1.1 on page 206, Section 7.2 on page 237, and Section 7.2.2 on page 246 for examples of how the remediation of former HAAF property is specifically addressed.
5	**Sections 2.4 and 5.2.5 Consistency.** The statements made in these two sections that address human health risk assessments need to be reviewed and modified, as appropriate, to make them consistent. For example, statements made in Section 2.4 about the revised risk assessment superceding the Tier 3 risk assessment are not in Section 5.4 and conversely, statements about receiving DTSC approval of the revised risk assessment in Section 5.4 are not in Section 2.4. The ecological risk discussions in Sections 2.5 and 5.2.6 seem more consistent but a check is recommended.	The requested change will be made. Sections 2.4 and 5.2.5 will be reviewed and revised where inconsistencies are identified.

Comment Number	Comment	Response
6	**Executive Summary.** The Executive Summary will need to be modified to be consistent with the changes made in the body of the CAP based on the comments below and those received from the regulatory agencies.	The requested change will be made. The executive summary will be updated to reflect revisions made to the body of the document based on addressing requests provided by commenters.
7	**May 2001 Monitoring Results.** The revised sections 5, 6 and 7 of the CAP occasionally refer to the May 2001 groundwater monitoring program results in the text and some of the figures. However, the May 2001 Monitoring results are not included in Sections 2, 3 or 4. Please update these sections to include the May 2001 monitoring results.	Sections 2, 3, and 4 provide a summary of all historical data for the site. May 2001 groundwater monitoring data was not available during the initial production of the CAP; however, it was available for the Draft Proposed Final Revision 1.0 CAP and was included in the revised sections. Because the inclusion of the May 2001 data in Sections 2, 3, and 4 would not affect the decision process of the CAP or provide any significant substance, the data will be included as it is now in Sections 5, 6, and 7.
	Specific Comments	
1	**Section 2.4.** The next to last sentence in the first paragraph states "The results of the *Final Revised Risk Assessment* supercede those in the Tier 3 RBCA for exposures that were evaluated in both assessments". We do not believe the concept that one risk assessment supercedes the other is accurate or appropriate. The two risk assessments provide the two separate perspectives generally used in conducting risk assessments and conceptually these include: 1. Performing a "forward" risk assessment on a chemical's maximum concentration in a given media for a specific potential exposure pathway to a specified receptor population. The results are (1) a numerical quantification of the likelihood that the receptor population would contract excess cancer from the chemical exposure and (2) a non-cancer risk expressed as a hazard index. This approach does not address remediation goals established for any chemicals or media. This is the perspective of the Navy's *Final Revised Risk Assessment*.	Comment noted. The issue averted by the comment is the fact that more recent site data was included in the "forward" assessment. No site-specific soil hydrocarbon data was assessed in the "reverse" Tier 3. The "forward" HHRA methods showed that soil concentrations observed in Order Task 2 activities and report are generally protective for the proposed commercial/industrial and residential uses around the site, even though some exceed the soil RBSLs presented in the Tier 3. For those pathways evaluated in the Revised Risk Assessment, almost 2 additional years of groundwater data, more soil gas data at additional locations, and all the soil data collected during Order Task 2 were available and included for appropriate pathways. It is reasonable therefore, to consider the Revised Risk Assessment superior to the Tier 3 for the pathways considered at the request of the DTSC commenters on the Tier 3.

Comment Number	Comment	Response
1 (continued)	2. Performing a "reverse" risk assessment starting with an acceptable potential excess cancer and non-cancer risk level for the intended site use and receptor population and backing in to a specific chemical concentration in a media for potentially complete exposure pathways. This concentration becomes a cleanup goal for that chemical in that media for the selected land use. These chemical-specific cleanup goal concentrations can be compared to chemical concentrations in samples from the medial and a determination can be made whether remediation of the media is necessary to meet the selected acceptable risk level. This is the perspective of the Tier 3 RBCA Assessment. It is clear that the risk assessment performed by the Navy and included in the CAP is a "forward" one that looked at the risk to receptors from onsite chemicals in the various media. It is also clear that the Tier 3 risk assessment was a "reverse" one that resulted in the development of Risk-Based Screening Levels (RBSL). Since the two risk assessments address different perspectives, they are complementary and one does not supercede the other. Please remove the statements that contain "supercede" language.	
2	**Section 2.4.1.** The last paragraph states in part "the Tier 3 RBCA Assessment … is considered final because the document responded to all comments provided by the RWQCB on the draft version of the document and the RWQCB provided no further comments on the revised document". While this is true, it is misleading because it gives the impression the document has RWQCB approval when, in fact, it has not been provided to the Navy as of this date. Therefore, the text should be revised to state that the RWQCB has provided verbal approval of the Tier 3 and is in the process of preparing an approval letter.	Historically, the document review and concurrence process for this project (and BCT) has not included a concurrence letter being issued by the RWQCB or DTSC for all documents. Nevertheless, the Navy understands the concerns of future property stakeholders and has requested a concurrence letter from the RWQCB for the Tier 3 RBCA Assessment. If a concurrence letter cannot be issued by the RWQCB, it is the Navy's position that the status of the Tier 3 should not be changed from "final."
3	**Section 2.4.2.** The first paragraph, fourth sentence states the revised risk assessment supercedes the Tier 3. This needs to be revised in accordance with Specific Comment 1 above.	Please see response to specific comment 1 on page 20.

Comment Number	Comment	Response
4	**Section 2.4.2.1.** The last sentence of the first paragraph states that the exposure pathways that were evaluated in the revised risk assessment supercede those in the Tier 3 and the exposure pathways are listed for the revised risk assessment. The pathways are the same with the exception that the Tier 3 also included surface water pathways of ingestion, dermal contact and outdoor air inhalation and included dermal contact with groundwater. An explanation should be provided why the groundwater and surface water were omitted, especially in view of the proximity of the daycare center and charter school to Pacheco Creek.	Dermal contact with groundwater or ingestion, dermal contact, and outdoor air inhalation of surface water are not hazards that exist on the site as defined in the revised risk assessment. Therefore, results of the Tier 3 pertaining to the referenced exposure pathways still apply. A statement addressing this subject will be added to the next draft of the CAP.
5	**Section 2.5.** The last sentence of the first paragraph needs to be expanded or supplemented to state the time period the update covers and whether the new data will be reviewed or evaluated to see if the risks have changed. It seems that if you are going to include the data, it needs to have some level of evaluation. This is important because the last sentence of Section 2.5 states that further evaluation of ecological risks is not required at this time. However, the new data does warrant evaluation. These statements need to be compatible.	New data was reviewed in a recent update to the Ecological Risk Assessment (ERA). The conclusion of the revised ERA was that no further evaluation is necessary. This information will be reflected in Section 2.5 of the revised CAP. The proposed first paragraph of Section 2.5 in the next draft of the CAP will read: "A draft scoping level ecological risk assessment was prepared to determine if the Site poses a risk to the environment. The draft report, submitted on December 8, 1999, was titled the *Draft Ecological Risk Scoping Assessment for Former UST Site 957/970, Department of Defense Housing Facility and Adjoining Portions of Hamilton Army Airfield, Novato, California* (Battelle, 1999a). This report was updated to incorporate the results of surface water sampling in a pre-draft final version of the ecological risk assessment dated June 19, 2001. The following paragraphs discuss the results of the ecological risk assessment."
6	**Section 5.2.2.** (a). The last paragraph states the Navy is planning to perform specific field tests to determine the likelihood of MTBE transport or storage in the bedrock at the Site. Please provide a summary of these tests and their purpose and a schedule for their implementation and follow up reporting. The public may question how a final CAP can be approved and implemented when bedrock contamination has only been partially addressed, the extent of contamination has not been determined, and remedial actions have not been addressed.	(a) The Navy has ongoing communication with regulators regarding the field tests to determine the likelihood of MTBE transport or storage in the bedrock at the Site, their purpose, and a schedule for their implementation. The Navy will produce a detailed Remedial Design Workplan, which will provide a detailed description of the planned bedrock field tests. Also, the Navy will address any additional bedrock questions as they arise. The Site groundwater monitoring plan will be revised as needed, to address any existing bedrock monitoring issues.
	(b). Please add the stakeholders to the third sentence as parties that will receive the bedrock test information in addition to the regulators.	(b) The Navy will provide bedrock test information to all members of the BCT, but this fact does not need to be reflected in the CAP.

