AR TARGET SHEET

The following document was too large to scan as one unit, therefore it has been broken down into sections.

DOCUMENT # DOE/EIS-0189D

EDMC # 0043485

SECTION 3 **OF** 3

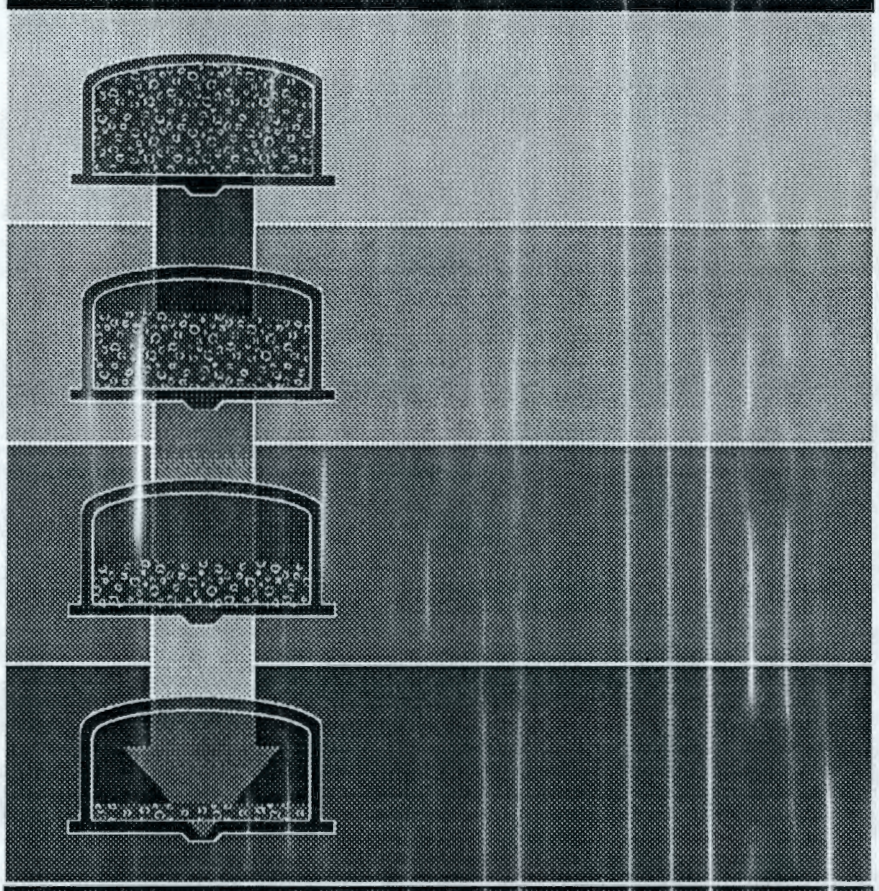
9613409.1356

0043485
5/6

DOE/EIS-0189D

Draft Environmental Impact Statement for the Tank Waste Remediation System

Volume Four



Appendix E: Risk from Accidents
Appendix F: Groundwater Modeling

Prepared by:

U.S. Department of Energy
and
Washington State Department of Ecology

April 1996

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS xvi

NAMES AND SYMBOLS FOR UNITS OF MEASURE AND RADIOACTIVITY xvii

E.1.0 INTRODUCTION AND METHODOLOGY E-1
E.1.1 RADIOLOGICAL LATENT CANCER FATALITY RISK AND CHEMICAL EXPOSURE E-13
E.1.1.1 Accident Identification E-14
E.1.1.2 Accident Scenario Selection E-14
E.1.1.3 Source Term and Direct Exposure E-26
E.1.1.3.1 Inventory E-27
E.1.1.4 Probabilities E-27
E.1.1.5 Receptor Locations E-28
E.1.1.6 Radiological Dose and Chemical Exposure Assessment E-29
E.1.1.7 Risk Development E-31
E.1.2 OCCUPATIONAL INJURIES, ILLNESSES, AND FATALITIES E-33
E.1.3 TRANSPORTATION FATALITIES AND INJURIES E-34
E.1.4 SEISMIC EVENT PRIOR TO OR DURNG REMEDIATION E-35
E.1.5 UNCERTAINTY E-35

E.2.0 NO ACTION ALTERNATIVE (TANK WASTE) E-36
E.2.1 TRANSPORTATION ACCIDENTS E-36
E.2.1.1 Radiological Cancer Risk E-36
E.2.1.2 Chemical Exposure E-36
E.2.1.3 Occupational Injuries and Fatalities E-37
E.2.2 OPERATION ACCIDENTS E-37
E.2.2.1 Continued Operations Accident E-37
E.2.2.1.1 Scenario and Source Term Development for Continued Operation Accident - Mispositioned Jumper E-40
E.2.2.1.2 Probability of Mispositioned Jumper E-40
E.2.2.1.3 Radiological Consequence from Mispositioned Jumper E-40
E.2.2.1.4 Radiological Cancer Risk from Mispositioned Jumper E-41
E.2.2.1.5 Chemical Consequences of Mispositioned Jumper E-41
E.2.2.2 Beyond Design Basis Accidents E-47
E.2.2.2.1 Scenario and Source Term Development for Hydrogen Burn in Waste Storage Tank E-47
E.2.2.2.2 Probability of Hydrogen Burn in Waste Storage Tank E-47

TABLE OF CONTENTS (cont'd)

E.2.2.2.3 Radiological Consequence from Hydrogen Burn in Waste Storage Tank E-47
E.2.2.2.4 Radiological Cancer Risk from Hydrogen Burn in Waste Storage Tank E-48
E.2.2.2.5 Chemical Consequences from Hydrogen Burn in Waste Storage E-48
E.2.2.3 Occupational Injuries and Fatalities from Operations E-55
E.2.3 POST-REMEDIATION ACCIDENT E-56

E.3.0 LONG-TERM MANAGEMENT ALTERNATIVE E-57
E.3.1 CONSTRUCTION ACCIDENTS E-57
E.3.2 TRANSPORTATION ACCIDENTS E-58
E.3.2.1 Radiological Cancer Risk E-58
E.3.2.2 Chemical Exposure E-58
E.3.2.3 Occupational Injuries and Fatalities E-58
E.3.3 OPERATION ACCIDENTS E-60
E.3.3.1 Continued Operations Accident E-60
E.3.3.2 Beyond Design Basis Accident E-62
E.3.3.3 Occupational Injuries and Fatalities from Operations E-64
E.3.4 POST-REMEDIATION ACCIDENT E-65

E.4.0 IN SITU FILL AND CAP ALTERNATIVE E-65
E.4.1 CONSTRUCTION ACCIDENTS E-65
E.4.2 TRANSPORTATION ACCIDENTS E-65
E.4.2.1 Radiological Cancer Risk E-66
E.4.2.2 Chemical Exposure E-66
E.4.2.3 Occupational Injuries and Fatalities E-66
E.4.3 OPERATION ACCIDENTS E-68
E.4.3.1 Continued Operation Accident E-69
E.4.3.2 Treatment Accident E-71
E.4.3.2.1 Scenario and Source-Term Development for Deflagration In Tank During Fill and Cap E-71
E.4.3.2.2 Probability of the Event E-73
E.4.3.2.3 Radiological Consequence for Tank Dome Collapse E-73
E.4.3.2.4 Radiological Cancer Risk for Tank Dome Collapse E-73
E.4.3.2.5 Chemical Consequences of Tank Dome Collapse E-74
E.4.3.2.6 Beyond Design Basis Accident E-76
E.4.3.2.7 Occupation Injuries, Illnesses, and Fatalities from Operations E-78
E.4.4 POST-REMEDIATION ACCIDENT E-78

9613409.1358

TABLE OF CONTENTS (cont'd)

E.4.4.1 Deflagration in Storage Tank E-78
E.4.4.2 Seismic Induced Rupture of Stabilized Tanks E-80

E.5.0 IN SITU VITRIFICATION ALTERNATIVE E-81
E.5.1 CONSTRUCTION ACCIDENTS E-81
E.5.2 TRANSPORTATION ACCIDENTS E-81
E.5.2.1 Radiological Cancer Risk E-82
E.5.2.2 Chemical Exposure E-82
E.5.2.3 Occupational Injuries and Fatalities E-83
E.5.3 OPERATION ACCIDENTS E-83
E.5.3.1 Continued Operation Accidents E-86
E.5.3.2 Treatment Accidents E-89
E.5.3.2.1 Scenario and Source Term Development for Off-Gas Rupture E-90
E.5.3.2.2 Probability of Off-Gas Duct Rupture E-90
E.5.3.2.3 Radiological Consequence of Off-Gas Duct Rupture E-90
E.5.3.2.4 Radiological Cancer Risk for Off-Gas Duct Rupture E-91
E.5.3.2.5 Chemical Consequences of Off-Gas Duct Rupture E-91
E.5.3.3 Beyond Design Basis Accidents E-97
E.5.3.4 Occupational Injuries and Fatalities from Operations E-99
E.5.4 POST-REMEDIATION ACCIDENT E-99
E.5.4.1 Deflagration in Storage Tank E-99
E.5.4.2 Seismic Induced Rupture of Stabilized Tanks E-99

E.6.0 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE E-100
E.6.1 CONSTRUCTION ACCIDENTS E-100
E.6.2 TRANSPORTATION ACCIDENTS E-100
E.6.2.1 Radiological Cancer Risk E-100
E.6.2.1.1 Truck Transport of Retrieved Tank Waste E-101
E.6.2.1.2 Rail Transport of Vitrified High-Level Waste E-102
E.6.2.2 Chemical Exposure E-102
E.6.2.3 Occupational Injuries and Fatalities E-103
E.6.3 Operation Accidents E-107
E.6.3.1 Routine Operation Accidents E-107
E.6.3.2 Retrieval Accidents E-113
E.6.3.2.1 Scenario and Source Term Development for Loss of Filtration E-113
E.6.3.2.2 Probability of Loss of Filtration E-114
E.6.3.2.3 Radiological Consequence from Loss of Filtration E-114
E.6.3.2.4 Radiological Cancer Risk from Loss of Filtration E-114

TABLE OF CONTENTS (cont'd)

E.6.3.2.5 Chemical Consequences from Loss of Filtration E-115
E.6.3.3 Pretreatment E-122
E.6.3.3.1 Scenario and Source Term Development for Seismic Induced Line Break in Vault E-122
E.6.3.3.2 Probability of Seismic Induced Line Break in Vault E-123
E.6.3.3.3 Radiological Consequences of Seismic Reduced Line Break in Vault E-123
E.6.3.3.4 Radiological Cancer Risk of Seismic Induced Line Break in Vault E-123
E.6.3.4 Treatment Accidents E-129
E.6.3.4.1 Source Term for Breached Canister E-129
E.6.3.4.2 Radiological Consequences of Immobilization Accident E-130
E.6.3.4.3 Probability of Breached Canister E-130
E.6.3.4.4 Radiological Cancer Risk of Breached Canister E-130
E.6.3.4.5 Chemical Consequences of Breached Canister E-130
E.6.3.5 Disposal/Storage Accidents E-130
E.6.3.6 Beyond Design Basis Accident E-131
E.6.3.7 Occupational Injuries and Fatalities E-133
E.6.4 POST-REMEDIATION ACCIDENT E-134
E.6.4.1 Deflagration in Storage Tank E-134
E.6.4.2 Seismic Induced Rupture of Stabilized Tanks E-134

E.7.0 EX SITU NO SEPARATIONS ALTERNATIVE E-134
E.7.1 CONSTRUCTION ACCIDENTS E-134
E.7.2 TRANSPORTATION ACCIDENTS E-135
E.7.2.1 Radiological Consequences E-135
E.7.2.1.1 Truck Transport of Retrieved Tank Waste E-135
E.7.2.1.2 Rail Transport of Vitrified High-Level Waste E-136
E.7.2.1.3 Chemical Consequences E-136
E.7.2.2 Occupational Injuries and Fatalities E-136
E.7.3 Operation Accidents E-141
E.7.3.1 Continued Operation - Mispositioned Jumper Accident E-141
E.7.3.2 Retrieval - Loss of Filtration Accident E-142
E.7.3.3 Treatment - Canister of Vitrified High-Level Waste Inadvertently Drops and Ruptures E-145
E.7.3.4 Beyond Design Basis Accident E-146
E.7.3.5 Occupation Injuries, Illnesses, and Fatalities from Operations E-148
E.7.4 CALCINATION SUBALTERNATIVE E-149
E.7.4.1 Transportation E-149
E.7.4.1.1 Radiological Consequences E-149

TABLE OF CONTENTS (cont'd)

E.7.4.1.2 Chemical Exposure E-150
E.7.4.1.3 Occupational Injuries and Fatalities E-150
E.7.5 POST-REMEDIATION ACCIDENT E-154
E.7.5.1 Deflagration in Storage Tank E-154
E.7.5.2 Seismic Induced Rupture of Stabilized Tanks E-154

E.8.0 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE E-154
E.8.1 CONSTRUCTION ACCIDENTS E-154
E.8.2 TRANSPORTATION ACCIDENTS E-155
E.8.2.1 Radiological Consequences E-155
E.8.2.1.1 Truck Transport of Retrieved Tank Waste E-155
E.8.2.1.2 Rail Transport of Vitrified High-Level Waste E-155
E.8.2.2 Chemical Exposure E-155
E.8.2.3 Occupational Injuries and Fatalities E-156
E.8.3 OPERATION ACCIDENTS E-160
E.8.3.1 Continued Operation Accident E-160
E.8.3.2 Retrieval Accidents E-162
E.8.3.3 Pretreatment Accidents E-164
E.8.3.4 Treatment Accidents E-166
E.8.3.5 Beyond Design Basis Accident E-167
E.8.4 OCCUPATION INJURIES, ILLNESSES, AND FATALITIES FROM OPERATIONS E-169
E.8.5 POST-REMEDIATION ACCIDENT E-170
E.8.5.1 Deflagration in Storage Tank E-170
E.8.5.2 Seismic Induced Rupture of Stabilized Tanks E-170

E.9.0 EX SITU/IN SITU COMBINATION ALTERNATIVE E-170
E.9.1 CONSTRUCTION ACCIDENTS E-170
E.9.2 TRANSPORTATION ACCIDENTS E-171
E.9.2.1 Radiological Consequences E-171
E.9.2.1.1 Truck Transport of Retrieved Tank Waste E-171
E.9.2.1.2 Rail Transport of Vitrified High-Level Waste E-172
E.9.2.2 Chemical Exposure E-172
E.9.2.3 Occupational Injuries and Fatalities E-173
E.9.3 OPERATION ACCIDENTS E-176
E.9.3.1 Routine Operation - Mispositioned Jumper Accident E-176
E.9.3.2 Retrieval - Loss of Filtration Accident E-178
E.9.3.3 Pretreatment - Seismic Induced Line Break in Vault E-180
E.9.3.4 Treatment (Ex Situ Vitrification) - Canister of Vitrified High-Level Waste Inadvertently Drops and Ruptures E-182

TABLE OF CONTENTS (cont'd)

E.9.3.5 Treatment - In Situ Fill and Cap E-183
E.9.3.5.1 Chemical Consequences of Tank Dome Collapse E-184
E.9.3.6 Beyond Design Basis Accident E-185
E.9.3.7 Occupation Injuries, Illnesses, and Fatalities from Operations E-188
E.9.4 POST-REMEDIATION ACCIDENT E-188
E.9.4.1 Deflagration in Storage Tank E-188
E.9.4.2 Seismic Induced Rupture of Stabilized Tanks E-189

E.10.0 PHASED IMPLEMENTATION ALTERNATIVE E-189
E.10.1 PHASE 1 . . . . . E-190
E.10.1.1 Construction Accidents E-190
E.10.1.2 Transportation Accidents E-190
E.10.1.2.1 Radiological Cancer Risk from Transportation E-191
E.10.1.2.2 Chemical Exposure from Transportation Accidents E-191
E.10.1.2.3 Occupational Injuries and Fatalities E-191
E.10.1.3.1 Continued Operation Accidents E-195
E.10.1.3.2 Pretreatment Accidents E-196
E.10.1.3.3 Treatment Accidents E-198
E.10.1.3.4 Disposal/Storage Accidents E-199
E.10.1.3.5 Beyond Design Basis Accident E-199
E.10.1.3.6 Occupational Injuries and Fatalities E-202
E.10.2 TOTAL ALTERNATIVE E-202
E.10.2.1 Construction Accidents E-202
E.10.2.2 Transportation Accidents E-202
E.10.2.2.1 Radiological Cancer Risk E-203
E.10.2.2.2 Chemical Exposure E-204
E.10.2.2.3 Occupational Injuries and Fatalities E-204
E.10.2.3 Operation Accidents E-207
E.10.2.3.1 Routine Operation Accidents E-207
E.10.2.3.2 Retrieval Accidents E-209
E.10.2.3.3 Pretreatment E-211
E.10.2.3.4 Treatment Accidents E-213
E.10.2.3.5 Disposal/Storage Accidents E-214
E.10.2.3.6 Beyond Design Basis Accident E-214
E.10.2.3.7 Occupational Injuries and Fatalities E-217
E.10.3 POST-REMEDIATION ACCIDENT E-217
E.10.3.1 Deflagration in Storage Tank E-217
E.10.3.2 Seismic Induced Rupture of Stabilized Tanks E-217

TABLE OF CONTENTS (cont'd)

E.11.0 NO ACTION ALTERNATIVE (CAPSULES) E-217
E.11.1 TRANSPORTATION ACCIDENTS E-217
E.11.2 OPERATION ACCIDENTS E-218
E.11.2.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility E-218
E.11.2.1.1 Scenario and Source Term Development for Pool Cell Storage Accident E-218
E.11.2.1.3 Radiological Consequence of Pool Cell Storage Accident . . E-218
E.11.2.1.5 Chemical Consequences for Pool Cell Accident E-221

E.12.0 ONSITE DISPOSAL ALTERNATIVE E-221
E.12.1 CONSTRUCTION ACCIDENTS E-221
E.12.2 TRANSPORTATION ACCIDENTS E-222
E.12.2.1 Radiological Cancer Risk E-222
E.12.2.2 Chemical Exposure E-222
E.12.2.3 Occupational Fatalities and Injuries E-222
E.12.3 OPERATION ACCIDENTS E-224
E.12.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility E-225
E.12.3.2 Overpacking and Dry-Well Disposal Accident E-225
E.12.3.2.1 Scenario and Source Term Development for Crushed Strontium Capsule E-227
E.12.3.2.2 Probability of Crushed Strontium Capsule E-228
E.12.3.2.3 Radiological Consequence from Crushed Strontium Capsule E-228
E.12.3.2.4 Radiological Cancer Risk from Crushed Strontium Capsule E-228
E.12.3.2.5 Chemical Consequences from Crushed Strontium Capsule E-228
E.12.3.3 Occupational Fatalities and Injuries E-229

E.13.0 OVERPACK AND SHIP ALTERNATIVE E-229
E.13.1 CONSTRUCTION ACCIDENTS E-230
E.13.2 TRANSPORTATION ACCIDENTS E-230
E.13.2.1 Radiological Cancer Risk E-230
E.13.2.2 Chemical Exposure E-231
E.13.2.3 Occupational Fatalities and Injuries E-231
E.13.3 OPERATION ACCIDENTS E-233

TABLE OF CONTENTS (cont'd)

E.13.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility . . . E-233
E.13.3.2 Overpacking Accident . . . E-233
E.13.3.3 Occupational Injuries and Fatalities . . . E-236