Comment Number	Comment	Response
7	**Section 5.2.3.1.1.** The second paragraph should include an explanation of why the concentration increase is occurring because, as it is written, it looks like the plume may not be as stable as the CAP states so please provide some reasons for the increased concentrations. It might help to discuss the May 2001 GMP results because Figure 5-3 shows the benzene concentrations at or below November 2000 concentrations.	Further clarification will be added to the next draft of the CAP to explain the very slight increase in the estimated dissolved mass of benzene in February 2001. The proposed final sentence of the second paragraph in Section 5.2.3.1.1 of the next draft of the CAP will read: "This estimated benzene mass increased slightly from the previous sampling event (from 0.26 kg to 0.34 kg), which is likely due to an increase in the saturated thickness of the aquifer during the rainy season (November – February); however, the estimate remains significantly lower than the benzene mass estimates from February sampling events in the previous two years (Table 5-1 and Figure 5-3)."
8	**Section 5.2.5.** (a). The words "at the Site and enforce the use of their preferred risk assessment method" should be removed from the second sentence, first paragraph. The use of the term "enforce" makes it look as if the Navy has not been cooperating and was made to perform the risk assessment against their will. Obviously this is not the case and the explanation for doing the risk assessment is sufficient without the end of the sentence.	(a). The requested change will be made. "Enforce" will be removed from the referenced sentence. In the next draft of the CAP, the proposed sentence will read: "After the Tier 3 RBCA Assessment was considered final, the DTSC opted to exercise their regulatory oversight for the human health risk assessment at the Site and requested the use of their preferred risk assessment method."
	(b). In the first paragraph, fourth sentence, please replace "target concentrations", which doesn't define what the target is, with Risk Based Screening Levels.	(b). The requested change will be made. "Risk Based Screening Levels" will replace "target concentrations." In the next draft of the CAP, the proposed first paragraph, fourth sentence will read: "In the preferred approach, a multimedia, multichemical risk assessment is performed in the *forward* direction to estimate cancer risk and chemical hazard (non-cancer risk), rather than in the *reverse* direction as was done in the RBCA assessment by deriving Risk Based Screening Levels."

Comment Number	Comment	Response
8 (continued)	(c) In the second paragraph, first sentence, the end of it states that "the risk estimates in the Sale Area are most likely overestimated". Please provide a follow on sentence or two supporting this unsubstantiated statement so the reader will be able to know why it is overstated.	(c) The requested change will be made. Proposed additional text supporting this statement will be taken from the revised risk assessment and added to the next draft of the CAP as follows: "Results of the *Final Revised Risk Assessment* (Battelle, 2001c) indicate the cancer risk estimates to the occupational receptor in the Sale Area fall within the risk range (1×10^{-6} to 1×10^{-4}) that warrants a site-specific risk management decision regarding the suitability of the property for its intended future use; however, the total cancer risk estimates in the Sale Area are most likely overestimated because of the following key assumptions that were made during the calculation of risks (Battelle, 2001c): ▪ Asphalt pavement exists at the site that precludes direct contact with soil; nevertheless, it was assumed that the receptors could be exposed to soil via direct contact by ingestion, dermal contact, and inhalation of dust ▪ Outdoor-air risks were based on the maximum dissolved groundwater concentrations measured across the entire site in November 2000 ▪ The maximum indoor-air risks were based on soil-gas data collected from locations in the Sale Area that overlie groundwater containing the highest concentrations of dissolved gasoline constituents ▪ The model that was used to predict indoor-air risks is known to provide conservative estimated of risk due to several key assumptions. For example, the model assumed that the concentrations of gasoline constituents will remain constant in the future; therefore, risks do not change over time. In reality, most of the gasoline constituents at the site, including benzene, are highly amenable to natural attenuation and it is likely that they will degrade in a relatively short timeframe, thereby lowering future risks." Therefore, these various conservative assumptions indicate that the total cancer risk estimates for the Sale Area are most likely overestimated."

Comment Number	Comment	Response
8 (continued)	(d) The end of the second paragraph states that the Sale Area is suitable for the intended commercial/industrial use and cites USEPA guidance as the justification. While this is fine, the USEPA has not been actively involved at the base for a few years and its closure and transfer are the responsibilities of Cal EPA. Therefore, please add a discussion explaining how the site complies with Cal EPA guidance so the picture is complete and accurate.	(d) The requested change will be made. The proposed end of the second paragraph of Section 5.2.5 in the next draft of the CAP will read: "The risk assessment was conducted in accordance with DTSC risk assessment guidance, which adheres to U.S. EPA's RAGS (U.S. EPA 1989) and U.S. EPA Office of Solid Waste and Emergency Response (OSWER) directives, in addition to supplemental guidance provided by DTSC regarding technical or scientific issues. Sites or facilities under DTSC jurisdiction must conform to the guidance in RAGS and OSWER directives (DTSC supplemental guidance at http://www.dtsc.ca.gov/sppt/herd). Per U.S. EPA OSWER directive No. 9355.0-30 (U.S. EPA, 1991), remedial action generally is not warranted at a site if the total cancer risk is below 1×10^{-4} (one in ten thousand) and the total non-cancer risk (hazard index) does not exceed 1.0, unless a risk manager decides that there are extenuating circumstances. DTSC concurred with the methodology and results of the risk assessment and the Sale Area is suitable for its intended commercial/industrial use."
	(e) Please include the last sentence of the third paragraph in Section 2.4.	(e) The requested change will be made. The referenced sentence will be added in Section 2.4.1 of the next draft of the CAP.