E.14.0 VITRIFY WITH TANK WASTE ALTERNATIVE . . . E-236
E.14.1 CONSTRUCTION ACCIDENTS . . . E-236
E.14.2 TRANSPORTATION ACCIDENTS . . . E-237
E.14.2.1 Radiological Cancer Risk . . . E-237
E.14.2.2 Chemical Exposure . . . E-237
E.14.2.3 Occupational Fatalities and Injuries . . . E-240
E.14.3 OPERATION ACCIDENTS . . . E-241
E.14.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility . . . E-241
E.14.3.2 Overpacking Accident . . . E-242
E.14.3.3 Vitrification Preparation Accident . . . E-244
E.14.3.3.1 Scenario and Source Term Development for Cesium Ion Exchange Column Explosion . . . E-244
E.14.3.3.2 Probability of Cesium Ion Exchange Column Explosion . . . E-246
E.14.3.3.3 Radiological Consequence from Cesium Ion Exchange Column Explosion . . . E-246
E.14.3.3.4 Radiological Cancer Risk from Cesium Ion Exchange Column Explosion . . . E-246
E.14.3.3.5 Chemical Consequences from Cesium Ion Exchange Column Explosion . . . E-247
E.14.3.4 Occupational Fatalities and Injuries . . . E-247

E.15.0 UNCERTAINTY . . . E-247

TABLES:

E.1.0.1 List of Evaluation Basis Accidents Analyzed in Accelerated Safety Analysis . . . E-4
E.1.0.2 Safe Storage Criteria . . . E-10
E.1.0.3 Summary of Operation Evaluation . . . E-11
E.1.1.1 Summary of Potential Tank Waste Accidents . . . E-15
E.1.1.2 Example Accident Screening Table . . . E-25
E.1.1.3 Frequency Category Definition . . . E-25
E.1.1.4 Qualitative Accident Severity Levels . . . E-26
E.1.2.1 DOE and Contractor Incidence Rates . . . E-34
E.1.3.1 Unit-Risk Factors for Fatalities and Injuries for Truck and Rail . . . E-34
E.2.2.1 Accident Screening Table for the No Action Alternative (Tank Waste) . . . E-38

9613409.1361

TABLE OF CONTENTS (cont'd)

E.5.2.4 Injuries/Fatalities Resulting from Truck and Rail Transportation Accidents for the In Situ Vitrification Alternative E-85
E.5.2.5 Cumulative Injuries and Fatalities from Traffic Impacts for the In Situ Vitrification Alternative E-85
E.5.3.1 Accident Screening Table for the In Situ Vitrification Alternative E-87
E.5.3.2 Dose Consequence from Mispositioned Jumper E-89
E.5.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper E-89
E.5.3.4 Dose Consequence for Off-Gas Duct Rupture E-90
E.5.3.5 Latent Cancer Fatality Risk from Off-Gas Duct Rupture E-91
E.5.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Off-Gas Duct Rupture E-92
E.5.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Off-Gas Duct Rupture E-95
E.5.3.8 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-97
E.5.3.9 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank E-98
E.6.2.1 Integrated Radiological Impact from Retrieval Transport Accidents E-101
E.6.2.2 MEI Radiological Impact from Retrieval Transport Accidents E-101
E.6.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository E-102
E.6.2.4 Chemical Releases from Postulated Accidents for the Ex Situ Intermediate Separations Alternative E-102
E.6.2.5 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Ex Situ Intermediate Sepa E-103
E.6.2.6 Summary of Transportation Activities for the Ex Situ Intermediate Separations Alternative E-104
E.6.2.7 Distance Traveled in Population Zones for the Ex Situ Intermediate Separations Alternative E-105
E.6.2.8 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ Intermediate Separations Alternative E-106
E.6.2.9 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ Intermediate Separations Alternative E-106
E.6.3.1 Accident Screening Table for the Ex Situ Intermediate Separations Alternative E-108
E.6.3.2 Dose Consequence from Mispositioned Jumper E-112
E.6.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper E-112
E.6.3.4 Dose Consequence from Loss of Filtration E-114
E.6.3.5 Latent Cancer Fatality Risk from Loss of Filtration E-115
E.6.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Loss of Filtration Accident E-116

TABLE OF CONTENTS (cont'd)

E.2.2.2 Dose Consequence from Mispositioned Jumper E-40
E.2.2.3 Latent Cancer Fatality Risk from Mispositioned Jumper E-41
E.2.2.4 Comparison of Chemical Concentrations to Toxic Concentration Limits for Mispositioned Jumper E-42
E.2.2.5 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Mispositioned Jumper E-45
E.2.2.6 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-47
E.2.2.7 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank E-48
E.2.2.8 Comparison of Chemical Concentrations to Toxic Concentration Limits for Hydrogen Burn in Waste Storage Tank E-49
E.2.2.9 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Hydrogen Burn in Waste Storage Tank E-53
E.3.2.1 Summary of Transportation Activities for the Long-Term Management Alternative E-59
E.3.2.2 Distance Traveled in Population Zones for the Long-Term Management Alternative E-59
E.3.2.3 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Long-Term Management Alternative E-59
E.3.2.4 Cumulative Injuries and Fatalities from Traffic Impacts for the Long-Term Management Alternative E-60
E.3.3.1 Dose Consequence from Mispositioned Jumper E-61
E.3.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper E-61
E.3.3.3 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-62
E.3.3.4 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank E-63
E.4.2.1 Summary of Transportation Activities for the In Situ Fill and Cap Alternative . . E-67
E.4.2.2 Distance Traveled in Population Zones for the In Situ Fill and Cap Alternative . E-67
E.4.2.3 Injuries and Fatalities Resulting from Truck Transportation Accidents for the In Situ Fill and Cap Alternative E-68
E.4.2.4 Cumulative Injuries and Fatalities from Traffic Impacts for the In Situ Fill and Cap Alternative E-68
E.4.3.1 Accident Screening Table for the In Situ Fill and Cap Alternative E-69
E.4.3.2 Dose Consequence from Mispositioned Jumper E-70
E.4.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper E-70
E.4.3.4 Dose Consequence for Tank Dome Collapse E-74
E.4.3.5 Latent Cancer Fatality Risk from Tank Dome Collapse E-74
E.4.3.6 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-76
E.4.3.7 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank E-77
E.5.2.1 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the In Situ Vitrification Alternative E-82
E.5.2.2 Summary of Transportation Activities for the In Situ Vitrification Alternative . . E-84
E.5.2.3 Distance Traveled in Population Zones for the In Situ Vitrification Alternative . . E-85

9613409.1362

TABLE OF CONTENTS (cont'd)

E.6.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Loss of Filtration Accident E-120
E.6.3.8 Dose Consequence for Seismic Reduced Line Break in Vault E-123
E.6.3.9 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault E-124
E.6.3.10 Comparison of Chemical Concentrations to Toxic Concentration Limits for Pretreatment Spray Release E-125
E.6.3.11 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Pretreatment Spray Release E-128
E.6.3.12 Dose Consequence for Breached Canister E-130
E.6.3.13 Latent Cancer Fatality Risk from Breached Canister E-131
E.6.3.14 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-132
E.6.3.15 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank . . . E-132
E.7.2.1 Integrated Radiological Impact from Retrieval Transport Accidents E-135
E.7.2.2 MEI Radiological Impact from Retrieval Transport Accidents E-135
E.7.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository E-136
E.7.2.4 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Ex Situ No Separations Alternatives E-137
E.7.2.5 Summary of Transportation Activities for the Ex Situ No Separations Alternative E-138
E.7.2.6 Distance Traveled in Population Zones for the Ex Situ No Separations Alternative E-139
E.7.2.7 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ No Separations Alternative E-140
E.7.2.8 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ No Separations Alternative E-140
E.7.3.1 Dose Consequence from Mispositioned Jumper E-141
E.7.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper E-142
E.7.3.3 Dose Consequence from Loss of Filtration E-143
E.7.3.4 Latent Cancer Fatality Risk from Loss of Filtration E-143
E.7.3.5 Dose Consequence from Breached Canister E-145
E.7.3.6 Latent Cancer Fatality Risk from Breached Canister E-146
E.7.3.7 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-147
E.7.3.8 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank E-147
E.7.4.1 Integrated Radiological Impact from Retrieval Transport Accidents E-149
E.7.4.2 MEI Radiological Impact from Retrieval Transport Accidents E-150
E.7.4.3 Radiological Impact from Transport Accidents While Transporting Calcined HLW to a Potential Geologic Repository E-150
E.7.4.4 Summary of Transportation Activities for the Ex Situ No Separations Alternative (Calcination) E-151

TABLE OF CONTENTS (cont'd)

E.7.4.5 Distance Traveled in Population Zones for the Calcination Subalternative E-153
E.7.4.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Calcination Subalternative E-153
E.7.4.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Calcination Subalternative E-154
E.8.2.1 Integrated Radiological Impact from Retrieval Transport Accidents E-156
E.8.2.2 Maximally-Exposed Individual Radiological Impact from Retrieval Transport Accidents E-156
E.8.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository E-156
E.8.2.4 Summary of Transportation Activities for the Ex Situ Extensive Separations Alternative E-157
E.8.2.5 Distance Traveled in Population Zones for the Ex Situ Extensive Separations Alternative E-159
E.8.2.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ Extensive Separations Alternative E-159
E.8.2.7 Cumulative Fatalities and Injuries from Traffic Impacts for the Ex Situ Extensive Separations Alternative E-160
E.8.3.1 Dose Consequence from Mispositioned Jumper E-161
E.8.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper E-161
E.8.3.3 Dose Consequence from Loss of Filtration E-163
E.8.3.4 Latent Cancer Fatality Risk from Loss of Filtration E-163
E.8.3.5 Dose Consequence from Seismic Induced Line Break in Vault E-165
E.8.3.6 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault E-165
E.8.3.7 Dose Consequence from Breached Canister E-166
E.8.3.8 Latent Cancer Fatality Risk from Breached Canister E-167
E.8.3.9 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-168
E.8.3.10 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank . . . E-168
E.9.2.1 Integrated Radiological Impact from Retrieval Transport Accidents E-171
E.9.2.2 Maximally-Exposed Individual Radiological Impact from Retrieval Transport Accidents E-172
E.9.2.3 Radiological Impact from Transport Accidents While Transporting Vitrified HLW to a Potential Geologic Repository E-172
E.9.2.4 Summary of Transportation Activities for the Ex Situ/In Situ Combination Alternative E-174
E.9.2.5 Distance Traveled in Population Zones for the Ex Situ/In Situ Combination Alternative E-175
E.9.2.6 Fatalities and Injuries Resulting from Truck and Rail Transportation Accidents for the Ex Situ/In Situ Combination Alternative E-176

TABLE OF CONTENTS (cont'd)

E.9.2.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ/In Situ Combination Alternative E-176
E.9.3.1 Dose Consequence from Mispositioned Jumper E-177
E.9.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper E-177
E.9.3.3 Dose Consequence from Loss of Filtration E-179
E.9.3.4 Latent Cancer Fatality Risk from Loss of Filtration E-179
E.9.3.5 Dose Consequence from Seismic Induced Line Break in Vault E-181
E.9.3.6 Latent Cancer Fatality Risk from Seismic-Induced Line Break in Vault E-181
E.9.3.7 Dose Consequence from Breached Canister E-182
E.9.3.8 Latent Cancer Fatality Risk from Breached Canister E-183
E.9.3.9 Dose Consequence from Tank Dome Collapse Due to Deflagration E-184
E.9.3.10 Latent Cancer Fatality Risk from Tank Dome Collapse Due to Deflagration . E-184
E.9.3.11 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-186
E.9.3.12 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank . . . E-186
E.10.1.1 Chemical Releases from Postulated Accidents for Phase 1 . . . . . E-192
E.10.1.2 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Phase 1 . . . . . E-192
E.10.1.3 Summary of Transportation Activities for Phase 1 . . . . . E-193
E.10.1.4 Distance Traveled in Population Zones for Phase 1 . . . . . E-194
E.10.1.5 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for Phase 1 . . . . . E-194
E.10.1.6 Cumulative Injuries and Fatalities from Traffic Impacts for Phase 1 . . . . . E-195
E.10.1.7 Dose Consequence from Mispositioned Jumper E-195
E.10.1.8 Latent Cancer Fatality Risk from Mispositioned Jumper E-196
E.10.1.9 Dose Consequence from Seismic Induced Line Break in Vault E-197
E.10.1.10 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault E-197
E.10.1.11 Dose Consequence from Crushed Cesium Canister E-198
E.10.1.12 Latent Cancer Fatality Risk from Crushed Cesium Canister E-199
E.10.1.13 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-200
E.10.1.14 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank . . E-200
E.10.2.1 Integrated Radiological Impact from Retrieval Transport Accidents E-203
E.10.2.2 Maximally Exposed Individual Radiological Impact from Retrieval Transport Accidents E-203
E.10.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository E-204
E.10.2.4 Summary of Transportation Activities for the Total Alternative E-205
E.10.2.5 Distance Traveled in Population Zones for the Total Alternative E-206
E.10.2.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Total Alternative E-207

TABLE OF CONTENTS (cont'd)

E.10.2.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Total Alternative E-207
E.10.2.8 Dose Consequence from Mispositioned Jumper E-208
E.10.2.9 Latent Cancer Fatality Risk from Mispositioned Jumper E-208
E.10.2.10 Dose Consequence for Loss of Filtration E-210
E.10.2.11 Latent Cancer Fatality Risk from Loss of Filtration E-210
E.10.2.12 Dose Consequence for Seismic Reduced Line Break in Vault E-212
E.10.2.13 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault E-212
E.10.2.14 Dose Consequence for Breached Canister E-213
E.10.2.15 Latent Cancer Fatality Risk from Breached Canister E-214
E.10.2.16 Dose Consequence from Hydrogen Burn in Waste Storage Tank E-215
E.10.2.17 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank . . E-215
E.11.2.1 Accident Screening Table for the No Action Alternative (Capsules) E-219
E.11.2.2 Dose Consequence for Pool Cell Storage Accident E-220
E.11.2.3 Latent Cancer Fatality Risk from Pool Cell Accident E-220
E.12.2.1 Integrated Radiological Impact from Accidents for the Onsite Dry Storage Alternative E-222
E.12.2.2 Maximum Individual Radiological Impact from Accidents for the Onsite Dry Storage Alternative E-222
E.12.2.3 Summary of Transportation Activities for the Onsite Disposal Alternative . . . E-223
E.12.2.4 Distance Traveled in Population Zones for the Onsite Disposal Alternative . . E-223
E.12.2.5 Injuries/Fatalities Resulting from Truck Accidents for the Onsite Disposal Alternative E-223
E.12.2.6 Cumulative Injuries and Fatalities from Traffic Impacts for the Onsite Disposal Alternative E-224
E.12.3.1 Accident Screening Table for the Onsite Disposal Alternative E-226
E.12.3.2 Dose Consequence for Pool Cell Storage Accident E-227
E.12.3.3 Latent Cancer Fatality Risk from Pool Cell Accident E-227
E.12.3.4 Dose Consequence from Crushed Strontium Capsule E-228
E.12.3.5 Latent Cancer Fatality Risk from Crushed Strontium Capsule E-229
E.13.2.1 Integrated Radiological Impact from Accidents for the Overpack and Ship Alternative E-230
E.13.2.2 Maximum Individual Radiological Impact from Accidents for the Overpack and Ship Alternative E-231
E.13.2.3 Summary of Transportation Activities for the Overpack and Ship Alternative E-231
E.13.2.4 Distance Traveled in Population Zones for the Overpack and Ship Alternative E-232
E.13.2.5 Injuries/Fatalities Resulting from Transportation Accidents for the Overpack and Ship Alternative E-232

9613409.1364

ACRONYMS AND ABBREVIATIONS

AIHA	American Industrial Hygiene Association
ARF	airborne release fraction
ARR	airborne release rate
ASA	accelerated safety analysis
AWF	aging waste facility
CEDE	committed effective dose equivalent
CES	Consensus Exposure Standard
DCRT	double-contained receiver tank
DOE	U.S. Department of Energy
DR	damage ratio
DST	double-shell tank
EBA	evaluation basis accident
EDE	effective dose equivalent
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERPG	emergency response planning guideline
FR	Federal Register
FY	fiscal year
HEHF	Hanford Environmental Health Foundation
HEPA	high-efficiency particulate air
HLW	high-level waste
IOSR	Interim Operational Safety Requirement
ISB	Interim Safety Basis
LAW	low-activity waste
LCF	latent cancer fatality
LFL	lower flammability limit
LPF	leak path factor
MAR	material at risk
MCNP	Monte Carlo Neutron Photon
MEI	maximally-exposed individual
MUST	miscellaneous underground storage tank
NCR	Nuclear Regulatory Commission
PNL	Pacific Northwest National Laboratory
RF	respirable fraction
SAR	Safety Analysis Report
SHMS	standard hydrogen monitoring systems
SpG	specific gravity
SSC	structure and component
SST	single-shell tank
TOC	total organic carbon

TABLE OF CONTENTS (cont'd)

E.13.2.6 Cumulative Injuries and Fatalities from Traffic Impacts for the Overpack and Ship Alternative E-232
E.13.3.1 Dose Consequence for Pool Cell Storage Accident E-234
E.13.3.2 Latent Cancer Fatality Risk from Pool Cell Accident E-234
E.13.3.3 Dose Consequence from Crushed Strontium Capsule E-235
E.13.3.4 Latent Cancer Fatality Risk from Crushed Strontium Capsule E-235
E.14.2.1 Integrated Radiological Impact from Accidents for the Vitrify with Tank Waste Alternative E-237
E.14.2.2 Maximum Individual Radiological Impact from Accidents for Vitrify with Tank Waste Alternative E-237
E.14.2.3 Radiological Impact from Transport Accident While Transporting Vitrified HLW to a National HLW Repository E-238
E.14.2.4 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Capsules Alternative E-239
E.14.2.5 Comparison of Exposed Chemical Concentrations to Concentration Limits for the Vitrify with Tank Waste Alternative E-239
E.14.2.6 Summary of Transportation Activities for the Vitrify with Tank Waste Alternative E-240
E.14.2.7 Distance Traveled in Population Zones for the Vitrify with Tank Waste Alternative E-240
E.14.2.8 Injuries and Fatalities Resulting from Truck Accidents for the Vitrify with Tank Waste Alternative E-240
E.14.2.9 Cumulative Injuries and Fatalities from Traffic Impacts for the Vitrify with Tank Waste Alternative E-241
E.14.3.1 Dose Consequence for Pool Cell Storage Accident E-242
E.14.3.2 Latent Cancer Fatality Risk from Pool Cell Accident E-243
E.14.3.3 Dose Consequence from Crushed Strontium Capsule E-243
E.14.3.4 Latent Cancer Fatality Risk from Crushed Strontium Capsule E-244
E.14.3.5 Accident Screening Table for the Vitrify with Tank Waste Alternative E-245
E.14.3.6 Dose Consequence from Cesium Ion Exchange Column Explosion E-246
E.14.3.7 Latent Cancer Fatality Risk from Cesium Ion Exchange Column Explosion . . E-246
E.15.0.1 Uncertainty Evaluation for Mispositioned Jumper - Common to All Tank Alternatives E-248
E.15.0.2 Uncertainty Evaluation for HLW Glass Transport Accident - Ex Situ Intermediate Separations Alternative E-248

REFERENCES E-249

9613409.1365

ACRONYMS AND ABBREVIATIONS (cont'd)

TWRS	Tank Waste Remediation System
ULD	unit liter dose
USQ	unreviewed safety question
WESF	Waste Encapsulation and Storage Facility
WHC	Westinghouse Hanford Company
X/Q	atmospheric dispersion coefficient

NAMES AND SYMBOLS FOR UNITS OF MEASURE AND RADIOACTIVITY

Length

cm	centimeter
ft	foot
in.	inch
km	kilometer
m	meter
mi	mile

Area

ac	acre
ft^2	square foot
ha	hectare
km^2	square kilometer
mi^2	square mile

Volume

cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Mass

g	gram
kg	kilogram
lb	pound
mg	milligram
mt	metric ton

Radioactivity

Ci	curie
mCi	millicurie (1.0E-03 Ci)
μCi	microcurie (1.0E-06 Ci)
nCi	nanocurie (1.0E-09 Ci)
pCi	picocurie (1.0E-12 Ci)

This page intentionally left blank.

9613409.1366

APPENDIX E
RISK FROM ACCIDENTS

E.1.0 INTRODUCTION AND METHODOLOGY

This appendix describes the current safety concerns associated with the tank waste and analyzes the potential accidents and associated potential health effects that could occur under the alternatives included in this Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS).

Current Tank Safety Issues

The 177 underground storage tanks and approximately 60 active and inactive miscellaneous underground storage tanks (MUSTS) included in the TWRS contain a wide variety of waste that has numerous safety concerns associated within their current condition. The principal safety issues associated with maintaining an adequate margin of safety for tank farm operations include flammable gas, noxious vapor, organic solvent, organic complexant, ferrocyanide, high-heat, criticality, and tank structural integrity. An accelerated safety analysis (ASA) is currently being developed that will more completely define the current hazards, provide a thorough accident analysis, and develop associated operational safety requirements (controls) that, when implemented, will provide an adequate safety margin for tank farm operations. A summary and status of the TWRS Safety Program, including current hazards and accident analysis, safety issues in progress, and the approach for their resolution is found in a document entitled TWRS Safety Basis (Lipke et al. 1995). The text from that document is presented nearly verbatium in the remaining paragraphs of Section E.1.0.

Historically, the Hanford Waste Tank Safety Program focused on resolving specific safety issues that were identified from a variety of sources. These issues include flammable gas, noxious vapor, organic solvent, organic complexant, ferrocyanide, high-heat, criticality, and tank structural integrity. The approach to evaluating waste tank safety concerns included developing a safety basis by applying safety analysis methodology. The TWRS ASA will provide the necessary documentation to define the safety margin for conducting safe tank farm operations.

The results from the ASA will demonstrate that the waste tanks can be safely managed with the appropriate controls as specified in the Interim Operational Safety Requirements (IOSRs). Continued characterization by sampling of the waste will be used to 1) further confirm the models of waste behavior used in the safety analysis; 2) reduce the uncertainty associated with the calculations; and 3) confirm the conservatism of the source term data used in the analysis. This additional characterization information will provide the basis for confirming, reducing, or eliminating controls presently in place through the IOSRs.

Safety Issues

Several tank farm safety issues have been previously identified and progress has been made to resolve and close these safety issues with the appropriate documentation and/or controls. The major safety issues are related to the potential for flammable-gas generation, storage, and release, organic solvent combustion reactions, exothermic ferrocyanide-nitrate reactions, deflagration associated with organic

complexants, criticality, high-heat generating waste, and tank structural integrity. Identifying and making progress toward resolving of these safety issues helped focus attention on the fact that the original safety basis for the Hanford Site waste tanks was lacking and that specific controls needed to be implemented to ensure that the health and safety of the public, workers, and environment were being adequately protected. Resolution of the remaining safety issues requires gathering information from laboratory energetics and waste degradation studies, assessing of existing sample data, evaluating historical data, and using various waste tank models to predict waste thermal behavior.

Safety Analysis

Developing the safe operating margin for the tanks system required integrating the current evolution of characterization data and understanding the safety issues to conservatively develop the safety basis for continued waste storage. An Interim Safety Basis (ISB) document was issued in November 1993 to establish the authorization basis for the tank farm facilities as part of implementing the U.S. Department of Energy (DOE) Order 5480.23, Nuclear Safety Analysis Reports. The ISB provided the basis for interim operations and controls until an upgraded Safety Analysis Report (SAR) for the tank farm facilities is completed.

Because of the importance of the safety issues associated with the Hanford Site waste tanks, a strategy was developed in mid fiscal year (FY) 1993 to accelerate the hazards and accident analyses for the waste tanks. Developing a full SAR that addressed each of the topics specified by the DOE order would follow, based on the completed hazards and accident analyses.

Application of Data to Determine Source Terms - Because of the variability of waste in the waste tanks, conservative assumptions were used to develop an upper bound for safe operations. Radiological and toxicological source terms were developed from a combination of theoretical models, recent characterization sampling, and historical sample data. Existing data were evaluated from all sources to determine representative and bounding source-term concentrations for radioactive isotopes and hazardous chemical species. Data from further waste characterization efforts will result in reducing the conservatism in the source-terms used in the ASA analysis.

Development of Safety Envelope - The safety analysis as documented in a SAR for a nuclear facility is intended to define an operating margin or envelope including necessary controls to ensure that the facility can be operated, maintained, shut down, and decommissioned safely in compliance with applicable laws and regulations. The ASA documents the hazards and accident analysis information that will be used in the upgraded Hanford Site tank farm SAR. The ASA systematically identifies facility hazards, selects accident scenarios, and evaluates credible accident scenarios analyzed for potential consequences. When the ASA is approved, the results of the hazards and accident analyses, in combination with the IOSRs, will define the facility's safety envelope. Selecting safety class equipment and performing unreviewed safety question (USQ) determinations will be based on this safety envelope. Results presented in the ASA indicate that the tank farms can be safely maintained within acceptable bounds using appropriate design features and controls.

The hazards analysis validated that the selection of accidents analyzed in the ASA was an appropriate spectrum of bounding and representation events, which are known as evaluation basis accidents (EBAs). The hazard evaluation process also provides a thorough qualitative evaluation of the spectrum of potential accidents involving identified hazards.

The hazards analysis considered a comprehensive range of potential process-related hazards as well as those hazards associated with internal and external events for all 177 waste tanks. The hazards analysis forms the basis for understanding facility worker protection, environmental protection, selecting or confirming potential EBAs to be further developed and quantified, and determining the facility hazard classification.

The analysis results of the selected EBAs provided the basis for developing controls needed for protecting the public and co-located workers. The unmitigated consequences and associated likelihood of the evaluation basis accidents were compared to the Hanford Site management and operating contractor's risk acceptance guidelines. If the unmitigated consequences and likelihoods exceeded the risk acceptance guidelines, appropriate design features, safety systems, structures and components (SSCs), or administrative controls were identified to reduce the consequence or frequency of the accidents to acceptable levels.

Each EBA was described in the following order:

- Accident scenario;
- Accident frequency;
- Radiological source term and unmitigated consequences;
- Toxicological source term and unmitigated consequences;
- Mitigated or prevented radiological consequences;
- Mitigated or prevented toxicological consequences; and
- SSCs, design features, or controls required to meet risk acceptance guidelines.

Table E.1.0.1 provides a list of the EBAs that were analyzed in the ASA and for which radiological and toxicological consequences were determined.

A primary purpose of the accident analysis is to identify whether SSCs, design features, or controls are required for preventing or mitigating postulated accidents. By including this information in the evaluation basis accidents documentation, safety functions that required consideration for the IOSRs were easily identified. The IOSRs included the definition of acceptable conditions, safe boundaries, basis thereof, and management or administrative controls required to ensure safe operation of the tank farms.

Operational Controls

The accident analysis of the ASA calculated the consequences for unmitigated accidents and identified a range for the accident sequence event frequencies. For each accident sequence, if the consequence and frequency were outside of the risk acceptance guidelines, additional physical and/or administrative

Table E.1.0.1 List of Evaluation Basis Accidents Analyzed in Accelerated Safety Analysis

Type of Accidents	Accelerated Safety Analysis Accident Name
Waste Storage Tank Accidents	Tank Dome Collapse
	SST Flammable Gas Headspace Deflagration
	DST/AWF Flammable Gas Headspace Deflagration
	DCRT Flammable Gas Headspace Deflagration
	Ferrocyanide Exothermic Propagating Reaction
	Organic Exothermic Pool Fire (in progress)
	Tank Bump
	Steam Release from Waste
	Pressurization from Steam Jet Pumping
	Criticality
Tank Ventilation Accidents	SST Passive Ventilation (90% Filtration)
	SST Passive Ventilation (0% Filtration)
	SST Passive Ventilation (Filter Blowout)
	SST Active Ventilation (90% Filtration)
	SST Active Ventilation (0% Filtration)
	SST Active Ventilation (Filter Blowout)
	DST Active Ventilation (90% Filtration)
	DST Active Ventilation (0% Filtration)
	DST Active Ventilation (Filter Blowout)
	AWF Active Ventilation (90% Filtration)
	AWF Active Ventilation (0% Filtration)
	AWF Active Ventilation (Filter Blowout)
Waste Transfer Accidents	Leak or Break from Single Encased Pipeline
	Spray Release from Waste Transfer System
	Pipeline Break from Excavation
204-AR Waste Handling Facility Accidents	Railcar Spill (with and without fire)
	Unfiltered Ventilation System Release from Catch Tank
	Local Combustible Material Fire Inside Building
	Sodium Hydroxide Spill
244-AR Vault Storage/Handling Accidents	Unfiltered Release from Vent Ventilation Stack
	Unfiltered Release from Canyon Exhaust Ventilation System
	Hydrogen Gas Deflagration Inside Storage Tanks During Passive Ventilation

Notes:
AWF = Aging waste facility
DCRT = Double-contained receiver tank
DST = Double-shell tank
SST = Single-shell tank

controls were established that would either prevent the postulated accident or reduce the calculated consequences or likelihood of the accident. The controls will be incorporated into the IOSRs (technical safety requirements when the SAR is completed) for the facility.

An example of the controls are those used for tanks containing flammable gases. The unmitigated consequences and associated likelihood of a flammable gas deflagration with a tank dome collapse were above the risk acceptance guidelines. Therefore, controls were developed to prevent a gas deflagration. The controls specifically addressed flammable gases accumulating within the tank vapor space, monitoring vapor space flammability concentrations, limiting or preventing ignition sources, and minimizing intrusive activities to reduce hazard exposure.

Safety Relationship with Characterization

The objective of safe waste storage and disposal requires that the waste tank characterization strategy be structured to provide priority support to addressing tank farm safety issues in the most efficient manner.

The Safety Program and characterization approach for resolving priority safety issues related to flammable gas, noxious vapor, organic solvent, organic complexant, ferrocyanide, high-heat generating waste, criticality, and tank structural integrity has been influenced by the progress made to date. The progress includes 1) completing safety analyses for flammable gas, ferrocyanide, criticality, organic solvent (tank 241-C-103), and sludge dry out; 2) successfully mitigating tank 241-SY-101 safety issues; 3) demonstrating actual and simulated waste energetics; 4) demonstrating waste degradation (aging resulting in lower energy products) in laboratory experiments and limited waste sampling for ferrocyanide and organics; 5) completing laboratory tests to define conditions required for condensed phase propagating reactions, and 6) developing an increased understanding of safety-related information that can be obtained from tank headspace sampling.

Safety Issues

The characterization approach for the safety issues continues to evolve as the parameters affecting safe storage and their relationship are better understood. In general, characterization demands are lessened as safety issues become better understood. This section reviews the current safety issues to ensure safe storage and examines the direction of future efforts.

The high-level waste (HLW) tank subcriticality safety assessment concluded that the waste in the Hanford Site waste tanks is in a form that is favorable to maintaining a large margin of subcriticality because of the small quantities of fissile material and the large amounts of neutron-absorbing materials.

The Characterization Program will continue to provide appropriate confirmatory sample data (e.g., fissile material, absorber content, and alkalinity information) as waste samples are obtained for other reasons.

High-heat tanks have been identified through temperature monitoring coupled with thermal analyses. However, only one tank, tank 241-C-106, has demonstrated any substantial high-heat load. This tank is scheduled for retrieval in late 1996. In the meantime, a chiller is being procured for this tank to mitigate potential risk that may be associated with leaks that might result from accelerated corrosion because of the increased temperature.

Waste tank structural integrity evaluations are being completed for all waste tanks. Structural and seismic evaluations are being completed, and the tank life expectancy is being determined for each tank.

Flammable Gases. Flammable gas species (mainly hydrogen and ammonia) are produced at low rates by radiochemical and thermochemical degradation reactions in waste. Vapor from organic solvents may also contribute to headspace flammability. While a mixture of gases may contain flammable constituents, a flammability hazard exists only if a minimum flammability concentration can be retained within the tank headspace (i.e., enough to exceed the minimum fuel concentration known as the lower flammability limit [LFL]). Otherwise, the gases will be dissipated to the atmosphere at concentrations too low to represent a flammability hazard.

For a flammable gas to ignite and burn, it must be mixed with an oxidizer (usually oxygen) and be provided sufficient energy to initiate the chemical reactions. A sufficiently dilute mixture of flammable gas (i.e., a concentration below the LFL) and oxidizer will not burn. The National Fire Protection Association recommends that processes be controlled so that flammable gas concentrations are less than 25 percent of the LFL. DOE requires that Hanford Site waste tanks be operated within National Fire Protection Association guidelines, therefore, management efforts must ensure that flammable gas levels are maintained below 25 percent of the LFL.

The flammable gas hazard can be classified according to the mode by which the flammable gases are released from the waste. For a steady-state gas release, gases are released at approximately the rate at which they are formed, and the concern is an accumulation of flammable gases in the tank headspace (i.e., a steady-state flammability hazard). For a limited number of tanks, gases are released episodically at comparatively high rates. For these episodic releases, flammable gas concentrations could and have exceeded 25 percent of the LFL for brief time periods. The LFL has been exceeded several times by tank SY-101 (more than 100 percent of the LFL has been attained on occasion) and at least once by tank AN-105. Forty-seven Hanford Site waste tanks are on a flammable gas Watchlist because the waste in these tanks is believed to have the potential to retain hydrogen gas until appreciable quantities are released. Monitors have been installed on these tanks and access controls have been imposed to minimize the potential hazard.

Steady-State Release of Flammable Gases. All DSTs are actively ventilated, and air exchange is rapid enough (except during an episodic release) to keep steady-state bulk hydrogen concentrations in the headspace well below 25 percent of the LFL. However, most SSTs are passively ventilated and only exchange air with the environment by relatively slow barometric pressure changes and instrument air

purges. Therefore, potential accumulation of flammable gases in the headspace and risers of all SSTs has been explored.

Preliminary studies have examined the accumulation of flammable gases in the headspace and risers of SSTs that are not on the flammable gas Watchlist. A more detailed study on flammable gas accumulation is currently being developed. However, calculations performed thus far show that gas production and release rates from thermochemical and radiochemical processes are modest and that passive ventilation alone will keep the headspace well below 25 percent of the LFL. The contribution to the flammable gas mixture from organic solvent vapor is low because the bulk of organic solvent remaining in any tank would likely have a low vapor pressure. Sampling data from tank 241-C-103, which contains a floating organic layer, support this conclusion. Vapors from the organic solvent amount to less than 5 percent of the LFL.

Episodic Release of Flammable Gases. The ability of waste to retain large amounts of gas depends on its physical properties and chemical/radiological composition. The waste retains gases that increase the waste volume (slurry growth) until the gases escape. Slurry gas is only present in tank headspace at high concentrations when it is released by the waste, therefore, the most direct way to characterize gas may be to sample the waste directly.

The amount of gas retained in the waste will be estimated from analyzing the tank operational data. Tank monitoring data include changes in surface level (resulting from gas release events and changes in atmospheric pressure) and axial waste temperature profiles. New, more accurate level gages and instrument trees (that measure temperature) are being installed in Hanford Site waste tanks. In addition, standard hydrogen monitoring systems (SHMS) are also being installed on all flammable gas Watchlist tanks.

Near-Term Characterization of Flammable Gas. Sampling and/or continuous monitoring is being used to confirm that flammable gas does not accumulate in the SSTs. Headspace sampling results from 30 SSTs (none of which are on the flammable gas Watchlist) indicate that flammability in the headspace and risers is well below 25 percent of the LFL. Headspace sampling of passively ventilated SSTs for flammable gases will continue until all are sampled. None of these tanks are expected to contain steady-state flammable gas concentrations above 25 percent of the LFL. However, if concentrations greater than 25 percent of the LFL are measured for non-Watchlist tanks, then these tanks would become candidates for continuous gas monitoring and potential mitigation.

The headspace of tanks that are suspected of having waste that releases flammable gases episodically will be continuously monitored for flammable gases. SHMS have been designed, built, and installed on all flammable gas Watchlist tanks. Standard hydrogen monitoring systems contain instrumentation that support an online hydrogen detector and a gas grab sampler.

Future Characterization of Flammable Gases. Two techniques that are being developed to directly characterize waste for retained gas are 1) a void meter to measure the volume fraction of the gas phase in the waste, and 2) a retained gas sampling system to extract a waste sample from a tank so that the waste can be analyzed (gas can exist as a distinct phase in the waste, and it can also be absorbed on solid or dissolved in aqueous liquid phases). In the near future ammonia monitoring capability will be added to the SHMS. Another system is being developed for in situ measurement of physical properties (density, viscosity, shear strength) that are critical to evaluating stored gas. Development of these systems is underway.

Noxious Vapors

Several health and safety issues are related to noxious vapors that may be present in some of the HLW tanks at the Hanford Site. A tank-by-tank sampling approach is being pursued to resolve headspace issues dealing with flammability and noxious vapors. Vapor sampling will be conducted on all tanks in the Tank Farm Complex.

Modeling and vapor data from tank 241-C-103 indicate that the tank head space is well mixed except during an episodic gas release. To verify that the headspace is well mixed, additional headspace sampling at different vertical and horizontal locations will be conducted in selected tanks.

If any compounds are detected inside a tank dome with toxicological properties that exceed their respective trigger points, Westinghouse Hanford Company (WHC) Industrial Hygiene is advised that gases with toxicological concern are present in the tank headspace. The trigger point has been defined as 50 percent of the appropriate Consensus Exposure Standard (CES) concentration for all analyses of interest. A CES, which is generally defined as the most stringent of known regulatory or recommended toxicological values for the occupational setting, includes the threshold limit value, permissible exposure limit, recommended exposure limit, and biological exposure limit.

The data required to assess toxicity include 1) identifying chemical compounds in the tank headspace of concern for worker health and safety or toxicological importance; 2) estimating the concentrations of these toxicologically substantial compounds in the headspace; and 3) understanding the toxicological effects of these compounds and the CES for each constituent of concern.

Organic Solvents

Various separation processes involving organic solvents have been used at the Hanford Site. These organic solvents were inadvertently and/or purposely sent to the underground storage tanks, and subsequent waste transfer operations distributed organic solvents among several of the 177 HLW tanks. The potential hazards associated with organic solvent are 1) contributing to headspace flammability (as discussed previously); 2) igniting an organic solvent pool; and 3) igniting an organic solvent that is entrained in waste solids.

Currently, one tank (241-C-103) is known to contain an organic solvent pool. Additional tanks that may contain an organic solvent pool will be identified through continued vapor sampling of the tank

headspace. Analyses have shown that solvent pool fires are difficult to initiate. Waste that may contain entrained organic solvent will also be identified through vapor sampling of the tank headspace. These analyses have been integrated into the noxious vapor sampling campaign. If vapor sampling suggests the presence of organic solvent, liquid grab samples and/or near-surface samples will be obtained to better quantify the potential for an organic solvent fire.