Comment Number	Comment	Response
8 (continued)	(f) The fifth paragraph, third sentence used the average concentration along the creek for comparisons with the Tier 3 RBSLs. Please explain why the maximum concentrations or the average of the maximum concentrations were not used for comparisons with the RBSLs, which would have been more conservative.	(f) Text will be added to explain that the average concentration was used to represent concentrations over the entire likely exposure area (Pacheco Creek). The proposed fifth paragraph of Section 5.2.5 of the next draft of the CAP will read: "To further support the results of the Tier 3 RBCA Assessment with regard to exposure to surface water in Pacheco Creek, the most recent (May 2001) surface water monitoring data from sampling locations within Pacheco Creek were used to calculate the total risk presented by possible exposure in the creek. Risks were calculated for the inhalation, ingestion, and dermal contact exposure routes. The ratio of the observed average concentration along the length of the creek (14.7 µg/L) to the protective concentration calculated in the Tier 3 RBCA Assessment (Battelle, 1999c) for each of the exposure pathways considered (2,402 µg/L for inhalation; 4,600 µg/L for ingestion; and 9,350 µg/L for dermal contact) was multiplied by the 1×10^{-6} target risk level from which the protective concentrations were derived to estimate the risk associated with each exposure pathway. The average concentration (14.7 µg/L) was used in estimating the risk associated with each exposure pathway because it represents concentrations over the entire likely exposure area (Pacheco Creek). These risks were summed, yielding a total risk of approximately 1×10^{-8} for exposure in the creek. The total risk associated with the creek was minimal compared to the risks associated with the other exposure pathways evaluated at the Site (for example, inhalation of indoor air); therefore, the total risk estimated for the surface water in Pacheco Creek would not significantly add to the total site risk as reported in the *Final Revised Risk Assessment*."
	(g) In Section 5.2.6, the second paragraph, second sentence, states the highest MTBE concentration in the storm drain at Pacheco Creek was 2,400 µg/L. If so, then it is at the RBSL for inhalation of 2,402 µg/L presented in the fifth paragraph of this section. However, this occurrence is not mentioned nor addressed. What are the implications of the RBSL being matched by the MTBE concentrations in the creek? Please provide a discussion of this situation and address its significance.	(g) The 2,400 µg/L was a one-time observation in a storm sewer outfall to Pacheco Creek, not an observation in the creek itself. Additional sampling performed since the 2,400 µg/L was detected does not indicate that any trends of concern exist, meaning lower concentrations showing no consistent increase have been found.

Comment Number	Comment	Response
9	**Section 5.2.6.** Section 2.5 says the ecological screening report is being updated but it is not mentioned in this section. Please make the two sections consistent; see General Comment 4.	The requested change will be made. A review will be performed to ensure consistency between Sections 2.5 and 5.2.6. The proposed first paragraph of Section 5.2.6 in the next draft of the CAP will read: "A draft scoping level ecological risk assessment was prepared to determine if the Site poses a risk to the environment. The report focused on determining the potential ecological receptors and the potentially complete exposure pathways, according to the methodologies described by the Cal-EPA (1996) for scoping assessments and consistent with U.S. EPA guidance for problem formulation (U.S. EPA, 1998a). This report was updated in June 2001 to incorporate the results of surface water sampling. According to Cal-EPA (1996), additional assessment is not required if the scoping assessment determines that either no complete exposure pathways exist or that the impacted areas are not significantly utilized by biota."
10	**Section 5.3.** The first sentence, third paragraph states, in part, that the RAOs are "to reduce the time to achieve the final cleanup levels (background concentrations)". However, this part of the RAOs should be changed to read "to achieve the final cleanup levels (background concentrations)". Just reducing the time is not an adequate RAO for plume remediation. Please make the change.	In light of observed natural attenuation rates that exist at the Site, it is likely that final cleanup goals (MCLs) would be achieved even with no active remediation; therefore, it is the Navy's opinion that decreasing that time to reach final cleanup goals is a very appropriate objective for an active remedy and RAO.
11	**Section 5.3.** In the last sentence, third paragraph, please provide a definition for the term "specific observable concentration goals" or rephrase so the lay person can understand it.	The requested change will be made. The referenced term will be clarified in the next draft of the CAP.

Comment Number	Comment	Response
12	**Section 6.1.1.1.** The normal feasibility study process starts with the review and retention/elimination of technologies and process options. The retained technologies are combined into a few remedial action alternatives. At this point, the "no further action" alternative is evaluated with the remedial action alternatives using anywhere from three to ten evaluation criteria. From this evaluation, the preferred alternative (either one of the remedial actions or the no further action one) is selected and justified. Therefore, the "no further action" should not be considered a remedial technology but rather as the baseline for comparison with the remedial action alternatives. Considering "no further action" a technology in this report eliminates it before it can be compared to the remedial action alternatives. Please reword this section and move it to Section 6.1.2 as the first alternative that is evaluated with the other remedial action alternatives.	The "no further action (NFA)" alternative or baseline comparison has no possibility of meeting the requirements of Order No. 00-064 and will not change the final decision of the CAP; therefore, the Navy does not feel it is reasonable to include the NFA alternative in the detailed evaluation.
13	**Section 6.1.1.10.** The Excavation and Dewatering discussion needs to be expanded so the reader understands that the intention is to excavate, dewater and backfill a huge hole over most of the site; currently this is not clear. The preceding technology descriptions in Section 6.1.1 provides the reader with a picture of how the alternative applies to the Site but this description could be enhanced. Please add some clarifying discussions.	The requested change will be made. The general description of the excavation and dewatering technology will be enhanced with some clarifying text. Proposed Section 6.1.1.10 of the next draft of the CAP will read: "Excavation and dewatering contains the MTBE plume by excavating a large area of soil at the site, followed by dewatering of the excavated area, and finally backfilling of the excavated area. Structural sheet piling is placed around the perimeter of the excavation to stabilize the opening. Soil is then excavated from the unsaturated and saturated zones down to the fractured bedrock. The excavated soil is trucked to an off-site facility for disposal. The local groundwater level is lowered by pumping to allow excavation to proceed below the water table. Excavation and dewatering is a routine conventional method for site remediation and is expected to rapidly provide effective reduction of the concentrations of gasoline constituents in groundwater. However, the cost would be very high."
14	**Section 6.1.2.** (a). The "no further action" discussion should be moved from Section 6.1.1.1 to this section; see Specific Comment 12 above and 15 below.	(a) Please refer to the response to specific comment 12 above.

Comment Number	Comment	Response
14 (continued)	(b) This section needs a lead in paragraph that describes how the selection of retained vs. eliminated alternatives (as they are called in Section 6.1.2) or options (as they are labeled on Table 6-2) was made. Please select one term (alternatives or options) and use it consistently. Also, please summarize those alternatives/options eliminated, describe why they were eliminated, and add a reference to Table 6-2 in the lead in paragraph.	(b) The Navy will consistently use "alternative" throughout the revised CAP to clarify the discussion. Table 6-2, which clearly describes why particular alternatives were eliminated, will be referenced in the proposed lead-in sentence of Section 6.1.2 of the next draft of the CAP as follows: "The basis for selecting alternatives for the detailed evaluation is summarized in Table 6-2. The alternatives selected for detailed evaluation are as follows:"
	(c) It seems that Alternative 1 (excavation and dewatering) should have been eliminated in the technology screening because of its excessive cost that provides little, if any, additional protection. The only advantage seems the rapid time to reduce the chemical concentrations in groundwater. Please consider eliminating this alternative. If retained, please add a statement about what happens to the groundwater; i.e., it gets treated.	(c) Alternative 1 was retained to provide a frame of reference to the reader of the required cost to obtain RAOs on the Navy portion of the Site in a short timeframe. A statement will be added to the revised CAP to indicate that the groundwater will be treated and disposed. In the next draft of the CAP the proposed general description of Alternative 1 in Section 6.1.2 will be as follows: **"Alternative 1** – Excavation to remove soil and dewatering to remove groundwater containing elevated concentrations of gasoline constituents on currently Navy-owned property. Furthermore, groundwater will be treated and disposed of at an off-site facility. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater beyond excavated area to MCLs, monitoring, and institutional controls."
	(d) The description of Alternative 4 should mention the SVE component that will be installed but may not need to be operated.	(d) The requested change will be made. The SVE component of Alternative 4 will be mentioned in the proposed general description of Alternative for in Section 6.1.2 of the next draft of the CAP as follows: **"Alternative 4** – Biosparging to remediate groundwater migrating across the northern boundary of currently Navy-owned property and elevated concentrations of MTBE on currently Navy-owned property. A SVE system will serve as a contingency measure for off-gas control during biosparging system operation. This active remediation method is supplemented with MNA to remediate all gasoline constituents remaining in groundwater to MCLs, monitoring, and institutional controls."
15	**Section 6.2.** The "no further action" alternative should be added to this section.	Please refer to the response to specific comment 12 on page 28.

Comment Number	Comment	Response
16	**Section 6.2.2.** The format of this section and its subsections is to present a description of each alternative followed by an evaluation discussion on the cost, effectiveness, benefits, impacts on public health and welfare and the environment, and finally implementability. The order the evaluation criteria are presented makes review of the alternative difficult because new information on the design and operation is presented in each of the evaluation criteria, rather than in the description where it belongs. This is most evident in the implementability discussions where a lot of new information is presented at the end of the evaluation which makes the reader have to go back through the alternatives evaluation criteria again with the new information in mind. Therefore, it is recommended that the information contained in the evaluation criteria that are part of the alternative's description be relocated to that section. Also, the evaluation of the alternative would flow much better and be easier to follow and understand if the review criteria order were rearranged to discuss implementability first followed by effectiveness, impact to public health benefits and cost at the end.	The requested change will be made. Information that belongs in the alternative description will be relocated to that section, and the alternative evaluation criteria will be reordered as follows: Description Implementability Effectiveness Benefits Impact on Public Health and Welfare and the Environment Cost
17	**Section 6.2.1.3.** This section provides for a footnoted definition of the Site, which is helpful. Please provide a similar footnoted definition of the Sale Area.	The requested change will be made. The following proposed footnoted definition of the Sale Area will be added to Section 6.2.1.3 in the next draft of the CAP: "The Sale Area comprises an area of approximately 2 acres, bounded on the south by Main Entrance Road, and on the north by Public Benefit Conveyance Parcel 1 (refer to Figure 1-3). The eastern border of the Sale Area runs north-south from the intersection of Main Entrance Road and C Street and the western border runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street."

Comment Number	Comment	Response
18	**Section 6.2.2.1.1.** (a). In the first paragraph, if you are going to present the footprint dimensions and volume of the excavation, then please add the depth (range and/or average) of the excavation. Also, please add an estimate on the volume of water to be extracted for offsite treatment and put it in this paragraph	(a) The requested change will be made. The assumed depth of the excavation and estimated volume of water to be extracted will be added to the referenced paragraph. In the next draft of the CAP the proposed first paragraph will read as follows: "Sheet piling would be used as shoring to support the perimeter of the area being excavated. Buildings 970, 972, and 973 would be demolished to allow access for the excavation. During the excavation, clean soils (top 10 feet of soil) would be segregated from the remaining impacted soils (bottom 5 feet of soil). The impacted soils (approximately 33% of the excavated soils) would be trucked off site for disposal as a RCRA hazardous waste in a permitted treatment, storage, and disposal facility (TSDF). The remaining clean soil would be reused to backfill the excavation along with clean backfill coming from an off site source. The soil would be placed and compacted so as to minimize settling. The surface finish would be returned to its original condition (e.g., hydroseeding and mulching for grassy areas and paving for paved areas). Groundwater in the excavation area that leaks in past the piling would be extracted to dewater the Site and allow excavation below the water table. Based on the required volume of the excavation, the estimated volume of groundwater that would be extracted and trucked off site for management at an off-site facility is approximately 2,500,000 gallons."
	(b) In the first paragraph, is the remedial goal to reduce MTBE concentrations to MCLs as stated or to background as stated elsewhere in the RAP? Please clarify.	(b) In the next draft of the CAP, text will be added to clarify that MCLs will be the final cleanup goals.
	(c) According to Section 6.0, the depth to the aquatard is about 15 feet and the depth to groundwater is 7 to 13 feet. Therefore, it seems that perhaps the top 7 to 10 feet of soil within the excavation limits should be mostly clean except for a few areas around former Buildings 957 and 970. However, the second paragraph discussion indicates the plan is to take all excavated soil offsite for disposal at a huge cost. But, by segregating the clean upper soil, disposal costs would be significantly reduced, as would the cost for imported soil to backfill the excavation. Please modify the text and cost tables accordingly or present reasons why the clean soil cannot be recycled and save significant funds.	(c) The requested change will be made. The aspect of segregating clean soil and reusing it to backfill the excavation will be incorporated into the next draft of the CAP. However, the change in cost is not substantial enough to alter the remedy selection process of the CAP. Please see the response to comment 18(a) above for specific example of how the referenced paragraph will read in the next draft of the CAP.

Comment Number	Comment	Response
19	**Section 6.2.2.1.3.** This section says it will take about 25 weeks to remove the soil and groundwater and a similar period to restore the site. However, these operations can proceed simultaneously and do not have to be sequential. Not only will this save time when combined with soil segregation described in Specific Comment 14(c), but it will save money also. Please factor these common construction measures in you alternative description and cost estimates.	The requested change will be made. The revised CAP will include the concurrent removal of soil and groundwater and restoration of the site, in order to save time and money. The proposed second paragraph of Section 6.2.2.1.3 in the next draft of the CAP will read: "Use of excavation and dewatering is one of the oldest forms of site remediation. This method ensures that the gasoline constituents are removed from site groundwater resulting in a rapid reduction of the inventory at the Site. Soil excavation and site restoration, both of which are expected to require about 25 weeks to carry out (not including work plan development, reporting, or agency reviews), will be performed simultaneously at different areas of the site. Dewatering operations would be conducted throughout the 25-week period."
20	**Section 6.2.2.1.6.** This section describes the excavation and dewatering as being very difficult to implement. The remedial construction experts I talked with disagree and said that while it is a big job, it is not particularly difficult. Also, this was not mentioned in Table 6-2 as a limitation. This section also states that "extensive pavement and buried utilities make the field application very difficult. An extensive effort would be needed to find and relocate buried utilities in the area". However, when one places the excavation footprint over the historic utility maps provided by the Navy, the amount of utility lines present is manageable, especially considering that many of them do not meet City of Novato building code requirements and will have to be replaced and/or will not be needed in the future. Therefore, please modify this section to provide a more realistic assessment of the construction. Also, recall that most of the Phase I GSA Sale Area was remediated this way by Army contractors with over 120,000 cubic yards of soil successfully removed. That project went very well.	The difficulty of implementability is related to the scale and scope of the operation, not necessarily the technical difficulty of the operation. Considering three existing buildings would need to be demolished, a portion of C Street would need to be destroyed and re-paved, dust control would be required during the excavation and backfill process, and major limitations of site operations would be in place during the entire operation, the Navy feels it would be difficult to implement the alternative in the proximity of the Daycare and Youth Center. The GSA project context and objectives were very different from the NEX Gas Station project and are not germane to this process.