Fuel-Nitrate (Condensed-Phase) Reactions

Organic complexants and ferrocyanide were sent to the tanks. These compounds have the potential to act as a fuel when combined with an oxidizer. Nitrate salts have also precipitated in the tanks and are potential oxidizer sources. For the organic complexant (nonvolatile materials) and ferrocyanide safety issues, the approach to safety characterization is based on the fact that propagating reactions cannot occur if either the fuel, oxidizer, or potential initiators (e.g., temperature or energy) are controlled. Because specific limits of fuel, oxidizer, and initiators must be satisfied for a propagating chemical reaction to occur, waste can be stored safely if the conditions for the reaction are not possible. Therefore, the approach for obtaining characterization information is to obtain data that would confirm that one of the conditions of fuel or oxidizer is not present in sufficient quantities or that initiators are absent or can be controlled.

An important parameter in controlling propagating reactions is an inhibitor such as moisture. In sufficient quantity, moisture will prevent propagating reactions by 1) behaving as an inert diluent (lowering the effective fuel concentration); 2) preventing initiation of a propagating reaction (the energy from most credible initiators would be absorbed by the sensible and latent heat of the moisture before the waste reached the critical initiation temperature); and 3) providing a large heat sink that inhibits propagation (for a reaction to propagate, enough energy must be supplied to overcome the sensible and latent heat of the moisture present).

Fuel and Moisture Criteria - Experiments have shown that moisture can prevent condensed-phase propagating reactions. Tube propagation tests on waste simulants have shown that propagating reactions cannot occur in waste simulants containing more than 20 weight percent moisture. Sufficient moisture content can ensure that a propagating reaction will not occur, regardless of the fuel-oxidizer concentration. For example, if adequate moisture can be confirmed through monitoring, analysis, or sampling, then it can be concluded that condensed-phase exothermic reactions will not occur, thus ensuring interim safety waste storage.

The minimum required fuel concentration has been determined using a contact temperature ignition model. A necessary (but not sufficient) condition for a condensed-phased propagating chemical reaction is that the fuel concentration be greater than 4.5 weight percent total organic carbon (TOC), based on sodium acetate as fuel, or 1,200 joule/gram (J/g) on an energy equivalent basis. For fuel concentrations between 1,200 and 2,100 J/g, the waste moisture content required to prevent a propagating reaction varies linearly from 0 to 20 weight percent. Above 20 weight percent moisture, the fuel-moisture linear relationship no longer holds because the mixture become a continuous liquid

phase, effectively preventing propagating reactions. Note that the TOC criteria depends on the chemical concentration of the waste. Table E.1.0.2 summarizes the criteria for safe storage.

Table E.1.0.2 Safe Storage Criteria

Parameter	Criteria
Fuel concentration	< 1200 J/g
Total organic carbon concentration	< 4.5 weight percent
Moisture concentration	≥ 0.022 (Fuel [in J/g] - 1200) weight percent or >20 weight percent

Parameters Affecting Fuel Concentration - Waste tank operations have affected fuel concentration in the tanks. Experiments on waste simulants have shown that the high-energy organic complexants (i.e., the organic salts that could support a propagating reaction) are highly soluble in the tank supernatant solutions. Subsequent pumping of the tank liquid might have removed most of the organic complexant fuels.

Ferrocyanide waste stored in Hanford Site tanks has been exposed to caustic solutions and radiation for nearly 40 years. Long-term degradation (aging) of ferrocyanide is known to have occurred through chemical and radiolytic processes in the waste. Analyses of core samples taken from six of the 18 ferrocyanide tanks reveal fuel values about an order of magnitude less than the original flowsheet concentrations. These remaining fuel values are well below the concentration of concern. Experimental work at Georgia Tech and Pacific Northwest National Laboratory (PNL) has demonstrated that complexants and other organics degrade under radiation and/or chemical oxidation conditions found in tanks. In addition, analysis of the original tank 101-SY core sample complexant waste demonstrated extensive chemical degradation products.

Near-Term Characterization of the Condensed Phase - Current characterization efforts are focused on testing tank waste samples to confirm that the criteria shown in Table E.1.0.2 are conservative for actual waste. That is, if the waste meets the energy (fuel value), TOC, or moisture criterion, then the waste will not support a propagating reaction. Waste from selected tanks will be tested for reaction propagation in the same type of adiabatic calorimeter (the reactive system screening tool) that was used to develop the criteria.

Near-term sampling efforts are also focused on confirming degradation of ferrocyanide and organic complexant waste. Full-depth core samples from ferrocyanide tanks will be analyzed for fuel, nickel (a signature analyte of the sodium nickel ferrocyanide scavenging campaign), and total cyanide to confirm ferrocyanide aging. Full-depth core samples for organic complexant tanks will be analyzed for organic species to confirm that organic complexants have degraded to less energetic species. In addition, liquid and solid samples from organic complexant tanks will be analyzed to confirm the laboratory demonstration that high-energy organic complexants are soluble.

Reaction Ignition

Credible Ignition Sources - If the waste has a sufficiently high fuel and low moisture content, a propagating reaction could be initiated if an energy source raised the temperature of the waste to the reaction initiation temperature. The potential for tank farm equipment and operations to initiate propagating reactions has been evaluated and is summarized in Table E.1.0.3. In this evaluation, all credible initiators would be located near the waste surface, with the exception of rotary-core drilling incidents and lightning.

Table E.1.0.3 Summary of Operation Evaluation

Operation	Incident Conditions	Location of Heating	Heating Potential
In-tank instrumentation	Electrical overcurrent	Waste surface	<1 J
Still-camera photography	Dropping flash unit onto the waste surface, hot filament contacts waste	Waste surface	<70 J
Video camera	Dropping light unit onto the waste surface, hot filament contacts waste	Waste surface	<70 J
Rotary-core sampling	Loss of bit cooling and failure to shut down drill sampler causes frictional heating	Bit/waste interface	<66 °C
Vehicle operation above a tank	Rupture of fuel tank on aboveground equipment, fuel leakage into tank, subsequent fire	Waste surface	High
Welding or grinding	Hot slag/sparks contact waste	Waste surface	<100 J
Lightning strikes	Lightning strike on or near a tank or equipment causes lightning current to reach the waste	Arc to waste surface or from immersed object to waste below the surface	>1 MJ

Notes:
C = Centigrade
J = Joule
MJ = Megajoule

Although rotary-core drilling incidents and lightning strikes cannot be deemed incredible initiating events, the risk can be mitigated with controls. The rotary-core driller is designed with safety interlocks that limit increases in drill bit temperature. Ignition from lightning strikes can be prevented by appropriate grounding. The need to further ground the SSTs is being studied because of their unique construction.

The TWRS Safety Program is currently establishing the requirements for analytical data to confirm the models used in the safety analysis and the conservatism of the source-term. This additional characterization information will provide the basis for conforming, adjusting, or eliminating controls at Hanford Site waste tanks to ensure adequate protection of the workers, public, and the environment.

Criticality

Based on new information available to DOE, regarding nuclear criticality safety concerns during retrieval, transfer, and storage actions since the issuance of the Final SIS EIS, DOE has decided to defer a decision on the construction and operation of a retrieval system in tank 102-SY. Through an ongoing safety evaluation process, DOE recently revisited its operational assumptions regarding the potential for the occurrence of a nuclear criticality event during waste storage and transfers. Changes to the Tank Farm Authorization Basis for Criticality that were approved in September 1995 were rescinded by DOE in October 1995, pending the outcome of a criticality safety evaluation process outlined for the Defense Nuclear Facility Safety Board on November 8, 1995. Until these criticality safety evaluations are completed, the Hanford Site will operate under the historic limits, which maintain reasonable insurance of subcritical conditions during tank farm storage and transfer operations. Of the actions evaluated in the Final SIS EIS, only the retrieval of solids from tank 102-SY was affected by the technical uncertainties regarding criticality. Based on the quantities of plutonium in tank 102-SY sludge, retrieval of the solids falls within the scope of the criticality safety issues that will be evaluated over the next few months. As a result, a decision on retrieval of solids from tank 102-SY was deferred in the SIS EIS ROD. Also, pending the outcome of the technical initiative to resolve the tank waste criticality safety issue, transfers of waste (primarily saltwell liquid) through tank 102-SY will be limited to noncomplexed waste. Tank 101-SY mixer pump operations, interim operations of the existing cross-site transfer system, operation of the replacement cross-site transfer system, saltwell liquid retrievals, and 200 West Area facility waste generation all would occur within the applicable criticality limits and would be subcritical.

The remainder of this document analyzes potential accidents and the related consequences that could occur from implementing the alternatives addressed in this EIS.

Risk from Remediation Accidents

Accidents are unplanned events or a sequence of events that cause undesirable consequences. The risk associated with an accident is defined as the product of the probability of an accident occurring and the consequences of the accident. This includes nonradiological injuries, illnesses, and fatalities from construction, operations, or transportation accidents. Risk is also defined as the probability or the number of latent cancer fatalities from radiological or toxicological releases, given the occurrence and consequences of an accident. This analysis considers both types of risk.

An analysis was performed to determine the nonradiological and nontoxicological risks from construction, operations, and transportation. These are called occupational risks and include personal injuries, illnesses, and fatalities common to the work place such as falls, cuts, and operator-machine impacts.

An analysis was also performed to determine the potential for radiological and toxocological impacts. The results of the analyses are summarized in the following subsections. More detailed information concerning the methodology, supporting data, and assumptions for the basis of the analysis is contained in this appendix.

The alternatives, as described in Appendix B, include the following:

Tank Waste

No Action alternative
Long-Term Management alternative
In Situ Fill and Cap alternative
In Situ Vitrification alternative
Ex Situ Intermediate Separations alternative
Ex Situ No Separations alternative
Ex Situ Extensive Separations alternative
Ex Situ/In Situ Combination alternative
Phased Implementation

Cesium (Cs) and Strontium (Sr) Capsules

No Action alternative
Onsite Disposal alternative
Overpack and Ship alternative
Vitrify with Tank Waste alternative

The methodology used to identify and quantify the radiological cancer risks, chemical exposures, occupational injuries, illnesses and fatalities, and transportation risks from postulated accidents are discussed in this section.

E.1.1 RADIOLOGICAL LATENT CANCER FATALITY RISK AND CHEMICAL EXPOSURE

The radiological LCF risk and chemical exposure to humans from accidents was performed using the following steps:

- Identify the spectrum of potential accidents associated with each alternative (Section E.1.1.1, Accident Identification);
- Select the dominant (highest potential risk) accidents for risk analysis (Section E.1.1.2, Accident Scenario Selection);
- Determine the radiological and chemical inventories potentially released in the accidents (Section E.1.1.3, Source Term and Direct Exposure);
- Calculate the probability of occurrence of the potential accident (Section E.1.1.4, Probabilities);
- Determine the location of the worker, noninvolved worker, and general public (receptors) relative to the point of release of the waste material (Section E.1.1.5, Receptor Locations);
- Determine the radiological dose and chemical exposure to the worker, noninvolved worker, and general public at the location of the receptor (Section E.1.1.6, Radiological Dose and Chemical Exposure Assessment); and
- Calculate the LCF risk and compare the chemical exposure to concentration limits (Section E.1.1.7, Risk Development).

The following subsections discuss these steps in detail.

E.1.1.1 Accident Identification

A hazard is an inherent physical or chemical characteristic that has the potential for causing harm. The potential release of high-level radioactive waste to the environment from the tank farms and processing facilities that are included in the various alternatives is of concern to DOE, Hanford Site workers, and the public. Initiating events that could result in such a release include natural phenomena, human error, component failure, and spontaneous reactions.

Accidents are unplanned events or a sequence of events that result in undesirable consequences. The first step in the analysis was to identify the spectrum of potential accidents associated with construction, transportation, and operation activities involved in each TWRS EIS alternative. Construction activities include potential occupational accidents. Transportation activities include potential radiological, toxicological, and occupational accidents. Operation activities include potential radiological, toxicological, and occupational accidents.

The compilation of potential accident scenarios for tank farms, waste transfer facilities, pretreatment facilities, and processing facilities for each alternative is contained in the accident data package (Shire et al. 1995). This accident data package was prepared specifically to support the TWRS EIS. The spectrum of potential accidents identified in the data package are summarized in Table E.1.1.1.

Each alternative was divided into six components as applicable: continued operations (C), retrieval (R), pretreatment (separations of HLW from LAW) (P), treatment or immobilization (I), transportation (T), and disposal (D). A determination was then made whether each potential accident could occur during each component for each alternative. Not all alternatives involve every component. For example, there is no treatment component for the No Action alternative. In addition, not every potential accident can occur in a particular component for every alternative. For instance a dropped canister filled with vitrified HLW could only happen during treatment in the Ex Situ Vitrification alternatives. In Table E.1.1.1, an "x" indicates that the accident is applicable to the component for the identified alternative.

Each potential accident in Table E.1.1.1 is coded with a multi-digit number corresponding to the subsection in which it was found in the accident data package (Shire et al. 1995). A more detailed description of these accidents is provided in the referenced sections in the data package.

E.1.1.2 Accident Scenario Selection

After the potential accidents were identified, accidents with highest risks for each general waste-handling activity were screened and analyzed in further detail.

Screening for the highest risk accidents involved listing all the potential accidents from Table E.1.1.1 on an accident screening table. Table E.1.1.2 is an example of a screening table. The table identifies the broad range of potential accidents and assigns calculated or estimated risk (frequency of the event times the consequences) of each accident. The potential hazards were grouped according to the mode

9613409.1373

Table E.1.1.1 Summary of Potential Tank Waste Accidents

Postulated Accidents	No Action and Long-Term Management						In Situ Vitrification						In Situ Fill and Cap						Ex Situ/In Situ Combination					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
Waste Transfer Operations																								
4.1.1 Submersible pump - SST single-encased pipe leak on soil	X																							
4.1.2 Saltwell pump - SST single-encased pipe leak on soil	X																							
4.1.3 Saltwell pump - 80 psi SST spray release	X						X						X						X					
4.1.4 DCRT pump - 207 psi SST spray release	X						X						X						X					
4.1.5 DCRT pump - 207 psi DST spray release	X						X						X						X					
4.1.6 Saltwell pump - 80 psi SST spray release, cover off	X						X						X						X					
4.1.7 DCRT pump - 207 psi SST spray release, cover off	X						X						X						X					
4.1.8 DCRT pump - 207 psi DST spray release, cover off	X						X						X						X					
4.1.9 Excavation induced AWF double-encased pipe rupture	X						X						X						X					
4.1.10 Excavation induced DST double-encased pipe rupture	X						X						X						X					
4.1.11 Excavation induced cross-site transfer line rupture	X						X						X						X					
4.1.12 Spray release in cross-site transfer line	X						X						X						X					
4.1.11 Jacobs 1996 Seismic induced cross-site transfer line rupture		X						X												X				
Evaporator Operations																								
4.2.1 Underground slurry - line leak during emergency dump	X						X						X						X		X			
4.2.2 Spray release in pumproom with filtration	X						X						X						X		X			
4.2.3 Spray release in pumproom with filter damage	X						X						X						X		X			

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	No Action and Long-Term Management						In Situ Vitrification						In Situ Fill and Cap						Ex situ/In Situ Combination					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
4.2.4 Excavation induced underground slurry leak	X						X						X						X		X			
4.2.5 Red oil fire/deflagration	X						X						X						X		X			
4.2.6 Organics fire/deflagration	X						X						X						X		X			
4.2.7 Second-phase organics fire/deflagration	X						X						X						X		X			
4.2.8 Earthquake induced loss of confinement	X						X						X						X		X			
4.2.9 Evaporator release of ammonia	X						X						X						X		X			
Tank Waste Retrieval Operations - Mechanical Retrieval																								
4.3.1.1 Tank dome collapse due to overload																				X				
4.3.1.2 Ferrocyanide reaction																				X				
4.3.1.3 Criticality																				X				
4.3.1.4 Hydrogen burn																				X				
4.3.1.5 Seismic induced break in recirculation duct																				X				
4.3.1.6 Container loading spill																				X				
4.3.1.7 SST steam release																				X				
4.3.1.8 SST leak to soil column																				X				
Tank Waste Retrieval Operations - Hydraulic Retrieval																								
4.3.2.1 Tank dome collapse due to overload																				X				
4.3.2.2 Pressurized spray leak at slurry pump outlet																				X				

9613409.1374

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	No Action and Long-Term Management						In Situ Vitrification						In Situ Fill and Cap						Ex Situ/In Situ Combination					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
4.3.2.3 Pressurized spray leak at supernate/sluice inlet																				X				
4.3.2.4 Seismic rupture of slurry pump outlet waste transfer line																				X				
4.3.2.5 Seismic rupture of supernate pump inlet waste transfer line																				X				
4.3.2.6 Seismic rupture of ventilation recirculation duct																				X				
4.3.2.7 Slurry spill																				X				
4.3.2.8 SST steam release																				X				
4.3.2.10 SST leak to soil column																				X				
4.3.2.11 Ferrocyanide reaction																				X				
4.3.2.12 Criticality																				X				
4.3.2.13 Hydrogen burn										X										X				
4.3.2.14 Pressurized spray release																				X				
In Situ Vitrification																								
4.4.4.1 Confinement collapse due to dropped machine										X														
4.4.4.2 Dropped electrode										X														
4.4.4.3 Rupture off-gas duct										X														
4.4.4.4 Earthquake ruptures confinement										X														
4.4.4.5 Flammable gas burps										X														
4.4.4.6 Steam explosion during melt process										X														

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	No Action and Long-Term Management						In Situ Vitrification						In Situ Fill and Cap						Ex Situ/In Situ Combination					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
4.4.4.7 Organics reaction										X						X								
Waste Staging and Sampling Facility																								
4.5.1.1.1 DBE between tank farm and separations facilities and WESF																					X			
4.5.1.1.2 DBE pressurized spray release																					X			
Separations Facility																								
4.5.2.1 Processing tank spill																					X			
4.5.2.2 Cs ion exchange column explosion																					X			
Low-Level Waste Vitrification Facility																								
4.5.3.1 DBA																						X		
4.5.3.2 Kerosene/oxygen line rupture during normal operations																						X		
4.5.3.3 Dicyclopentadiene/cyclopentadiene fire																						X		
High-Level Waste Vitrification Facility																								
4.5.4.1 DBA																						X		
4.5.4.2 Hydrogen deflagration in melter feed adjustment tank																						X		
4.5.4.4 Canister drop																						X		
4.5.4.5 Canister storage cask breach																						X		
Low-Level Waste Onsite Permanent Repository Operation																								
4.7.1 Breach of LAW container																								X

9613409.1375

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	No Action and Long-Term Management						In Situ Vitrification						In Situ Fill and Cap						Ex Situ/In Situ Combination					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
Toxicological Accidents																								
5.1 Evaporator release of ammonia	X								X												X			
5.2 Sulfur deflagration																						X		
Breach of Cold-Chemical Tank																								
5.3.1 Ammonia tank and supply line rupture																						X		
5.3.2 Formic acid tank breach																						X		
5.3.3 Nitric acid tank breach																						X		
Beyond Design-Basis Accidents																								
7.1 Hydrogen burn in waste storage tanks	X						X						X						X					
7.2 Organic fire in waste storage tanks	X						X						X						X					
7.3 Ferrocyanide exothermic reactions	X						X						X						X					
7.4 Evaporator red oil fire/deflagration	X								X						X						X			
7.5 Evaporator organics fire/deflagration	X								X						X						X			
7.6 Evaporator second-phase organics fire/deflagration	X								X						X						X			
7.7 Tank dome collapse	X						X						X						X					
7.8 BDBE waste staging and sampling facilities																					X			
7.9 Processing tank spill																						X		
7.10 HLW vitrification facility																								

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	Ex Situ Intermediate Separations						Ex Situ No Separations						Ex Situ Extensive Separations						Phased Implementation					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
Waste Transfer Operations																								
4.1.1 Submersible pump - SST single-encased pipe leak on soil																								
4.1.2 Saltwell pump - SST single-encased pipe leak on soil																								
4.1.3 Saltwell pump - 80 psi SST spray release	X						X						X						X					
4.1.4 DCRT pump - 207 psi SST spray release	X						X						X						X					
4.1.5 DCRT pump - 207 psi DST spray release	X						X						X						X					
4.1.6 Saltwell pump - 80 psi SST spray release, cover off	X						X						X						X					
4.1.7 DCRT pump - 207 psi SST spray release, cover off	X						X						X						X					
4.1.8 DCRT pump - 207 psi DST spray release, cover off	X						X						X						X					
4.1.9 Excavation induced AWF double-encased pipe rupture	X						X						X						X					
4.1.10 Excavation induced DST double-encased pipe rupture	X						X						X						X					
4.1.11 Excavation induced cross-site transfer line rupture	X						X						X						X					
4.1.12 Spray release in cross-site transfer line	X						X						X						X					
Evaporator Operations																								
4.2.1 Underground slurry- line leak during emergency dump	X		X				X						X		X				X		X			
4.2.2 Spray release in pumproom with filtration	X		X				X						X		X				X		X			
4.2.3 Spray release in pumproom with filter damage	X		X				X						X		X				X		X			
4.2.4 Excavation induced underground slurry leak	X		X				X						X		X				X		X			
4.2.5 Red oil fire/deflagration	X		X				X						X		X				X		X			

9613409.1376

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	Ex Situ Intermediate Separations						Ex Situ No Separations						Ex Situ Extensive Separations						Phased Implementation					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
4.2.6 Organics fire/deflagration	X		X				X						X		X				X		X			
4.2.7 Second-phase organics fire/deflagration	X		X				X						X		X				X		X			
4.2.8 Earthquake induced loss of confinement	X		X				X						X		X				X		X			
4.2.9 Evaporator release of ammonia	X		X				X						X		X				X		X			
Tank Waste Retrieval Operations - Mechanical Retrieval																								
4.3.1.1 Tank dome collapse due to overload		X						X						X						X				
4.3.1.2 Ferrocyanide reaction		X						X						X						X				
4.3.1.3 Criticality		X						X						X						X				
4.3.1.4 Hydrogen burn		X						X						X						X				
4.3.1.5 Seismic induced break in recirculation duct		X						X						X						X				
4.3.1.6 Container loading spill		X						X						X						X				
4.3.1.7 SST steam release		X						X						X						X				
4.3.1.8 SST leak to soil column		X						X						X						X				
Tank Waste Retrieval Operations - Hydraulic Retrieval																								
4.3.2.1 Tank dome collapse due to overload		X						X						X						X				
4.3.2.2 Pressurized spray leak at slurry pump outlet		X						X						X						X				
4.3.2.3 Pressurized spray leak at supernate/sluice inlet		X						X						X						X				
4.3.2.4 Seismic rupture of slurry pump outlet waste transfer line		X						X						X						X				
4.3.2.5 Seismic rupture of supernate pump inlet waste transfer line		X						X						X						X				

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	Ex Situ Intermediate Separations						Ex Situ No Separations						Ex Situ Extensive Separations						Phased Implementation					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
4.3.2.6 Seismic rupture of ventilation recirculation duct		X						X						X						X				
4.3.2.7 Slurry spill		X						X						X						X				
4.3.2.8 SST steam release		X						X						X						X				
4.3.2.10 SST leak to soil column		X						X						X						X				
4.3.2.11 Ferrocyanide reaction		X						X						X						X				
4.3.2.12 Criticality		X						X						X						X				
4.3.2.13 Hydrogen burn		X						X						X						X				
4.3.2.14 Pressurized spray release		X						X						X						X				
In Situ Vitrification																								
4.4.4.1 Confinement collapse due to dropped machine																								
4.4.4.2 Dropped electrode																								
4.4.4.3 Rupture off-gas duct																								
4.4.4.4 Earthquake ruptures confinement																								
4.4.4.5 Flammable gas burps																								
4.4.4.6 Steam explosion during melt process																								
4.4.4.7 Organics reaction																								
Waste Staging and Sampling Facility																								
4.5.1.1.1 DBE between tank farm and separations facilities and WESF			X												X						X			
4.5.1.1.2 DBE pressurized spray release			X												X						X			

9613409.1377

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	Ex Situ Intermediate Separations						Ex Situ No Separations						Ex Situ Extensive Separations						Phased Implementation					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
Separations Facility																								
4.5.2.1 Processing tank spill			X												X						X			
4.5.2.2 Cs ion exchange column explosion			X												X						X			
Low-Level Waste Vitrification Facility																								
4.5.3.1 DBA				X												X						X		
4.5.3.2 Kerosene/oxygen line rupture during normal operations				X												X						X		
4.5.3.3 Dicyclopentadiene/cyclopentadiene fire				X												X						X		
High-Level Waste Vitrification Facility																								
4.5.4.1 DBA				X						X						X						X		
4.5.4.2 Hydrogen deflagration in melter feed adjustment tank				X						X						X						X		
4.5.4.4 Canister drop				X						X						X						X		
4.5.4.5 Canister storage cask breach				X						X						X						X		
Low- Level Waste Onsite Permanent Repository Operation																								
4.7.1 Breach of LAW container						X												X						X
Toxicological Accidents																								
5.1 Evaporator release of ammonia			X												X						X			
5.2 Sulfur deflagration				X						X						X						X		
Breach of Cold-Chemical Tank																								
5.3.1 Ammonia tank and supply line rupture				X						X						X						X		

Table E.1.1.1 Summary of Potential Tank Waste Accidents (cont'd)

Postulated Accidents	Ex Situ Intermediate Separations						Ex Situ No Separations						Ex Situ Extensive Separations						Phased Implementation					
	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D	C	R	P	I	T	D
5.3.2 Formic acid tank breach				X						X						X						X		
5.3.3 Nitric acid tank breach				X						X						X						X		
Beyond Design-Basis Accidents																								
7.1 Hydrogen burn in waste storage tanks	X						X						X						X					
7.2 Organic fire in waste storage tanks	X						X						X						X					
7.3 Ferrocyanide exothermic reactions	X						X						X						X					
7.4 Evaporator red oil fire/deflagration			X												X						X			
7.5 Evaporator organics fire/deflagration			X												X						X			
7.6 Evaporator second-phase organics fire/deflagration			X												X						X			
7.7 Tank dome collapse	X						X						X						X					
7.8 BDBE waste staging and sampling facilities			X												X						X			
7.9 Processing tank spill				X						X						X						X		
7.10 HLW vitrification facility				X						X						X						X		

Notes:

AWF = Aging waste facility
BDBE = Beyond design-basis accidents
C = Continued Operations
D = Disposal
DBA = Design basis accident
DBE = Design basis earthquake
DCRT = Double-contained receiver tank
DST=Double-shell tank
HLW = High-level waste
I = Treatment
LAW= Low-activity waste
P = Pretreatment
R = Retrieval
SST= Single-shell tank
T = Transportation
WESF = Waste Encapsulation Storage Facility

Table E.1.1.2 Example Accident Screening Table

Activity	Accident	Cause	Severity	Annual Frequency	Risk
Mode - (Example - Continued Operation)					
Waste Transfer	Spray	4.1.3 Ruptured SST submersible pump line in valve pit with cover on - 80 psi	Low	Unlikely	6

Notes:
SST= Single-shell tank

of operation and subdivided further according to the activity within this mode. The risk shown in the last column is the product of the annual frequency of the event happening and the severity (consequences) of the accident. The values used in the annual frequency and severity columns are qualitative as defined in Tables E.1.1.3 and E.1.1.4. For the frequency of the event, factor values of 4 (anticipated); 3 (unlikely); 2 (extremely unlikely); and 1 (beyond design basis) were assigned. For the severity of the events, factor values of 4 (high); 3 (moderate); 2 (low); and 1 (no) were assigned. The factor values used for the frequency of the event and the severity of the event are numbers used only for the purpose of screening. Where the risk values for more than one event in the same category are the same, the rationale for choosing the scenario to be evaluated was based on the accident with the highest severity. It should be noted that accident scenarios with the worst radiological consequences would also result in the worst chemical exposures.

Table E.1.1.3 Frequency Category Definition

Annual Frequency Range [1]	Category Description	Annual Frequency
1 to 1.0E-02	Incidents that may occur several times during the lifetime of the facility. (Incidents that commonly occur.)	Anticipated (4) [2]
1.0E-02 to 1.0E-04	Accidents that may occur at some time during the lifetime of the facility.	Unlikely (3) [2]
1.0E-04 to 1.0E-06	Accidents that will probably not occur during the life-cycle of the facility. This class includes the design basis accidents.	Extremely Unlikely (2) [2]
1.0E-06 to 1.0E-07	Accidents for which no credible (≥ 1.0E-06) scenario can be identified.	Beyond Design Basis Accidents (1) [2]

Notes:
[1] DOE 1993.
[2] Factor value.

Table E.1.1.4 Qualitative Accident Severity Levels

Dose Consequence Range [1] (rem EDE)	Consequences to the Public or Workers	Severity
≤ 0.005 rem onsite and ≤ 0.0001 rem offsite	Negligible onsite and offsite impact on people.	No (1) [2]
≤ 5 rem onsite and ≤ 0.0001 rem offsite	Minor onsite and negligible offsite impact on people.	Low (2) [2]
> 5 rem onsite and ≤ 0.1 rem offsite	Major onsite and minor offsite impact on people.	Moderate (3) [2]
> 5 rem onsite and > 0.1 rem offsite	Major onsite and offsite impacts on people.	High (4) [2]

Notes:
[1] Arbitrary values assigned for screening.
[2] Factor value.
EDE = Effective dose equivalent

Beyond design basis accidents were also analyzed for each alternative. For this analysis, beyond design basis accidents are accidents with a frequency range of 1.0E-06 to 1.0E-07 per year (design basis accidents are greater than 1.0E-06 per year) and therefore have a very low probability of occurrence. This does not mean that the facilities have been designed to this accident frequency range. Accidents with frequencies less than 1.0E-07 (less than one in ten million) per year were not examined because of their extremely low probability of occurrence.

When an alternative has been selected for remediation of the Hanford tank waste, if accidents associated with the alternative exceed the acceptable limits of risk, mitigation measures may be required to reduce the level of risk.

E.1.1.3 Source Term and Direct Exposure

For this analysis the source term is the respirable fraction of inventory from which the receptor dose is calculated. It is based on the inventory that could potentially be released to the environment from an accident, referred to as material at risk (MAR), multiplied by the applicable reduction factors listed in the following text. Use of the reduction factors is dependent on the nature of the accident (i.e., energy of accident at impact, waste form, and effectiveness of mitigating barriers such as high-efficiency particulate air [HEPA] filter).

Damage ratio (DR) - The fraction of the MAR impacted by the event.

Airborne release fraction (ARF) - The fraction of released material made airborne by the event at the point of origin.

Airborne release rate (ARR) - The fractional airborne release rate of material resulting from the accident at the point of origin. ARR is converted to ARF by integrating over the time available for release.

Leak path factor (LPF) - The fraction that escapes the confinement boundary by design, natural causes, or degradation caused by the event.

Respirable fraction (RF) - The fraction of airborne droplets or particulate matter with individual particle aerodynamic equivalent diameter less than or equal to 10 micrometers (μm) (3.9 E-04 inches [in.]).

Exposure also may result from direct exposure to radiation. Direct exposure is the direct gamma radiation dose rate to a receptor.

It should be noted that the ingestion and groundshine pathways were not included because of the corrective action that would be taken by DOE to remediate the release from the accident. Submersion doses (external dose from the radioactive plume during plume passage) were 2 to 3 orders of magnitude less than the inhalation doses and are therefore not included in this analysis.

E.1.1.3.1 Inventory

The tank waste inventory for the SSTs, DSTs, and MUSTs is presented in Appendix A, Section A.2.1, Tables A.2.1.1, A.2.1.2, and A.2.1.3 of this EIS. The Cs and Sr capsule inventory at WESF are presented in Table A.2.2.1. However, for developing tank farm accidents, a 100 percent inventory bounding composite was developed. This composite incorporates historical tank contents estimates, the results from prior individual tank analyses, and the results of recent tank characterization programs (Shire et al. 1995). This composite was developed because engineering information was not sufficiently mature to determine which tanks would have their inventory mixed during retrieval and transfer. This could be thought of as a single tank containing the highest activity concentration for each nuclide found in the sample data. This maximum sample activity composite grouping means the highest radioactivity concentration for each radionuclide is combined to define a hypothetical "highest concentration" inventory used to bound the accidents. For process facility accidents a 90 percent composite was assumed.

A less conservative approach was also analyzed in Shire (Shire et al. 1995) using a nominal 50 percent inventory composite. The radioactive concentrations of the more bounding source terms are approximately a factor of thirty greater than the nominal.

E.1.1.4 Probabilities

The probabilities of radiological and toxicological accidents occurring were taken from the accident data package (Shire et al. 1995). The accident probability data package was prepared specifically to support the TWRS EIS. The accident initiator frequencies were established using currently accepted sources of occurrence frequency such as natural phenomena statistics for the Hanford Site, recent analysis of the initiators, or industry-accepted frequencies.

The probabilities have conservatively not taken into account 1) the frequency of time the wind blows in the direction of the presumed receptor location (the wind is always assumed to blow towards the

receptor); 2) the likelihood the receptor would be at the presumed receptor location for the duration of the plume passage; 3) the likelihood that the source term (composite inventory) would be released. It is assumed that the composite inventory would always be released; and 4) emergency planning and evacuation programs are in place at the Hanford Site to mitigate potential consequences resulting from an accident. In the event of an accident, the Emergency Control Center is responsible for determining the correct plan of action in accordance with the Emergency Management Procedures (WHC 1996a). For example, if the appropriate plan of action is to take cover, individuals are notified by announcements over the public address system to go inside building(s). The ventilation system is turned off to prevent unfiltered air, with contaminants, from entering the buildings. If the appropriate plan of action is to evacuate the Site, an orderly evacuation with designated meeting places is conducted. It has been demonstrated that evacuation can be conducted in less than an hour (Sutton 1996).

Accidents with annual frequencies greater than 1.0E-06 were considered to be within design basis accidents. Beyond design basis accidents have an annual frequency range from 1.0E-06 to 1.0E-07. Accidents with annual frequencies less than 1.0E-07 were not examined.

E.1.1.5 Receptor Locations

The radiological dose to a receptor depends on the location of the receptor relative to the point of release of the radioactive material. Doses for a maximally-exposed individual (MEI) and population dose were computed for each receptor (worker, noninvolved worker, and general public). Workers are those involved in the proposed action and are in the work place performing work at the facility. Noninvolved workers are onsite workers but not involved in the proposed action. The general public are those located off the Hanford Site. The MEI for each of these three receptor categories is a single individual that is assumed to receive the highest exposure in the category. The location of each receptor is discussed in the following text.

Worker Population and Maximally-Exposed Individual Worker - The worker population and MEI worker are those individuals directly involved in implementing the alternatives. They are assumed to be in the center of a 10 meter (m) (32.8 feet [ft]) radius hemisphere where the airborne released material has spread instantaneously and uniformly and would expose a typical size crew of 10 people.

Noninvolved Worker Population - The noninvolved worker population was based on the Site employment and was assumed to extend from 100 m (328.1 ft) out to the Hanford Site boundary. The Hanford Site specific population was obtained from the Hanford Site phone directory and increased by 10 percent to account for uncertainties. No reduction was applied for multiple work shifts or absences. All employees were assumed to be present. For accidents at the tank farms, the noninvolved worker population would be 1,835. For accidents at the vitrification facilities, the population would be 5,500.

Maximally-Exposed Individual Noninvolved Worker - The MEI noninvolved worker was assumed to be located at 100 m (328.1 ft) from the release point in the direction that produces the highest dose. This distance was used rather than the actual nearest building location, because new construction or movement of trailers and relocateable buildings can change the actual nearest building locations.

General Public Population - The offsite population distribution from the Hanford Site boundary to a distance of 80 km (49.7 mi) was taken from the GENII computer code (Napier et al. 1988). The offsite population would be 114,734.

Maximally-Exposed Individual General Public - The MEI general public was assumed to be located at the Hanford Site boundary (Figure 1.0.1 Volume 1) in the direction that produces the highest dose. An adjusted Site boundary that excludes areas likely to be released by DOE in the near future was used in the analysis. The Site boundary for the EIS was defined as follows:

- N. Columbia River - 0.4 km (0.25 mi) south of the south river bank.
- E. Columbia River - 0.4 km (0.25 mi) west of the west river bank.
- S. A line running west from the Columbia River, just north of the Washington Public Power Supply System (Supply System) leased area, through the Wye Barricade to Highway 240.
- W. Highway 240 and Highway 24.

E.1.1.6 Radiological Dose and Chemical Exposure Assessment

The computer code GXQ was used to calculate the dispersion of potential radiological releases into the atmosphere referred to as the atmospheric dispersion coefficient (X/Q). GXQ has been verified and benchmarked against the GENII computer code. The calculations use the most recent available meteorological joint frequency data based on the nine-year (1983 through 1991) average data from the Hanford Site meteorology tower in the 200 Area (Schreckhise 1993). The method for computing X/Q is based on Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC 1982). All accident-induced releases were assumed to be ground level releases, and plume meander was factored into the GXQ model. Plume rise, building wake, and dry deposition were not used. The receptor was assumed to be located at the plume centerline (i.e., at the location of peak concentration). For the bounding scenarios, the greater of the 99.5 percent maximum sector or 95 percent overall Site X/Q values were used.

Doses for atmospheric releases were computed with the GENII code, which has been verified and validated. The doses from radioactivity deposited inside the body were computed using weighting factors for various body organs and the results summed to calculate a committed effective dose equivalent (CEDE). The computer code was used to calculate the inhalation dose for a 70-year dose commitment period.

The radiological dose [D (Sv)] for the noninvolved worker and general public receptors were calculated using the straight-line Gaussian dispersion model as shown in the following equation:

$$D\ (Sv) = [Q\ (L)] \cdot [X/Q\ (s/m^3)] \cdot [R\ (m^3/s)] \cdot [ULD\ (Sv/L)]$$

Where:

Q	=	Liters of respirable waste released from the accident
X/Q	=	Time integrated atmospheric dispersion coefficient calculated by GXQ code
R	=	Typical acute breathing rate of 3.3 E-04 cubic meter per second (m^3/second) (1.2E-02 cubic feet per second (ft^3/second) (ICRP 1975)
ULD	=	CEDE per unit liter inhaled.

The liters of respirable waste released (Q) is the source term as defined in Section E.1.1.3. The X/Q is generated by the GXQ computer code (Section E.1.1.5.3). The breathing rate (R) is the typical acute (light activity) breathing rate. The unit liter dose (ULD) was generated by the GENII computer code for composite source terms and the values are given in terms of CEDE per unit liter of waste inhaled at the receptor location.

The radiological dose [D (Sv)] for the worker receptor was calculated using the following equation:

$$D\ (Sv) = [Q\ (L)] \cdot [BR\ (m^3/s)] \cdot [t\ (s)] \cdot [2/3\pi r^3]^{-1} \cdot [ULD\ (Sv/L)]$$

Where:

Q	=	Liters of respirable tank waste released
t	=	Duration of worker exposure
BR	=	Typical acute breathing rate, 3.3E-04 m^3/second (1.2E-02 ft^3/second)
r	=	Assumed 10 m (3.28E+01 ft^3) radius from point of release for distribution of source activity
ULD	=	CEDE per unit liter inhaled.