Comment Number	Comment	Response
21	**Section 6.2.2.2.1.** (a). Please provide the length, width and depth of the trench and the volume of excavated soil as part of the description.	(a). The dimensions of the trench are provided in Section 6.2.2.2.2; however, as requested, the dimensions and volume of soil to be excavated will be stated in the following proposed text in Section 6.2.2.2.1 of the next draft of the CAP: "Implementing Alternative 2 would require constructing a trench that acts as a below ground treatment barrier. Air sparging in the barrier would remove dissolved volatile gasoline constituents as the groundwater passes through the barrier. A trench with large enough to intercept the majority of groundwater impacted by MTBE dimensions (approximately 250 ft in length, 4 ft wide, and 20 ft deep) would be excavated perpendicular to the direction of groundwater flow (i.e., in the area where the CPT investigation was performed as described in the Remedial Investigation report [Battelle, 2001b]). The estimated volume of soil that will require removal for the trench would be approximately 750 cubic yards"
	(b) Please add a conceptual cross section of the interception/aeration trench to Figure 6-2 similar to the cross section included in Figure 6-4.	(b) The requested change will be made. A conceptual cross section will be added to Figure 6-2 in the next draft of the CAP. A draft version of the updated Figure 6-2 is included in Attachment 1.
	(c) The second paragraph says the trench will be about 15 to 17 feet deep and elsewhere it is said that the depth to groundwater is 7 to 13 feet. Therefore, it seems that perhaps the top 7 to 10 feet or more of soil excavated for the trench should be clean and not require offsite disposal as stated in Section 6.2.2.3.5. By segregating the clean upper soil from the formerly saturated soil at depth, disposal costs would be reduced by one half to two thirds, as would the cost for imported soil to backfill the excavation. Please modify the text and cost tables accordingly or present reasons why the clean soil cannot be recycled and save significant funds.	(c) The segregation and recycling of clean soils removed during the excavation and dewatering alternative (Alternative 1) would have more impact on cost than for the alternatives that include excavation of an aeration or collection trench. Currently, the disposal cost of soils removed from the aeration or collection trench area is only $40K; therefore, any decrease in this cost will ultimately be insignificant when compared to the overall cost of each alternative.

Comment Number	Comment	Response
22	**Section 6.2.2.2.3.** (a). The last paragraph says that the MTBE mass removal rate would be low so no vapor extraction and treatment of the injected air would be necessary. However, there is no explanation of what happens to the MTBE removed from the groundwater into the air. Is it expected to naturally degrade aerobically in the gravel backfill? Please explain the fate of the MTBE removed from the water by the injected air.	(a) It is assumed that MTBE transfer from groundwater to vapors via aeration within the trench will be at level that allows them to be directly discharged below an atmospheric loading rate of about 1 lb/day. Text will be added to the next draft of the CAP stating that if needed, carbon canisters will be used to treat vapors before they are directly discharged. It should be noted that this treatment process would not significantly change the overall cost or effectiveness of the alternative. In the next draft of the CAP the proposed last paragraph in Section 6.2.2.2.3 will read: "Due to the limited inventory of MTBE and the time required for remediation, the mass removal rate of chemicals in the sparging air would be low. The estimated quantity of MTBE in the volume of groundwater on currently Navy-owned property with dissolved MTBE is 54 kg (120 lbs). Based on the estimated treatment duration of 3,650 days (1,000 ft divided by 100 ft/yr) the MTBE discharge rate would be 0.015 kg/day (0.033 lbs/day). Due to this low release rate, it is expected that no vapor extraction or treatment would be needed in the trench to collect and control release of the sparging air. However, if needed, carbon canisters will be used to treat vapors before they are directly discharged."
	(b) Figure 6-2 shows two monitoring wells in the trench presumably to monitor the effectiveness of the aeration on MTBE concentrations in the groundwater but there is no discussion about monitoring presented; please add this.	(b) The following proposed statement identifying the use of the two monitoring wells and the assumed monitoring schedule will be added to the next draft of the CAP: "The assumed design specifications of the aeration trench include the installation of four monitoring wells directly within the trench. To monitor the effectiveness of MTBE removal by groundwater aeration in the trench, these newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown."
	(c) It is questionable whether the two monitoring wells in the trench are sufficient to adequately monitor the post-aerated groundwater. Additional monitoring wells should be placed downgradient but close to the trench for more effective monitoring.	(c) The actual number and placement of monitoring wells will not be determined until the Remedial Design Workplan phase of the chosen remedy; furthermore, these variables do not change the remedy selection process of the CAP. Also, please see response to (b) above.

Comment Number	Comment	Response
22 (continued)	(d) The placement of the trench so close to the property boundary leaves little room for well installation so consideration should be given to relocating the trench a short distance to the south.	(d) The Navy will be responsible for specific design considerations. A more detailed Remedial Design Workplan will be prepared once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
23	**Section 6.2.2.3.** The SVE seems to be a critical part of this alternative so it should be added to the alternative's title here and throughout the CAP.	The requested change will be made. Alternative 3 will be referred to as "Collection Trench and Wells with Groundwater Pump and Treat and SVE" in the next draft of the CAP.
24	**Section 6.2.2.3.1.** (a). Please add all the dimensions of the trench and the volume of soil to be excavated to the description.	(a) The dimensions of the trench are provided in Section 6.2.2.3.2; however, as requested, the dimensions and volume of soil to be excavated will be stated in the following proposed text in Section 6.2.2.3.1 in the next draft of the CAP: "The proposed French drain would start northeast of Building 971 and run east-southeast for about 250 ft along the railroad easement (see Figure 6-3). The trench for the drain would be excavated to the weathered bedrock aquitard for a total excavation depth of about 15 to 17 ft and a width of 4 ft. (Note that pumping out of the French drain provides a driving force to capture water, unlike the aeration trench described in Alternative 2 which passively intercepts natural groundwater flow. Therefore, the French drain does not need to be keyed into the aquitard.) The estimated volume of soil that will require removal for the trench would be approximately 750 cubic yards."
	(b) The third paragraph says 10 extraction wells would be drilled in the higher MTBE concentration area yet Figure 6-3 shows seven wells. The other three extraction wells are shown located in the trench, two of which are not in the elevated concentration areas. Please include an explanation for why these apparently redundant wells are placed in the extraction trench.	(b) Figure 6-3 shows 10 wells including those in the trench. The three groundwater extraction wells located within the trench are included to establish hydraulic control at the Navy property boundary.