Peak concentrations, C (mg/m^3), for a continuous release of solid or liquid chemical materials were calculated using the following equation:

$$C\ (mg/m^3) = [Q\ (mg/s)] \cdot [X/Q\ (s/m^3)]$$

Where:

Q	=	Chemical material release rate
X/Q	=	Continuous release atmospheric dispersion coefficient.

The volume of respirable material released (Q) is the source term and the X/Q was generated by GXQ computer code.

For instantaneous or short duration releases of chemicals, the maximum puff X/Q was used.
The following equation was used to calculate the peak concentration:

$$C\ (mg/m^3) = Q\ (mg) \cdot X/Q\ (1/m^3)$$

Where:

Q	=	Toxic material released
X/Q	=	Puff release atmospheric dispersion coefficient.

E.1.1.7 Risk Development

Radiological risk. The likelihood that a dose of radiation would result in a fatal cancer at some future time is known as LCF and is calculated by multiplying the calculated dose (radiation effective man [rem]) by a risk factor, or dose-to-risk conversion factors. Conversion factors are predictions of health effects from radiation exposure. The dose-to-risk conversion factors used for estimating cancer deaths from low doses of radiological exposure and from high doses were taken from Recommendations of the International Commissions on Radiological Protection (ICRP 1991). They are summarized as follows:

- Onsite (worker and noninvolved worker) - 4.0E-04 LCF/person-rem or 400 cancer fatalities per million person-rem for low doses (less than 20 rem) and 8.0E-04 LCF/rem or 800 cancer fatalities for million person-rem for doses greater or equal to 20 rem.
- Offsite (general public) - 5.0E-04 LCF/person-rem or 500 cancer fatalities per million person rem for low doses (less than 20 rem) and 1.0E-03 LCF/rem or 1,000 cancer fatalities per million person-rem for high doses greater or equal to 20 rem.

  The difference in the onsite and offsite conversion factors is attributable to the presence of children offsite.

Multiplying the dose by the conversion factor shows the risk only if the accident takes place. Because the probability of the accident also needs to be factored into the evaluation, the radiological LCF risk is the product of the receptor dose, the dose-to-risk conversion factor, and the probability of the accident.

The quantitative estimates for the population receptors is the number of fatal cancers resulting from the radiological exposure. For the MEI receptors it is the probability the individual will die from cancer as a result of the exposure.

Other biological effects may result from radiological exposures. Somatic effects that occur early as a result of receiving a large dose in a short period of time (acute exposure) include vomiting, nausea, and diarrhea from a dose of 25 rem up to 220 rem. Deaths begin to occur beyond 220 rem with up to 100 percent deaths from doses between 500 to 750 rem.

Chemical risk - Potential acute hazards associated with exposure to concentrations of postulated accidental chemical releases were evaluated using a screening-level approach for the MEI worker, MEI noninvolved worker, and the MEI general public. This screening-level assessment involved direct comparison of calculated exposure point concentrations of chemicals to a set of site-specific (i.e., Hanford Site-specific) air concentration screening criteria, known as emergency response planning guidelines (ERPGs).

ERPGs, as developed by the American Industrial Hygiene Association (AIHA), are specific levels of chemical contaminants in air designed to be protective of acute adverse health impacts for the general population. ERPGs are defined as follows:

ERPG-1 - The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.

ERPG-2 - The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their ability to take protective action.

ERPG-3 - The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

For the accident scenarios evaluated, AIHA ERPGs were used as the primary criteria. For those chemicals lacking published AIHA ERPGs, Hanford Site-specific ERPGs were used as published in the Toxicological Evaluation of Tank Waste Chemicals, Hanford Environmental Health Foundation (HEHF) Industrial Hygiene Assessments (Dentler 1995). These tank farm-specific ERPGs were developed by HEHF for the purpose of evaluating health hazards associated with chemicals in the tank farms from accidental releases.

Chemicals were subdivided based on acute health impacts into toxic chemicals or corrosive/irritant chemicals. Given the lack of quantitative data and large number of target organs affected by a chemical from acute exposure, chemicals within each group were conservatively assumed to be additive. Cumulative hazards or the Acute Hazard Index for the toxic and corrosive/irritant chemical classes were evaluated as follows:

$$\text{Cumulative Hazard (Acute Hazard Index)} = C_1/E_1 + C_2/E_2 + \ldots + C_i/E_i$$

Where

C_i = Calculated airborne exposure point concentration for the ith chemical, (mg/m^3)

E_i = The ERPG for the ith chemical (mg/m^3)

Cumulative hazard indices were estimated for each MEI receptor and for each ERPG screening level (e.g., ERPG-1, ERPG-2, and ERPG-3). A cumulative hazard index greater than 1.0 (unity) indicates that the acute hazard guidelines for a mixture of chemicals has been exceeded and the chemical mixture may pose a potential acute health impact.

For accident scenarios involving the waste storage tanks (e.g., mispositioned jumper resulting in spray release, loss of tank ventilation filtration, and dome collapse, and hydrogen burn in storage tanks), the upper-bound, maximum receptor population that could be potentially impacted by an ERPG exceedance is:

- 10 workers (involved)
- 335 noninvolved workers at 290 m
- 1,500 noninvolved workers at 1,780 m
- 1 MEI noninvolved worker at 100 m
- 114,734 general public receptors

For accident scenarios involving the vitrification plant (e.g., pretreatment line break in ventilated vault and canister of vitrified HLW inadvertently dropped), the upper-bound, maximum population that could be potentially impacted by an ERPG exceedance is:

- 10 workers (involved)
- 1,500 noninvolved workers at 1,050 m
- 1,000 noninvolved workers at 20,500 m
- 3,000 noninvolved workers at 30,500 m
- 1 MEI noninvolved worker at 100 m
- 114,734 general public receptors

For any of the above receptor populations, a cumulative acute hazard index greater than 1.0 would be expected to result in the following ERPG-specific effects:

- ERPG-1 exceedance could result in mild transient effects such as minor irritation or objectionable odor perception;
- ERPG-2 exceedance could result in reversible adverse effects such as nausea, vomiting or bronchitis; and
- ERPG-3 exceedance could result in lethal exposures for some or all of the exposed population.

A calculated acute hazard index greater than 1.0 for an ERPG level (ERPG exceedance) is conservatively assumed to impact the entire receptor population.

Potential carcinogenic health effects from chemical exposure were not evaluated for these accident scenarios. Exposure to chemicals from accidental releases was assumed to occur only once, with a maximum duration of 24 hours. All of the carcinogenic chemicals have been shown to produce a carcinogenic response only after administering high doses for a lifetime of exposure. None of these carcinogenic chemicals have been shown to produce a carcinogenic response from an acute exposure. Consequently, a single acute dose can not be evaluated using cancer slope factors derived from chronic or lifetime studies.

E.1.2 OCCUPATIONAL INJURIES, ILLNESSES, AND FATALITIES

Total recordable cases, lost workday cases, and fatalities resulting from construction and operations were calculated by the following equations:

Total recordable cases = (occupational incidence rate) · (manpower required to complete the alternative)
Lost workday cases = (occupational incidence rate) · (manpower required to complete the alternative)
Fatalities = (occupational fatality rate) · (manpower required to complete the alternative).

The injuries, illnesses, and fatalities rates used in the analysis are incidence rates taken from the occupational injuries summary report (DOE 1994j). The total recordable case (injuries and illnesses requiring medical care) and lost workday case (an injury or illness resulting in an employee missing

work) rates are specific to the Hanford Site from 1988 through 1992. The fatality rate is the average for all DOE sites from 1988 through 1992 (the report does not distinguish between construction fatalities and operation fatalities). These incidence rates are summarized in Table E.1.2.1.

Table E.1.2.1 DOE and Contractor Incidence Rates

Incident	Lost Workday Cases Per 100 Worker-Years	
	Construction	Operations
Total recordable cases	9.75E+00	2.2E+00
Lost workday cases	2.45E+00	1.1E+00
Fatalities	3.2E-03	3.2E-03

E.1.3 TRANSPORTATION FATALITIES AND INJURIES

Truck and Rail Transport Accidents

The rates of transportation accidents are assumed comparable to that of average truck and rail transport in the United States. Unit-risk factors were developed based on statistics compiled by the U.S. Department of Transportation (Rao et al. 1982). These unit-risk factors are summarized in Table E.1.3.1.

Table E.1.3.1 Unit-Risk Factors for Fatalities and Injuries for Truck and Rail

Transport Mode	Population Zone		
	Urban	Suburban	Rural
Truck			
Fatalities/km	7.5E-09	1.3E-08	5.3E-08
Injuries/km	3.7E-07	3.8E-07	8.0E-07
Rail			
Fatalities/km	1.7E-08	1.7E-08	1.7E-08
Injuries/km	3.3E-08	3.3E-08	3.3E-08

Notes:
km = kilometers

The number of injuries and fatalities was calculated by multiplying the total distance traveled in each population zone by the appropriate risk factors shown in Table E.1.3.1. The distance traveled in each population zone was calculated by applying the fractions of travel from NUREG-0170 (NRC 1977). The values are 5 percent of the travel in urban, 5 percent of the travel in suburban, and 90 percent of the travel in rural areas. For this analysis the Hanford Site (onsite) is considered to be a suburban zone.

Employee Commuting Accidents

To calculate the expected number of injuries and fatalities resulting from vehicle accidents for employees commuting to and from work, the following injury/fatality rates were taken from the 1993 Washington State Highway Accident Report (WSDT 1993):

- 7.14E-07 injuries/km; and
- 8.98E-09 fatalities/km.

There were 18 recorded injuries and no fatalities at the Hanford Site for both 1993 and 1994. The estimated average vehicle distance driven was 3.46E+07 km (2.15E+07 mi). The injury rate for 1993 and 1994 is therefore calculated at 5.20E-07 injuries/km, which is comparable to the Washington State injury rates listed previously.

E.1.4 SEISMIC EVENT PRIOR TO OR DURNG REMEDIATION

The frequency and consequences of this potenital accident are preliminary and currently are under review. DOE will perform additional analysis and provide the results of this analysis in the Final EIS.

E.1.5 UNCERTAINTY

The uncertainties in calculating the radiological doses and the toxicological exposures resulting from operation accidents include the tank inventory concentration and the atmospheric dispersion once the source term is in the air. To demonstrate these uncertainties, a sample accident scenario is presented in Section E.15. The demonstration shows the difference between the bounding and nominal parameters; the concentration of the inventory is a factor of 30; and the atmospheric dispersion coefficient is a factor of 12 for the MEI noninvolved worker, a factor of 30 for the noninvolved worker population, a factor of 22 for the MEI general public, and a factor of 15 for the general public population. For the noninvolved worker population, a dose of 2.52E+03 person-rem was calculated based on bounding parameters, which is 3 orders of magnitude higher than the nominal dose calculated at 2.89E+00 person-rem.

The primary uncertainty associated with calculating the radiological doses resulting from transportation accidents while transporting vitrified HLW to a potential geologic repository was the percent of the waste by weight that could be mixed with the glass matrix. To demonstrate the uncertainties, a sample accident scenario is presented in Section E.15. The baseline analysis used in the EIS assumed a 20 weight percent waste loading. A range from the base line from as little as 15 weight percent to as much as 40 weight percent is used in the uncertainty evaluation. The population dose was calculated by RADTRAN 4 (Neuhauser-Kanipe 1992) and was based on the worst credible (probability of the accident approximating 1.0E-06) accident parameters in the urban population zone. The population dose with the probability of the accident factored in for the 40 weight percent loading was calculated to be 7.9E+03 person-rem, which is 2.4 times higher than the 15 weight percent loading calculated to be 3.3E+03 person-rem.

The accident initiator frequencies were established using currently accepted sources of occurrence frequency such as natural phenomena statistics for the Hanford Site or recent analysis of the initiators

from safety assessment reports. The frequency of these accidents is presented as estimates and is provided as an aid in screening accident scenarios. Differences in frequencies are significant only when orders of magnitude are present. An accident scenario with a frequency of 1E-6 and one with a frequency of 5E-05 should not be considered significantly different in frequency.

The nonradiological injuries and fatalities resulting from construction and operation accidents were based on incidence rates taken from the occupational injuries summary report (DOE 1994j).
The transportation injuries and fatalities from trucks and train were based on incidence rates taken from statistics compiled by the U.S. Department of Transportation (Rao et al. 1982). Injuries and fatalities resulting from employee vehicle accidents were based on incidence rates taken from the Washington State Highway Accident Report (WSDT 1993). Because these are widely accepted incidence rates, there was no attempt to evaluate the uncertainties.

E.2.0 NO ACTION ALTERNATIVE (TANK WASTE)

This section analyzes the risk resulting from potential accidents associated with the No Action alternative. The No Action alternative is to continue the following activities:

- Perform routine management and maintenance activities; and
- Continue pumping and evaporating liquid for 10 years.

This section analyzes the transportation and operation risk associated with this alternative. Because tanks and facilities would not be constructed under this alternative, there would be no risk from construction.

E.2.1 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative include employees commuting to work each day.

E.2.1.1 Radiological Cancer Risk

All operations would be conducted within established operating parameters for the tanks and would not involve transporting radioactive materials by container. Therefore, there would be no radiological cancer risk resulting from transportation. Accidents involving the transportation of waste in the transfer lines are discussed in Section E.2.2.

E.2.1.2 Chemical Exposure

Because there would be limited transportation of toxic materials (such as lubricants that are used in continued operations), it is extremely unlikely there would be any accidents resulting in chemical exposures. Therefore, transportation accidents involving chemical exposures were not quantified.

E.2.1.3 Occupational Injuries and Fatalities

Employee Traffic Accidents

Workers and other personnel required to perform the various activities would drive to the Hanford Site in their vehicles. The total person-years to perform the activities was estimated at 1.04E+05 (Jacobs 1996).

Each person was assumed to work 260 days a year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 kilometers (km) (87 miles [mi]) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated to be 2.80E+09 km (1.74E+09 mi).

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents are calculated as follows:

Injuries = (2.80E+09 km) · (7.1E-07 injuries/km) = 2.00E+03

Fatalities = (2.80E+09 km) · (8.98E-09 fatalities/km) = 2.52E+01

E.2.2 OPERATION ACCIDENTS

The potential exists for accidents resulting from routine operation activities. The routine operations are discussed in Appendix B.

The dominant accident scenarios analyzed in the following subsections were selected from the Accident Screening Table (Table E.2.2.1). The accidents listed in Table E.2.2.1 were taken from the accidents analysis data package (Shire et al. 1995). The methodology of screening was previously discussed in Section 1.1.2.

E.2.2.1 Continued Operations Accident

Continued operations include transferring liquid waste from the SSTs to an evaporator where the solids and liquid are separated. Types of radiological releases resulting from potential accidents associated with continued operations include sprays, leaks, fires/deflagrations, explosions, and ventilation. From Table E.2.2.1 the credible accident (accidents with a frequency of occurring greater than 1.0E-06 per year) identified as having the highest risk was Accident 4.1.7: "mispositioned jumper in SST double-contained receiver tank pump pit with cover off".

A pressurized-liquid spray release from a mispositioned jumper was postulated to occur in an SST double-contained receiver tank (DCRT) pump pit that services the transfer from DCRT to DST or pumps into or out of a receiver tank. A jumper is a short connection pipe that is used in a jumper pit to route tank waste transfers from one line to another line in sending tank waste to a specific location.

Table E.2.2.1 Accident Screening Table for the No Action Alternative (Tank Waste)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
		Mode - Routine Operations			
Waste Transfer	Spray	4.1.3 Ruptured SST submersible pump line in valve pit with cover on - 80 psi	No	A	4
		4.1.4 Mispositioned jumper in SST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.5 Mispositioned jumper in DST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.6 Mispositioned jumper in SST valve pit with cover off - 80 psi	Low	A	8
		4.1.7 Mispositioned jumper in SST DCRT pump pit with cover off - 207 psi	**High**	**U**	**12**
		4.1.8 Mispositioned jumper in DST DCRT pump pit with cover off - 207 psi	High	U	12
		4.1.12 Valve stem seal leak in cross-site transfer line - 1500 psi	No	EU	2
	Leak	4.1.9 Aging waste pipeline break due to excavation activities	Low	EU	4
		4.1.10 DST pipeline break due to excavation activities	Low	EU	4
		4.1.11 Cross-site transfer line break due to excavation activities	Low	EU	4
Evaporator Operations	Leak	4.2.1 Corroded underground slurry line leak during emergency dump	Low	BDBA	2
		4.2.4 Underground slurry line leak due to excavation activity	Low	EU	4
	Spray	4.2.2 Leak at connection between jumper and wall nozzle in P-B-2 Pump Room with filtration - 240 psi	No	A	4
		4.2.3 Leak at connection between jumper and wall nozzle in P-B-2 Pump Room with filter damage - 240 psi	No	A	4
	Fire/deflagration	4.2.5 Red oil compound deflagrate or burn under elevated temperature in evaporator	No	BDBA	1
		4.2.6 Flammable compounds ignite under elevated temperature in evaporator	No	BDBA	1
		4.2.7 Second-phase organics compounds ignite under elevated temperature in evaporator collection tank	No	BDBA	1

9613409.1385

Table E.2.2.1 Accident Screening Table for the No Action Alternative (Tank Waste) (cont'd)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
Evaporator Operations	Ventilation failure	4.2.8 Earthquake spills slurry in evaporator vessel and ruptures building ventilation	Moderate	U	9
	Ammonia release	4.2.9 Ammonia release from evaporator due to a blending error	High	EU	8

Notes:
A = Anticipated 1E-2 to 1 (value = 4)
BDBA = Beyond design-basis accident 1E-7 to 1E-6 (value = 1)
DCRT = Double-contained receiver tank
EU = Extremely unlikely 1E-6 to 1E-4 (value = 2)
High = Onsite fatalities, offsite exposure >1E-1 rem (value = 4)
Low = Onsite exposure < 5 rem, offsite exposure insignificant (value = 2)
Moderate = Onsite exposure > 5 rem, offsite exposure < 1E-1 rem (value = 3)
No = Negligible onsite and offsite impact. Onsite exposure < 5E-3 rem, offsite exposure < 1E-4 rem (value = 1)
U = Unlikely 1E-4 to 1E-2 (value = 3)

E.2.2.1.1 Scenario and Source Term Development for Continued Operation Accident - Mispositioned Jumper

This analysis was based on the following assumptions:

- A jumper was mispositioned and pinhole leaks develop at both ends of the jumper;
- The pump pressure was 1.43E+06 Pa (207 psi);
- The maximum spray leak from each end was calculated to be 0.027 L/min or 0.054 L/min (5.7 E-2 qt/min);
- All spray particles were assumed to evaporate to less than 10 μm before reaching the ground on their calculated trajectory, therefore, 100 percent of the spray was considered respirable;
- The fine spray is not detectable with installed leak detection devices;
- The pump pit was unintentionally left uncovered; and
- The release time was for two shifts or 16 hours (960 minutes [min]).

Source term - Assuming a spray duration of two shifts or 16 hours, the source term was calculated as follows:

$$0.054 \text{ L/min}) \cdot (960 \text{ min}) = 52 \text{ L (55 quarts [qt])}$$

E.2.2.1.2 Probability of Mispositioned Jumper

The frequency of a mispositioned jumper in a SST DCRT pump pit with its cover off was calculated to range from 1.1E-02 per year to 8.0E-03 per year (Shire et al. 1995). For conservatism, the frequency of 1.1E-02 was assumed for calculating risk. Waste transfers would take place for up to 10 years, therefore the probability of the accident was calculated to be 1.1E-01.

E.2.2.1.3 Radiological Consequence from Mispositioned Jumper

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section 1.1.6. The results, which were taken from the accident data package (Shire et al. 1995), are summarized in Table E.2.2.2.