Comment Number	Comment	Response
24 (continued)	(c) The last paragraph provides a very brief and sketchy description of the SVE system. The Appendix P cost estimate shows installation of 60 SVE wells. Please enhance the description and add these wells with the associated piping on Figure 6-3.	(c) The requested change will be made. The description of the SVE component of Alternative 3 will be expanded to describe its objective and the conceptual placement of the vapor extraction wells will be added to Figure 6-3. A draft version of the updated Figure 6-3 is provided in Attachment 1. The proposed last paragraph in Section 6.2.2.3.1 in the next draft of the CAP will read: "Approximately sixty air extraction wells would be evenly distributed over the entire dewatered treatment area to allow SVE treatment of the unsaturated and dewatered zones. The design objective of the SVE wells would be the removal and treatment of any residual MTBE contained within pockets of moisture that could not be effectively dewatered. The SVE system would force the circulation of air within the subsurface (dewatered and unsaturated zones) thereby enhancing the effect of removing any moisture left over after the site was dewatered. Air would be withdrawn from the wells using a blower that discharged through GAC treatment units to remove MTBE from the air stream prior to release. Figure 6-3 shows the conceptual placement of the SVE wells for Alternative 3."
	(d) There is no discussion of monitoring the SVE system for performance to assess whether the hydrocarbons have been removed to adequate levels. Please include this in the discussion.	(d) The type and assumed schedule of monitoring for the SVE component will be mentioned in Section 6.2.2.3.2 of the revised CAP; however, it would be inconsistent to discuss performance criteria that gauges SVE system operation, because the CAP does not currently discuss performance criteria for alternatives that are not selected.
	(e) There is no discussion of groundwater monitoring for this alternative; please add it. Figure 6-3 shows two monitoring well in the trench but the Appendix P cost estimate is for four wells; please rectify.	(e) The requested change will be made. The assumed monitoring schedule will be discussed in Section 6.2.2.3.2 of the revised CAP and the inconsistency between Figure 6-3 and Appendix P will be corrected.

Comment Number	Comment	Response
24 (continued)	(f) Figure 6-3 shows two monitoring wells in the trench presumably to monitor the effectiveness of the groundwater extraction on MTBE concentrations in the groundwater but there is no discussion about monitoring presented; please add this.	(f) The requested change will be made. The following proposed statement identifying the use of the two monitoring wells and the assumed monitoring schedule will be added to the next draft of the CAP: "The assumed design specifications of the collection trench include the installation of four monitoring wells directly within the trench. To monitor the effectiveness of MTBE removal by groundwater extraction in the trench, these newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown."
	(g) It is questionable whether the two monitoring wells in the trench are sufficient to adequately monitor the groundwater leaving the extraction trench. Please add additional wells downgradient but close to the trench for more effective monitoring. The placement of the trench so close to the property boundary leaves little room for well installation so consideration should be given to relocating the trench a short distance to the south.	(g) The actual number and placement of monitoring wells will not be determined until the design phase of the chosen remedy; furthermore, these variables do not change the decision process of the CAP. The Navy will be responsible for specific design considerations and will prepare a detailed Remedial Design Workplan once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
25	**Section 6.2.2.3.3.** There is no discussion on the effectiveness of the SVE system; please add a discussion to this section.	The requested change will be made. A discussion identifying how the SVE system will remove MTBE from dewatered soils will be added to the next version of the CAP. Please see response to comment 24(c) on page 36.

Comment Number	Comment	Response
26	**Section 6.2.2.3.3.** There is no discussion on the implementability of the SVE system which, with 60 wells and piping, could be more difficult to install than the trenching if the piping has to go underground. Please add a discussion on SVE implementability.	The requested change will be made. The difficulty of implementing a SVE system of such large scale will be discussed in the next draft of the CAP. The following proposed paragraph will be added to the Implementability section for Alternative 3 in the next draft of the CAP: "The SVE system can be constructed using standard commercial materials and methods. A variety of permits and administrative clearances would be required to support SVE installation, but these are routinely obtained. The pipes connecting the wells to the extraction blower system would be placed in trenches to avoid interference with site activities during system operation; however, due to the large scale of the SVE system, the trenching activities would be complicated by existing underground utilities and would significantly effect daily site operations during system installation. The SVE system would present minimal limitations to site operations following installation because all wells and associated piping would be below grade and only a structure to house the extraction system would be present on the Site surface."
27	**Section 6.2.2.4.** The terms "air sparging" and "biosparging" appear to be used almost interchangeably in the Alternative 4 discussions but they are not the same. Please define each term and explain the key similarities and differences and then use the terms appropriately throughout the text.	The distinction between biosparging and air sparging is defined in Section 6.1.1.4. Biosparging is air sparging in its engineering design. The difference relates to the air injection rate and the fate of stripped vapors. The discussion of Alternative 4 will be reviewed to confirm that terms are used appropriately.

Comment Number	Comment	Response
28	**Section 6.2.2.4.1.** (a). In the second paragraph, Figure 6-1 should be 6-4. The sparging "curtain" mentioned in the second paragraph presents a treatment length that is about 100 feet wide in the more permeable geologic areas that is perpendicular to the MTBE plume axis. The length is significantly less than 250 feet designed for the trenches in Alternatives 2 and 3. Based on review of Figure 6-4, it appears that additional sparging wells might need to be added to increase the sparging curtain length. It appears extending the curtain to the west might be necessary, even if the sparging wells are outside the most permeable areas, in order to ensure lowering the MTBE concentrations across the plume in that area because there are high concentrations and few biosparging wells in that area. Otherwise, it seems that higher MTBE concentrations could bypass the sparging curtain to the west and flow off Navy property to the north. Please reevaluate the conceptual design to determine if additional biosparging wells in the curtain are needed and modify the text and Figure 6-4 accordingly.	(a) In the second paragraph, Figure 6-1 will be changed to Figure 6-4. Regarding the need for additional biosparging wells to the west of the proposed sparge curtain, in the Final Remedial Investigation Report (Battelle, 2001) it was reported that MTBE concentrations decrease substantially toward that area of the site because the soils were finer, and sand zones were not connected hydraulically as completely as in the are a of the proposed sparging curtain. The Navy will be responsible for specific design considerations and a more detailed Remedial Design Workplan will be prepared once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
	(b) There is no discussion on the performance monitoring using the four new groundwater monitoring wells. Based on the well locations presented on Figure 6-4, it appears additional wells need to be installed close to but downgradient of the one well at the northern line of biosparging wells. Please adjust the number and locations of the new groundwater monitoring wells and add a discussion on the performance monitoring.	(b) The actual number and placement of monitoring wells will not be determined until the design phase of the chosen remedy; furthermore, these variables do not change the decision process of the CAP. The Navy will be responsible for specific design considerations and will prepare a detailed Remedial Design Workplan once a remedy has been agreed upon among the Navy, regulators, and stakeholders. The following proposed statement identifying the use of the new monitoring wells and the assumed monitoring schedule will be added to the next draft of the CAP. "The assumed design specifications of the biosparging system include the installation of four monitoring wells directly downgradient of the "sparge curtain" to monitor the effectiveness of MTBE removal by groundwater aeration in the area of the curtain. These newly installed monitoring wells would be sampled along with approximately six existing monitoring wells in close proximity of the treatment area on a quarterly basis during system operation to track the treatment system efficiency. Quarterly monitoring for rebound would also occur for one annual cycle following system shutdown."

Comment Number	Comment	Response
28 (continued)	(c) Please include additional discussion on the CPT investigation plan and show the preliminary probe locations on Figure 6-4.	(c) A more detailed Remedial Design Workplan that will discuss the CPT investigation plan will be prepared once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
	(d) The fourth paragraph states that the SVE wells will be installed when the biosparging wells are installed. Does this include the installation of the piping network and the treatment unit shown on Figure 6-4 or would these items be installed only if SVE system operation is needed? Please clarify this in the text. Also, please provide the type of treatment system that will be used for the collected off gas.	(d) The requested change will be made. The discussion of the SVE component of Alternative 4 will be expanded to state that the piping network for the SVE system will be installed while biosparging and SVE wells are installed. Carbon is the assumed off-gas treatment system and the carbon canisters would be purchased from a local vendor in the event that the SVE contingency is required. The proposed fourth through sixth sentences of the fourth paragraph in Section 6.2.2.4.1 will be read as follows: "During each phase of the biosparging system installation, SVE wells (including piping) would also be installed in the treatment area. The SVE system would serve as a contingency measure for biosparging system operation. Carbon is the assumed off-gas treatment system and carbon canisters would be procured if SVE operation were required."
29	**Section 6.2.2.4.2.** This section does not address the costs for the CPT investigation mentioned in Section 6.2.2.4.1 and the onsite test mentioned in Section 6.2.2.4.6 (see Specific Comment 31 b). Please add these to the text. Also, these requirements could add from 6 to 12 months to the remediation schedule; please adjust the schedule accordingly.	The costs associated with the CPT investigation of Alternative 4 were not mentioned as an assumption in Section 6.2.2.4.2, but $11K was included in the detailed cost estimate of Appendix P for the CPT investigation. Section 6.2.2.4.6 does mention that the design of a biosparging system typically requires performance of an on-site test, but the paragraph goes on to say that because air sparging has already been implemented at the Site, the design of a newly installed biosparging system can be developed based on parameters measured during operation of the previous air sparging system. Therefore, the on-site test will not be required and the schedule will not need adjustment.
30	**Section 6.2.2.4.3.** (a). The second sentence, first paragraph says plume stabilization and containment at the boundary is achieved once "clean water" reaches the boundary. Is the "clean water" the same as background concentrations? Please add the definition of "clean water" to the text.	(a) Clean water is water that has "reduced and remediated MTBE." In the revised CAP, the term "clean water" will be changed to "treated water" to avert any confusion associated with the terminology. The more detailed discussion of performance goals is provided in Section 7.2.1.4.

Comment Number	Comment	Response
30 (continued)	(b) The second paragraph states that biosparging/air sparging has an established operating history. However, all of the examples cited and shown on Table 6-9 are for air sparging and none are for biosparging. The inference is that the biosparging is the same as air sparging, a technology that has been proven effective most of the time. While there are many similarities in the two methods, obviously there are some meaningful differences. Therefore, the discussion is misleading because no evidence is provided that biosparging has an established and successful history. Please rectify this discrepancy and provide case studies that demonstrate biosparging is effective.	(b) The Navy has researched many case studies applying to biosparging remediation and a summary discussion of those case studies will be included in the next draft of the CAP.
	(c) The third paragraph states the dissolved MTBE removal rate is the mass of MTBE in the Navy owned property groundwater at 54 kilograms (kg) divided by 365 days per year which equal 0.15 kg/day. It is further stated that this is conservative because it does not include any MTBE biodegradation. However, the biosparging system does not appear to be designed neither to sparge all the groundwater containing MTBE within the Navy property nor to sparge all of the MTBE out of the groundwater to non-detectable concentrations. Both of these conditions would have to be met if all 54 kilograms were to be biosparged in one year at a removal rate of 0.15 kg. Therefore, it appears the MTBE removal rate is not correct. Please revise the MTBE removal rate to be more reflective of actual anticipated conditions and present the impact that the revised removal rate has on the stated treatment time of one year.	(c) The objective of the text cited is to make a conservative (high) assumption of loading rate to the atmosphere from stripped MTBE. That is why no biodegradation is assumed. The objective of the text is not to estimate time required to remediate groundwater.
31	**Section 6.2.2.4.6.** (a). The first sentence says biosparging has "developed an established record of full-scale application". However, as stated in Specific Comment 30 (b), no evidence for this has been provided for biosparging. Please add data supporting the first sentence.	(a) Please refer to the response for specific comment 30 (b) above.
	(b) The second sentence says an "onsite test" is typically required for biosparging system design. However, there is no discussion in the CAP of what the test consists of, how long it would take or the cost. Is this a small scale or a full scale pilot test? Please clarify and provide and explanation under the description of this alternative.	(b) Please refer to the response for specific comment 29 on page 40.

Comment Number	Comment	Response
31 (continued)	(c) The last sentence says that the remedial system piping will be underground. Please include a discussion on the construction impacts that the existing underground utilities will have on system installation as was provided for the other alternatives.	(c) The requested change will be made. The construction difficulty associated with implementing below-grade piping near existing underground utilities for Alternative 4 will be mentioned in Section 6.2.2.4.6 of the revised CAP. The following proposed sentence will be added after the referenced sentence in the next draft of the CAP: "Installation of the below grade piping and wells could be affected by existing underground utilities, but this issue would be averted by reviewing existing utility maps and clearing areas where trenches would be installed."
32	**Section 6.3.** (a). It should be noted in the second paragraph under "Effectiveness" that biosparging will take six times longer for the plume to stabilize and over twice as long to achieve the Basin Plan goals than Alternative 3. This is an illustration that most of the comparisons are with Alternatives 1 and 2 with little said about Alternative 3 which is the next least expensive but much quicker than Alternative 4. Please include more comparisons with Alternative 3	(a) Please note that footnote (a), located at the end of Table 6-10, was mistakenly not inserted in the rows of the table associated with "time to stabilize" and "time to cleanup". Footnote (a) indicates that the published timeframes to cleanup are associated to the Navy portion of the Site only, because MNA is the common element of each alternative to be used to reach final cleanup goals (MCLs) on former HAAF property. Biosparging will take six times longer (or 1.5 years) than the collection trench with wells and groundwater pump and treat (0.25 years) to stabilize the MTBE plume at the Navy property boundary because biosparging relies on treated groundwater to migrate from the treatment area to the property boundary and the collection trench can achieve plume stabilization simply after achieving hydraulic control at the property boundary. More comparisons with Alternative 3 will be included in the effectiveness discussion of Section 6.3 in the next draft of the CAP.
	(b) The last paragraph under "Effectiveness" claims biosparging can "achieve cleanup in 1 to 2 years, which is inconsistent with Table 6-10, which says it will take 7 years; please rectify. Part of the problem is that the statement does not provide the cleanup goal to be achieved; please add this.	(b) Cleanup means achieving RAOs, which is expected, as stated, in about 1.5 years. RAOs and final cleanup goals are discussed and distinguished in Section 7.