Table E.2.2.2 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

E.2.2.1.4 Radiological Cancer Risk from Mispositioned Jumper

The LCF risk is the product of the dose to the receptor measured in rem, the dose to risk conversion factor, and the probability of the event. A dose-to-risk conversion factor of 8.0 E-04 LCF per person-rem for the workers, MEI worker, and MEI noninvolved worker was used because the individual doses were greater than 20 rem. Dose-to-risk conversion factors of 4.0 E-04 LCF per person-rem for the noninvolved worker and 5.0 E-04 LCF per person-rem for the general public were used, because the individual doses were less than 20 rem.

Using the MEI worker as an example, a dose to the MEI worker of 1.4E+02 rem would result in an estimated 1.1E-01 latent cancer deaths if the accident were to occur. Factoring in the probability of 1.1E-01 the LCF risk (point estimate) was calculated as follows:

$$(1.4E+02 \text{ rem}) \cdot (1.1E-01) \cdot (8.0 \text{ E-04 LCF/rem}) = 1.2E-02 \text{ LCF}$$

The LCF risks for each receptor are calculated in Table E.2.2.3.

Table E.2.2.3 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF[1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	1.1E-01	1.2E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	1.1E-01	1.2E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	1.1E-01	1.1E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	1.1E-01	5.9E-03
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	1.1E-01	3.4E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	1.1E-01	1.6E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

E.2.2.1.5 Chemical Consequences of Mispositioned Jumper

The chemical exposure to the receptors from the postulated accident were calculated in Appendix A of the accident data package (Shire et al. 1995) and summarized in the exposure column in Table E.2.2.4 and Table E.2.2.5 for toxic effects and corrosive/irritant effects, respectively. The tables compare the concentration of the postulated chemical releases to acute exposure criteria (ERPGs) discussed in Section 1.1.7.

Table E.2.2.4 Comparison of Chemical Concentrations to Toxic Concentration Limits for Mispositioned Jumper

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Antimony [1]	Threshold Value		2.00E+00	4.00E+01	7.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	1.43E-02	7.15E-03	3.58E-04	2.04E-04
	MEI Noninvolved Worker	1.15E-03	5.75E-04	2.88E-05	1.64E-05
	MEI General Public	2.79E-06	1.40E-06	6.98E-08	3.99E-08
Arsenic [2]	Threshold Value		1.00E-01	7.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	1.16E-03	1.16E-02	1.66E-04	1.16E-04
	MEI Noninvolved Worker	9.32E-05	9.32E-04	1.33E-05	9.32E-06
	MEI General Public	2.26E-07	2.26E-06	3.23E-08	2.26E-08
Beryllium [3]	Threshold Value		6.00E-03	2.50E-02	1.00E-01
			Ratio of Exposure to ERPG		
	MEI Worker	1.16E-04	1.93E-02	4.64E-03	1.16E-03
	MEI Noninvolved Worker	9.32E-06	1.55E-03	3.73E-04	9.32E-05
	MEI General Public	2.26E-08	3.77E-06	9.04E-07	2.26E-07
Cadmium [4]	Threshold Value		2.00E-01	1.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	1.93E-02	9.65E-02	1.93E-02	1.93E-03
	MEI Noninvolved Worker	1.55E-03	7.75E-03	1.55E-03	1.55E-04
	MEI General Public	3.76E-06	1.88E-05	3.76E-06	3.76E-07
Cerium [5]	Threshold Value		7.00E+01	5.00E+02	7.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	6.77E-01	9.67E-03	1.35E-03	9.67E-04
	MEI Noninvolved Worker	5.43E-02	7.76E-04	1.09E-04	7.76E-05
	MEI General Public	1.32E-04	1.89E-06	2.64E-07	1.89E-07
Cobalt [6]	Threshold Value		5.00E-02	2.00E-01	8.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	5.11E-04	1.02E-02	2.56E-03	6.39E-05
	MEI Noninvolved Worker	4.10E-05	8.20E-04	2.05E-04	5.13E-06
	MEI General Public	9.94E-08	4.99E-06	4.97E-07	1.24E-08
Cyanide [7]	Threshold Value		5.00E+00	4.10E+01	2.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	2.05E+00	4.10E-01	5.00E-02	1.03E-02
	MEI Noninvolved Worker	1.65E-01	3.30E-02	4.02E-03	8.25E-04
	MEI General Public	3.99E-04	7.98E-05	9.73E-06	2.00E-06

Table E.2.2.4 Comparison of Chemical Concentrations to Toxic Concentration Limits for Mispositioned Jumper (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Mercury [8]	Threshold Value		7.50E-02	1.00E-01	1.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	3.25E-02	4.33E-01	3.25E-01	2.32E-03
	MEI Noninvolved Worker	6.32E-06	8.43E-05	6.32E-05	4.51E-07
	MEI General Public	2.61E-03	3.48E-02	2.61E-02	1.86E-04
Neodymium [9]	Threshold Value		7.20E+01	5.04E+02	7.20E+02
			Ratio of Exposure to ERPG		
	MEI Worker	5.41E-02	7.51E-04	1.07E-04	7.51E-05
	MEI Noninvolved Worker	4.35E-03	6.04E-05	8.63E-06	6.04E-06
	MEI General Public	1.05E-05	1.46E-07	2.08E-08	1.46E-08
Oxalate [10]	Threshold Value		4.00E+00	2.00E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI Noninvolved Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI General Public	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium [11]	Threshold Value		2.00E-01	4.00E-01	2.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	3.09E-02	1.55E-01	7.73E-02	1.55E-02
	MEI Noninvolved Worker	2.48E-03	1.24E-02	6.20E-03	1.24E-03
	MEI General Public	6.02E-06	3.01E-05	1.51E-05	3.01E-06
Tellurium [12]	Threshold Value		1.30E-01	3.00E-01	1.40E+00
			Ratio of Exposure to ERPG		
	MEI Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI Noninvolved Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI General Public	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thallium [13]	Threshold Value		3.00E-01	2.00E+00	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	9.67E-02	3.22E-01	4.84E-02	4.84E-03
	MEI Noninvolved Worker	7.76E-03	2.59E-02	3.88E-03	3.88E-04
	MEI General Public	1.88E-05	6.27E-05	9.40E-06	9.40E-07
Uranium [14]	Threshold Value		1.00E+00	1.00E+01	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	5.41E-01	5.41E-01	5.41E-02	2.71E-02
	MEI Noninvolved Worker	4.35E-02	4.35E-02	4.35E-03	2.18E-03
	MEI General Public	1.05E-04	1.05E-04	1.05E-05	5.25E-06

Table E.2.2.4 Comparison of Chemical Concentrations to Toxic Concentration Limits for Mispositioned Jumper (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Vanadium [15]	Threshold Value		1.20E+00	1.10E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	1.59E-03	1.33E-03	1.45E-04	3.98E-05
	MEI Noninvolved Worker	1.27E-04	1.06E-04	1.15E-05	3.18E-06
	MEI General Public	3.09E-07	2.58E-07	2.81E-08	7.73E-09
Total Organic Carbon (as tributyl phosphate) [16]	Threshold Value		3.00E+00	1.50E+01	5.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	1.55E+01	5.17E+00	1.03E+00	3.10E-01
	MEI Noninvolved Worker	1.24E+00	4.13E-01	8.27E-02	2.48E-02
	MEI General Public	3.01E-03	1.00E-03	2.01E-04	6.02E-05
	Total MEI Worker Ratios		**7.18E+00**	**1.62E+00**	**3.74E-01**
	Total MEI Noninvolved Worker Ratios		**5.41E-01**	**1.03E-01**	**2.98E-02**
	Total MEI General Public Ratios		**3.61E-02**	**2.64E-02**	**2.59E-04**

Notes:
[1] Guidelines are based on total antimony content.
[2] Guidelines are based on total arsenic content.
[3] Guidelines are based on total beryllium content and were developed by PNL.
[4] Guidelines are based on total cadmium content and were developed by HEHF.
[5] ERPGs for cerium were developed by HEHF using data for cerium chloride.
[6] Guidelines are based on total cobalt content and were developed by HEHF.
[7] Guidelines are based on total cyanide content and were developed by HEHF.
[8] Guidelines are based on total mercury content. ERPG-2 is the EPA Level of Concern. The ERPG-3 is the NIOSH IDLH f mercury vapor.
[9] Guidelines are based on total neodymium content and were based on neodymium chloride.
[10] Guidelines are based on oxalic acid and adjusted by ERPG (oxalic acid) · molecular weight compound/molecular weight oxalic acid.
[11] Guidelines are based on the toxicity of sodium selenate.
[12] Guidelines are based on sodium selenate and were developed by HEHF.
[13] ERPGs were developed by HEHF.
[14] ERPGs were based on soluble uranium compounds.
[15] ERPGs were based on vanadium pentoxide and were developed by HEHF.
[16] ERPGs were based on toxicity of tributylphosphate.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

Table E.2.2.5 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Mispositioned Jumper

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Ammonia [1]	Threshold Value		4.60E-01	9.20E+00	2.30E+01
			Ratio of Exposure to ERPG		
	MEI Worker	4.25E-01	9.24E-01	4.62E-02	1.85E-02
	MEI Noninvolved Worker	3.42E-02	7.43E-02	3.72E-03	1.49E-03
	MEI General Public	8.28E-05	1.80E-04	9.00E-06	3.60E-06
Barium [2]	Threshold Value		6.80E+00	1.38E+02	3.44E+02
			Ratio of Exposure to ERPG		
	MEI Worker	2.05E-02	3.01E-03	1.49E-04	5.96E-05
	MEI Noninvolved Worker	1.65E-03	2.43E-04	1.20E-05	4.80E-06
	MEI General Public	3.99E-06	5.87E-07	2.89E-08	1.16E-08
Calcium [3]	Threshold Value		1.00E+00	2.20E+01	5.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	4.25E-01	4.25E-01	1.93E-02	7.87E-03
	MEI Noninvolved Worker	3.42E-02	3.42E-02	1.55E-03	6.33E-04
	MEI General Public	8.28E-05	8.28E-05	3.76E-06	1.53E-06
Chromium [4]	Threshold Value		2.60E+00	5.15E+01	1.29E+02
			Ratio of Exposure to ERPG		
	MEI Worker	6.19E+00	2.38E+00	1.20E-01	4.80E-02
	MEI Noninvolved Worker	4.97E-01	1.91E-01	9.65E-03	3.85E-03
	MEI General Public	1.20E-03	4.62E-04	2.33E-05	9.30E-06
Dysprosium [5]	Threshold Value		8.00E+01	6.00E+02	8.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI Noninvolved Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI General Public	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lanthanum [6]	Threshold Value		6.90E+00	1.37E+02	3.43E+02
			Ratio of Exposure to ERPG		
	MEI Worker	7.35E-02	1.07E-02	5.36E-04	2.14E-04
	MEI Noninvolved Worker	5.90E-03	8.55E-04	4.31E-05	1.72E-05
	MEI General Public	1.43E-05	2.07E-06	1.04E-07	4.17E-08
Sodium Hydroxide	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	6.96E+01	3.48E+01	1.74E+00	6.96E-01
	MEI Noninvolved Worker	5.59E+00	2.80E+00	1.40E-01	5.59E-02
	MEI General Public	1.36E-02	6.80E-03	3.40E-04	1.36E-04

Table E.2.2.5 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Mispositioned Jumper (cont'd)

Analyte (Threshold Values are Presented in mg/m³)	Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Total MEI Worker Ratios		**3.85E+01**	**1.93E+00**	**7.71E-01**
Total MEI Noninvolved Worker Ratios		**3.10E+00**	**1.55E-01**	**6.19E-02**
Total MEI General Public Ratios		**7.53E-03**	**3.76E-04**	**1.50E-04**

Notes:
[1] Guidelines were based on ammonium hydroxide normalized to sodium hydroxide.
[2] Guidelines were based on barium hydroxide normalized to sodium hydroxide.
[3] ERPGs were normalized to sodium hydroxide.
[4] Guidelines were based on chromium hydroxide normalized to sodium hydroxide.
[5] Guidelines were based on cerous hydroxide and were developed by HEHF.
[6] Guidelines were based on lanthanum fluoride normalized to sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00 and exceeds 1.0, indicating reversible health effects would be expected. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate which is the most acutely toxic constituent of the organic analytes identified. Tributylphosphate was used because a breakdown of the various chemicals that make up the TOCs is not available. Consequently, use of this surrogate chemical provides a conservative estimate of the potential acute hazards. The cumulative acute hazard index for the MEI noninvolved worker and general public ratio were less than 1.0 for ERPG-1 values, indicating that no adverse acute health effects would be expected for these two receptors.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00 and exceeds the ratio of 1.0, indicating reversible health effects would be expected. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard) and indicates that only mild reversible irritant effects would be expected for the noninvolved worker. The acute hazard index for the MEI general public ratio was less than 1.0 for all ERPGs, indicating that no acute health impacts would be expected.

E.2.2.2 Beyond Design Basis Accidents

Beyond design basis accidents for the purpose of this analysis have a frequency range of 1.0E-06 to 1.0E-7 per year does not necessarily mean that the facilities have been designed to this accident frequency range. It is a term used to identify accidents within this frequency range. These types of accidents include fires and exothermic reactions in the storage tanks and evaporator as well as tank dome collapse.

E.2.2.2.1 Scenario and Source Term Development for Hydrogen Burn in Waste Storage Tank

For the beyond design basis accident it was postulated that a hydrogen deflagration or fire could occur in waste storage tanks, Accident 7.1. Hydrogen could be generated in tank waste, rise into tank headspace, and reach the concentrations necessary for combustion. Ignition would occur in the tank headspace during a 1-hour time period when the gas concentration exceeds the lower flammability limit (LFL). Turbulence accompanying rapid combustion could suspend waste as aerosols and pressure drive some of the particulate out the ventilation system into the environment.

Source Term - The MAR was assumed to be 5.0E+05 L (5.3E+05 qt), the ARF · RF = 6.5E-06, and the LPF = 7.5E-01. The source term was calculated as follows:

$$(5.0E+05\ L) \cdot (6.5E-06) \cdot (7.5E-01) = 2.4E+00\ L\ (2.5E+00\ qt)$$

E.2.2.2.2 Probability of Hydrogen Burn in Waste Storage Tank

The frequency of a hydrogen burn in a waste storage tank was estimated at 9.0E-07 per year (Shire et al. 1995). The probability for this scenario based on 25 flammable gas Watchlist tanks and 100 years of operation was therefore estimated to be 2.25E-03.

E.2.2.2.3 Radiological Consequence from Hydrogen Burn in Waste Storage Tank

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section 1.1.6. The results are presented in Table E.2.2.6.

Table E.2.2.6 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10)[1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835)[1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734)[1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

E.2.2.2.4 Radiological Cancer Risk from Hydrogen Burn in Waste Storage Tank

All 10 workers and the MEI noninvolved worker would potentially receive a fatal dose and would assumably die directly after the exposure. The LCFs and LCF point estimate risk are presented in Table E.2.2.7.

Table E.2.2.7 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF[1]	Probability	LCF Risk (point estimate)
Workers (10)[3]	2.2E+05	N/A	N/A	2.3E-03	2.3E-03[2]
MEI worker	2.2E+04	N/A	N/A	2.3E-03	2.3E-03[2]
Noninvolved workers (1,835)[3]	2.5E+04	4.0E-04	9.8E+00	2.3E-03	2.2E-02
MEI noninvolved worker	1.7E-+03	N/A	N/A	2.3E-03	2.3E-03[2]
General public (114,734)[3]	3.7E+03	5.0E-04	1.9E+00	2.3E-03	4.2E-03
MEI general public	4.2E+00	5.0E-04	2.1E-03	2.3E-03	4.8E-06

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk is the probability of the accident times the consequence of the accident (lethal dose).
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = LCFs do not apply for a lethal dose

In addition to all 10 workers and the MEI noninvolved worker dying directly after the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers, and 2 LCFs to the general public if the accident occurred.

E.2.2.2.5 Chemical Consequences from Hydrogen Burn in Waste Storage

The chemical exposure to the receptors from the postulated accident was calculated in Appendix A of the accident data package (Shire et al. 1995) and summarized in the exposure column in Table E.2.2.8 and Table E.2.2.9 for toxic and corrosive/irritant chemicals, respectively. The tables compare the concentration of the postulated chemical releases to acute exposure criteria (ERPGs) discussed in Section 1.1.7.

Chemical impacts were not evaluated for the MEI worker because all workers would receive a lethal radiation dose, as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01, which exceeds 1.0 and indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);

Table E.2.2.8 Comparison of Chemical Concentrations to Toxic Concentration Limits for Hydrogen Burn in Waste Storage Tank

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Antimony [1]	Threshold Value		2.00E+00	4.00E+01	7.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.23E-02	6.15E-03	3.08E-04	1.76E-04
	MEI Noninvolved Worker at 290 m	4.46E-05	2.23E-05	1.12E-06	6.37E-07
	MEI Noninvolved Worker at 1,780 m	6.00E-07	3.00E-07	1.50E-08	8.57E-09
	MEI General Public	4.90E-07	2.45E-07	1.23E-08	7.00E-09
Arsenic [2]	Threshold Value		1.00E-01	7.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.40E+01	1.40E+02	2.00E+00	1.40E+00
	MEI Noninvolved Worker at 290 m	5.09E-02	5.09E-01	7.27E-03	5.09E-03
	MEI Noninvolved Worker at 1,780 m	6.84E-04	6.84E-03	9.77E-05	6.84E-05
	MEI General Public	5.59E-04	5.59E-03	7.99E-05	5.59E-05
Beryllium [3]	Threshold Value		6.00E-03	2.50E-02	1.00E-01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.45E-01	5.75E+01	1.38E+01	3.45E+00
	MEI Noninvolved Worker at 290 m	1.25E-03	2.08E-01	5.00E-02	1.25E-02
	MEI Noninvolved Worker at 1,780 m	1.68E-05	2.80E-03	6.72E-04	1.68E-04
	MEI General Public	1.37E-05	2.28E-03	5.48E-04	1.37E-04
Cadmium [4]	Threshold Value		2.00E-01	1.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.40E+01	3.20E+02	6.40E+01	6.40E+00
	MEI Noninvolved Worker at 290 m	2.32E-01	1.16E+00	2.32E-01	2.32E-02
	MEI Noninvolved Worker at 1,780 m	3.12E-03	1.56E-02	3.12E-03	3.12E-04
	MEI General Public	2.55E-03	1.28E-02	2.55E-03	2.55E-04
Cerium [5]	Threshold Value		7.00E+01	5.00E+02	7.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.40E+00	9.14E-02	1.28E-02	9.14E-03
	MEI Noninvolved Worker at 290 m	2.32E-02	3.31E-04	4.64E-05	3.31E-05
	MEI Noninvolved Worker at 1,780 m	3.12E-04	4.46E-06	6.24E-07	4.46E-07
	MEI General Public	2.55E-04	3.64E-06	5.10E-07	3.64E-07