Comment Number	Comment	Response
33	**Section 7.0.** Please address the remediation of the offsite portion of the MTBE plume north of the Navy property in this section.	Throughout the discussion of MNA in Section 7 of the Draft Proposed Final Revision 1.0 CAP, it is explicitly stated that MNA has been selected to reach background concentrations on the Navy portion of the site and on former HAAF property. Please refer to Section 7.2 on page 237 and Section 7.2.2 on page 246 for examples of how the remediation of former HAAF property is specifically addressed.
34	**Section 7.1.** (a). In the first paragraph, please state what the final cleanup levels are for MTBE and BTEX; see General Comment 3.	(a) Please refer to the response for general comment 3 on page 19.
	(b) In the second paragraph, please provide a definition for the term "specific observable concentration goals" or rephrase so the layperson can understand it.	(b) The requested change will be made. The text will be clarified in the next draft of the CAP.
35	**Section 7.2.** The next to last sentence in the first paragraph says institutional controls will be in place during the entire remediation process. However, the institutional controls will be part of the deeds that will not change hands and become effective until the property is transferred to the City for the Sale Parcel and NUSD for the PBC Parcels. It would seem to be more appropriate to refer to the Interim Site Control Plan for the initial remediation prior to transfer and then the institutional controls for ongoing remediation after transfers.	The proposed next to last sentence of Section 7.2 in the next revision of the CAP will read: "During remediation activities, investigative derived wastes will be managed as outlined in the Interim Site Control Plan (Battelle, 2001e). After the property is transferred, institutional controls will be in place to protect human health and the environment, and to allow the corrective action to progress without the interference of site operations on the property."
36	**Section 7.2.1.1.** Please include in the design section a description of the CPT investigation planned in order to locate the biosparging wells and include this in the project schedule. Also, please add a discussion on the site test mentioned in Section 6.2.2.4.2 and add it to the schedule.	Please refer to the responses to specific comments 28(c) and 29 on page 40.

Comment Number	Comment	Response
37	**Section 7.2.1.1.3.** Section 6.2.2.4.1 describes the two-phase approach to implementing the biosparging alternative but it is not discussed anywhere in this or other parts of Section 7. Please correct this by including a phasing discussion in Section 7.	The requested change will be made. The two-phase approach of biosparging system installation will be described in Section 7 of the next draft of the CAP using the following proposed text: "Preliminary design of the biosparging system calls for a barrier of sparge wells to be installed in proximity to the Navy property boundary (see Figure 7-1). The sparge wells within the barrier will be placed in a relatively narrow channel of more permeable soil deposits (see Section 4.1.2) to treat groundwater as it passes through the barrier, thereby allowing only treated groundwater that is being transported within the preferential flowpath to pass across the Navy property boundary. Sparge wells will also be within the areas of higher permeability, upgradient of the sparge barrier, to decrease the highest concentrations of MTBE and accelerate the remediation process. Approximately 40 sparge wells are planned for the initial installation phase. Additional sparge wells would be installed after the initial installation phase if routine biosparging system operation indicated performance goals might not be achieved within the anticipated time frame. The number of sparge wells that may be added is not known and would depend on how effectively the initial sparge wells performed. It is possible the initial sparge wells would prove to be very effective and that no additional wells would be necessary."
38	**Section 7.2.1.1.6.** Based on the well locations presented on Figure 7-1, it appears additional wells need to be installed close to, but downgradient, of the one well at the northern line of biosparging wells. These wells will provide more accurate indications of the MTBE levels leaving the Navy property. Please adjust the number and locations of the new groundwater monitoring wells.	The actual number and placement of monitoring wells will not be determined until the design phase of the chosen remedy; furthermore, these variables do not change the decision process of the CAP. The Navy will be responsible for specific design considerations and will prepare a more detailed Remedial Workplan once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
39	**Section 7.2.1.2.1.** In the second sentence, proper review of existing Navy utility plans, proper site clearance activities using USA Alert and/or geophysical methods should provide adequate clearance and enable bore holes to be installed without doing slow hand-augered starter holes. Please adjust the discussion accordingly.	To protect site workers from encountering any known or unknown underground utilities, the site health and safety plan (HASP) states that starter holes will be advanced at least 3 ft bgs using a hand auger prior to any drilling activities being performed at the site.
40	**Section 7.2.1.1.5.** The three shallow soil gas monitoring probes are all located near Buildings 930 and 931. However, Building 971 is much closer to the plume and active remediation area, and it may be occupied in the future. Therefore, please install an appropriate number of shallow soil gas probes adjacent to it for monitoring.	The requested change will be made. Shallow soil-gas monitoring probes between the treatment area and Building 971 will be added to the conceptual design of the remediation system (Figure 7-1), in the next draft of the CAP. A draft version of the updated Figure 7-1 is provided in Attachment 1.

Responses to Comments From Mr. James C. Davies Dated October 19, 2001 on Draft Proposed Final Revision 1.0, Corrective Action Plan for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, California (Continued)

Comment Number	Comment	Response
41	**Section 7.2.1.3.2.** Please add the sampling frequency for the deep and shallow soil gas monitoring probes and the groundwater monitoring wells during routine operations.	The Navy will be responsible for specific design considerations. A detailed Remedial Design Workplan will be prepared once a remedy has been agreed upon among the Navy, regulators, and stakeholders.
42	**Section 7.2.1.4.** (a). In the sixth paragraph, please define "a first order removal rate expression" or rephrase the term.	(a) The requested change will be made. The phrase will be clarified in the revised CAP.
	(b) In the last paragraph of this section, it is stated that once the MTBE plume is stable, benzene is below the RBSL and MTBE on Navy property is substantially reduced, the RAOs will be considered achieved. This statement is incorrect because the RAOs of the CAP should be changed to include actual achievement of the final cleanup levels (background concentrations). See Specific Comment 10.	(b) Please refer to the response to specific comment 10 on page 27.
43	**Section 7.2.1.5.** As discussed in Specific Comment 40, MTBE in soil gas may migrate towards and under Building 971, so please add one or two contingency SVE wells near it.	The requested change will be made. One or two SVE contingency wells between the treatment area and Building 971 will be added to the conceptual design of the remediation system (Figure 7-1), in the next draft of the CAP. A draft version of updated Figure 7-1 is provided in Attachment 1.
44	**Section 7.2.3.** This section provides restrictions and controls for the entire Site and the Sale Area. Please add a footnoted definition for the Site and one for the Sale Area (see Specific Comment 17).	The requested change will be made. Please see the response to specific comment 17 on page 30.
45	**Section 7.3.** The schedule presented in Table 7-4 should be revised into a bar or Gantt chart format for clarity and must include time for the CPT investigation, onsite test, and regulatory agency review and approval of all reports and plans.	The schedule will be modified into a bar chart format and include time for regulatory agency review and concurrence of all reports and plans.