Table E.2.2.8 Comparison of Chemical Concentrations to Toxic Concentration Limits for Hydrogen Burn in Waste Storage Tank (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Cobalt [6]	Threshold Value		5.00E-02	2.00E-01	8.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.60E+00	3.20E+01	8.00E+00	2.00E-01
	MEI Noninvolved Worker at 290 m	5.80E-03	1.16E-01	2.90E-02	7.25E-04
	MEI Noninvolved Worker at 1,780 m	7.80E-05	1.56E-03	3.90E-04	9.75E-06
	MEI General Public	6.37E-05	1.27E-03	3.19E-04	7.96E-06
Cyanide [7]	Threshold Value		5.00E+00	4.10E+01	2.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.16E+00	2.32E-01	2.83E-02	5.80E-03
	MEI Noninvolved Worker at 290 m	4.19E-03	8.38E-04	1.02E-04	2.10E-05
	MEI Noninvolved Worker at 1,780 m	5.64E-05	1.13E-05	1.38E-06	2.82E-07
	MEI General Public	4.61E-05	9.22E-06	1.12E-06	2.31E-07
Mercury [8]	Threshold Value		7.50E-02	1.00E-01	1.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.71E-01	3.61E+00	2.71E+00	1.94E-02
	MEI Noninvolved Worker at 290 m	9.82E-04	1.31E-02	9.82E-03	7.01E-05
	MEI Noninvolved Worker at 1,780 m	1.32E-05	1.76E-04	1.32E-04	9.43E-07
	MEI General Public	1.08E-05	1.44E-04	1.08E-04	7.71E-07
Neodymium [9]	Threshold Value		7.20E+01	5.04E+02	7.20E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.72E+01	2.39E-01	3.41E-02	2.39E-02
	MEI Noninvolved Worker at 290 m	6.25E-02	8.68E-04	1.24E-04	8.68E-05
	MEI Noninvolved Worker at 1,780 m	8.40E-04	1.17E-05	1.67E-06	1.17E-06
	MEI General Public	6.86E-04	9.53E-06	1.36E-06	9.53E-07
Oxalate [10]	Threshold Value		4.00E+00	2.00E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.77E+02	1.69E+02	3.39E+01	1.69E+01
	MEI Noninvolved Worker at 290 m	2.45E+00	6.13E-01	1.23E-01	6.13E-02
	MEI Noninvolved Worker at 1,780 m	3.30E-02	8.25E-03	1.65E-03	8.25E-04
	MEI General Public	2.70E-02	6.75E-03	1.35E-03	6.75E-04

Table E.2.2.8 Comparison of Chemical Concentrations to Toxic Concentration Limits for Hydrogen Burn in Waste Storage Tank (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Selenium [11]	Threshold Value		2.00E-01	4.00E-01	2.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	5.91E-01	2.96E+00	1.48E+00	2.96E-01
	MEI Noninvolved Worker at 290 m	2.14E-03	1.07E-02	5.35E-03	1.07E-03
	MEI Noninvolved Worker at 1,780 m	2.88E-05	1.44E-04	7.20E-05	1.44E-05
	MEI General Public	2.34E-05	1.18E-04	5.88E-05	1.18E-05
Tellurium [12]	Threshold Value		1.30E-01	3.00E-01	1.40E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.29E+00	1.76E+01	7.63E+00	1.64E+00
	MEI Noninvolved Worker at 290 m	8.30E-03	6.38E-02	2.77E-02	5.93E-03
	MEI Noninvolved Worker at 1,780 m	1.12E-04	8.62E-04	3.73E-04	8.00E-05
	MEI General Public	9.11E-05	7.01E-04	3.04E-04	6.51E-05
Thallium [7]	Threshold Value		3.00E-01	2.00E+00	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.20E+01	1.07E+02	1.60E+01	1.60E+00
	MEI Noninvolved Worker at 290 m	1.16E-01	3.87E-01	5.82E-02	5.80E-03
	MEI Noninvolved Worker at 1,780 m	1.56E-03	5.21E-03	7.80E-04	7.80E-05
	MEI General Public	1.27E-03	4.23E-03	6.35E-04	6.35E-05
Uranium [14]	Threshold Value		1.00E+00	1.00E+01	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.08E+02	1.08E+02	1.08E+01	5.40E+00
	MEI Noninvolved Worker at 290 m	3.93E-02	3.93E-01	3.93E-02	1.97E-02
	MEI Noninvolved Worker at 1,780 m	5.28E-03	5.28E-03	5.28E-04	2.64E-04
	MEI General Public	4.31E-03	4.31E-03	4.31E-04	2.16E-04
Vanadium [7]	Threshold Value		1.20E+00	1.10E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.69E-02	3.08E-02	3.35E-03	9.23E-04
	MEI Noninvolved Worker at 290 m	1.34E-04	1.12E-04	1.22E-05	3.35E-06
	MEI Noninvolved Worker at 1,780 m	1.80E-06	1.50E-06	1.64E-07	4.50E-08
	MEI General Public	1.47E-06	1.23E-06	1.34E-07	3.68E-08

Table E.2.2.8 Comparison of Chemical Concentrations to Toxic Concentration Limits for Hydrogen Burn in Waste Storage Tank (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Total Organic Carbon (as tributyl phosphate) [16]	Threshold Value		3.00E+00	1.50E+01	5.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.85E+02	6.16E+01	1.23E+01	3.69E+00
	MEI Noninvolved Worker at 290 m	6.69E-01	2.23E-01	4.46E-02	1.34E-02
	MEI Noninvolved Worker at 1,780 m	9.00E-03	3.00E-03	6.00E-04	1.80E-04
	MEI General Public	7.35E-03	2.45E-03	4.90E-04	1.47E-04
	Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
	Total MEI Noninvolved Worker at 100 m Ratios		**1.02E+03**	**1.73E+02**	**4.11E+01**
	Total MEI Noninvolved Worker at 290 m Ratios		**3.70E+00**	**6.26E-01**	**1.49E-01**
	Total MEI Noninvolved Worker at 1,780 m ratios		**4.97E-02**	**8.42E-03**	**2.00E-03**
	Total MEI General Public Ratios		**4.06E-02**	**6.88E-03**	**1.64E-03**

Notes:
[1] Guidelines are based on total antimony content.
[2] Guidelines are based on total arsenic content.
[3] Guidelines are based on total beryllium content and were developed by PNL.
[4] Guidelines are based on total cadmium content and were developed by HEHF.
[5] ERPGs for cerium were developed by HEHF using data for cerium chloride.
[6] Guidelines are based on total cobalt content and were developed by HEHF.
[7] Guidelines are based on total cyanide content and were developed by HEHF.
[8] Guidelines are based on total mercury content. ERPG-2 is the EPA Level of Concern. The ERPG-3 is the NIOSH IDLH for mercury vapor.
[9] Guidelines are based on total neodymium content and were based on neodymium chloride.
[10] Guidelines are based on oxalic acid and adjusted by ERPG (oxalic acid) · molecular weight compound/molecular weight oxalic acid.
[11] Guidelines are based on the toxicity of sodium selenate.
[12] Guidelines are based on sodium selenate and were developed by HEHF.
[13] ERPGs were developed by HEHF.
[14] ERPGs were based on soluble uranium compounds.
[15] ERPGs were based on vanadium pentoxide and were developed by HEHF.
[16] ERPGs were based on toxicity of tributylphosphate.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = LCFs do not apply for a lethal dose.

Table E.2.2.9 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Hydrogen Burn in Waste Storage Tank

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Ammonia [1]	Threshold Value		4.60E-01	9.20E+00	2.30E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.60E+01	3.48E+01	1.74E+00	6.96E-01
	MEI Noninvolved Worker at 290 m	5.80E-02	1.26E-01	6.30E-03	2.52E-03
	MEI Noninvolved Worker at 1,780 m	7.80E-04	1.70E-03	8.48E-05	3.39E-05
	MEI General Public	6.37E-04	1.38E-03	6.92E-05	2.77E-05
Barium [2]	Threshold Value		6.80E+00	1.38E+02	3.44E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	7.14E+00	1.05E+00	5.17E-02	2.08E-02
	MEI Noninvolved Worker at 290 m	2.59E-02	3.81E-03	1.88E-04	7.53E-05
	MEI Noninvolved Worker at 1,780 m	3.48E-04	5.12E-05	2.52E-06	1.01E-06
	MEI General Public	2.84E-04	4.18E-05	2.06E-06	8.26E-07
Calcium [3]	Threshold Value		1.00E+00	2.20E+01	5.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.40E+01	6.40E+01	2.91E+00	1.19E+00
	MEI Noninvolved Worker at 290 m	2.32E-01	2.32E-01	1.05E-02	4.30E-03
	MEI Noninvolved Worker at 1,780 m	3.12E-03	3.12E-03	1.42E-04	5.78E-05
	MEI General Public	2.55E-03	2.55E-03	1.16E-04	4.72E-05
Chromium [4]	Threshold Value		2.60E+00	5.15E+01	1.29E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.67E+02	6.42E+01	3.24E+00	1.29E+00
	MEI Noninvolved Worker at 290 m	6.07E-01	2.33E-01	1.18E-02	4.71E-03
	MEI Noninvolved Worker at 1,780 m	8.16E-03	3.14E-03	1.58E-04	6.33E-05
	MEI General Public	6.66E-03	2.56E-03	1.29E-04	5.16E-05
Dysprosium [5]	Threshold Value		8.00E+01	6.00E+02	8.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.04E-01	2.55E-03	3.40E-04	2.55E-04
	MEI Noninvolved Worker at 290 m	7.41E-04	9.26E-06	1.24E-06	9.26E-07
	MEI Noninvolved Worker at 1,780 m	9.96E-06	1.25E-07	1.66E-08	1.25E-08
	MEI General Public	8.13E-06	1.02E-07	1.36E-08	1.02E-08

Table E.2.2.9 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Hydrogen Burn in Waste Storage Tank (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Lanthanum [6]	Threshold Value		6.90E+00	1.37E+02	3.43E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	7.39E+01	1.07E+01	5.39E-01	2.15E-01
	MEI Noninvolved worker at 290 m	2.68E-01	3.88E-02	1.96E-03	7.81E-04
	MEI Noninvolved Worker at 1,780 m	3.60E-03	5.22E-04	2.63E-05	1.05E-05
	MEI General Public	2.94E-03	4.26E-04	2.15E-05	8.57E-06
Sodium Hydroxide	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	5.66E+02	2.83E+02	1.42E+01	5.66E+00
	MEI Noninvolved Worker at 290 m	2.05E+00	1.03E+00	5.13E-02	2.05E-02
	MEI Noninvolved Worker at 1,780 m	2.76E-02	1.38E-02	6.90E-04	2.76E-04
	MEI General Public	2.25E-02	1.13E-02	5.64E-04	2.25E-04
	Total MEI Worker Ratios		N/A	N/A	N/A
	Total MEI Noninvolved Worker at 100 m Ratios		4.58E+02	2.26E+01	9.08E+00
	Total MEI Noninvolved Worker at 290 m Ratios		1.66E+00	8.21E-02	3.29E-02
	Total MEI Noninvolved Worker at 1,780 m Ratios		2.23E-02	1.10E-03	4.42E-04
	Total MEI General Public		1.82E-02	9.01E-04	3.61E-04

Notes:
[1] Guidelines were based on ammonium hydroxide normalized to sodium hydroxide.
[2] Guidelines were based on barium hydroxide normalized to sodium hydroxide.
[3] ERPGs were normalized to sodium hydroxide.
[4] Guidelines were based on chromium hydroxide normalized to sodium hydroxide.
[5] Guidelines were based on cerous hydroxide and were developed by HEHF.
[6] Guidelines were based on lanthanum fluoride normalized to sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = LCFs do not apply for a lethal dose.

- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.2.2.3 Occupational Injuries and Fatalities from Operations

The total person-years required for operations was estimated at 1.04E+05 (Jacobs 1996) for the 100 years of continued operations. The total recordable injuries or illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (1.04E+05 person-years) · (2.2E+00 incidences /100 person-years) = 2.29E+03

Lost Workday Cases = (1.04E+05 person-years) · (1.1E+00 incidences/100 person-years)= 1.14E+03

Fatalities = (1.04E+05 person-years) · (3.2E-03 fatalities/100 person-years) = 3.33E+00

E.2.3 POST-REMEDIATION ACCIDENT

For the No Action alternative, the waste would remain in the tanks and the tanks would not be stabilized. During the 100-year institutional control period, the tanks would be maintained. After the 100 years there would be no additional maintenance of the aging tanks (the design life of the tanks would be exceeded) and the tanks would deteriorate and lose their structural strength. With the tanks in an unstable condition, a seismic event (a 0.2 gravity earthquake with an annual frequency of 2.0E-04) collapses the tank dome into the tanks resulting in an acute release of contaminants followed by a chronic release at much lower levels until the waste would be covered with earth by natural forces.

Source-Term Development

It was conservatively assumed that all 177 tanks collapse and that the radiological and chemical contaminants in the headspace are available for release. The collapse of a portion of the dome and overburden compresses the vapor in the headspace as it descends, enhancing the vapor release rate by sudden pressure difference. Assuming for each tank a respirable concentration of contaminants in the headspace of 100 mg/m^3, a liquid SpG of 1.5 and a headspace volume of 1,000 m^3, the potential source term contribution from the headspace release for 177 tanks was calculated as follows:

(100 mg/m^3) · (1 g/L,000 mg) · (1 L/1,000 g) · (1,000 m^3) · (1/1.5) · (177) =
1.18E+01 L (1.25E+01 qt)

It was conservatively assumed that the liquids had drained from leaks in the tanks so that the surface was dry and crumbly and the MAR was 2,500 L for each tank. It was postulated that the fall of the dome and overburden generated a substantial air movement to suspend a fraction the MAR. Assuming the respirable release fraction to be 2.0E-03 (Shire et al. 1995), the potential source term contribution from entrainment for all 177 tanks was calculated as follows:

(2,500 L) · (2.0E-03) · (177) = 8.85E+02 L (9.35E+02 qt)

The combined source term for the acute release is calculated as follows:

(1.18E+01 L) + (8.85E+02 L) = 8.97E+02 L (9.48E+02 qt)

Following the initial release, no corrective action would be taken and the waste would continually be released by air currents lifting a fraction of the waste into the air for 1 year. After the first year it was assumed the waste would be covered by natural forces. It was assumed that the dome and overburden covers most of the waste surface reducing the MAR to 10 percent or 250 L, and a respirable release fraction of 4.0E-05/hr was assumed. The source term for the chronic release for one year from 177 tanks is calculated as follows:

(2.50E+02) · (4.0E-05/hr) · (8.74E+03 hr/yr) · (177) = 1.55 E+04 L (1.63E+04 qt)

Consequence for Tank Dome Collapse

The 50 percentile tank inventory was used in calculating the radiological dose to the receptors. It was assumed that the offsite population size and location remained the same and the onsite population of people living on the Hanford Site was 10 percent of the current Hanford population or 1,090. The radiological dose to the receptors was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section E.1.1.6.

The onsite population of 183 people living downwind from the acute release would potentially receive a lethal dose from a radiological dose of 1.79E+04 person-rem and exposure to toxic chemicals that would exceed the ERPG-3 threshold values by a factor of 1.16E+01.

The acute downwind offsite population radiological dose and the chronic population radiological dose of 3.64E+04 person-rem would result in 1.82E+01 LCFs. The population living closest to the Hanford Site would receive an exposure to toxic chemicals that would exceed the ERPG-2 threshold value by a factor of 8.41E+00, indicating they would suffer from reversible health effects.

E.3.0 LONG-TERM MANAGEMENT ALTERNATIVE

This section analyzes the risk resulting from potential accidents associated with the Long-Term Management alternative. The Long-Term Management alternative is to continue safe storage activities. This includes:

- Perform routine management and maintenance activities;
- Continue pumping and evaporation of liquid;
- Construct replacement DSTs and associated evaporators;
- Waste transfer system upgrade (W314); and
- Transfers waste via pipeline to the Evaporator Facility or replacement tanks.

E.3.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Long-Term Management alternative are discussed in Appendix B of the EIS. It should be noted that there are no radiological or chemical consequences associated with construction accidents because the replacement tanks and associated transfer lines and evaporators would be constructed in uncontaminated areas. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated in the following text.

Construction would require an estimated 3.75E+03 person-years (Jacobs 1996). The total recordable injuries and illnesses, lost workday cases, and fatalities for the 10 years of construction were calculated using the incidence rates from Table E.1.2.1 of this Appendix as follows:

Total Recordable Cases = (3.75E+03 person-years) · (9.75E+00 incidences/100 person-years) = 3.66E+02

Lost Workday Cases = (3.75E+03 person-years) · (2.45E+00 incidences/100 person-years) = 9.19E+01

Fatalities= (3.75E+03 person-years) · (3.2E-03 fatalities/100 person-years) = 1.2E-01

E.3.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are 1) transporting construction material from offsite; and 2) employees commuting to work each day.

E.3.2.1 Radiological Cancer Risk

All operations would be conducted within established operating parameters for the tanks and would not involve transporting radioactive materials by container. Therefore, there would be no radiological cancer risks resulting from transportation. Accidents involving the transfer of waste in the transfer lines are discussed in Section E.3.3.

E.3.2.2 Chemical Exposure

Because there would be very limited transportation of toxic materials (e.g., lubricants for routine operations), it is extremely unlikely there would be any accidents resulting in chemical exposures. Therefore, transportation accidents involving chemical exposures were not quantified.

E.3.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation Accident

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Truck and rail transportation activities to transport material and supplies to the Hanford Site for this alternative are summarized in Table 3.2.1. The total distance was calculated by multiplying the number of trips by the round-trip distance.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.3.2.2 by the appropriate unit risk factors shown in Table E.3.2.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3. The expected injuries and fatalities resulting from truck and rail transportation accidents associated with the Long-Term Management alternative are summarized in Table E.3.2.3.

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, Site workers and other personnel required to perform the various activities would drive to the Site in their vehicles. The total person-years to perform the activities was estimated at 1.08E+05 (Jacobs 1996).

Each person was assumed to work 260 days of the year. The round trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated to be 2.91E+09 km (1.81E+09 mi).

Table E.3.2.1 Summary of Transportation Activities for the Long-Term Management Alternative

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Routine							
Construction Truck - onsite	Earthen Borrow	3.24E+04	1.00E+01 [1]	3.24E+05	N/A	N/A	N/A
Truck - offsite	Construction material	2.01E+04	1.40E+02 [2]	N/A	N/A	2.81E+06	NA/
	Construction material	7.75E+03	8.00E+02 [3]	N/A	N/A	6.20E+06	N/A
	Miscellaneous	5.20E+03/year (19 year)	1.40E+02 [2]	N/A	N/A	1.38E+07	N/A
			Total	3.24E+05	N/A	2.28E+07	N/A

Notes:
[1] Round-trip distance from Pit 30 borrow site
[2] Round-trip distance from Tri-Cities area
[3] Round-trip distance from Portland/Seattle area
N/A= Not Applicable

Table E.3.2.2 Distance Traveled in Population Zones for the Long-Term Management Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	1.14E+06	1.47E+06	2.06E+07
Rail	N/A	N/A	N/A

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.3.2.1.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.3.2.1.
[3] Rural represents 90 percent of total offsite distance from Table E.3.2.1.
N/A = Not Applicable

Table E.3.2.3 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Long-Term Management Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	8.57E-03	1.91E-02	1.09E+00	1.12E+00	N/A
	Injury	4.23E-01	5.57E-01	1.64E+01	N/A	1.74E+01
Rail	Fatality	N/A	N/A	N/A	N/A	N/A
	Injury	N/A	N/A	N/A	N/A	N/A
				Total	1.12E+00	1.74E+01

Notes:
N/A = Not Applicable

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents are calculated as follows:

Injuries = (2.91E+09 km) · (7.1E-07 injuries/km) = 2.08E+03
Fatalities = (2.91E+09 km) · (8.98E-09 fatalities/km) = 2.61E+01

Cumulative Transportation Injuries and Fatalities
The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents and are summarized in Table E.3.2.4.

Table E.3.2.4 Cumulative Injuries and Fatalities from Traffic Impacts for the Long-Term Management Alternative

Mode	Fatalities	Injuries
Truck and rail (from Table E.3.2.3)	1.11E+00	1.74E+01
Employee vehicle (from Section E.12)	2.61E+01	2.08E+03
Total	2.72E+01	2.09E+03

E.3.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from continued operation activities. The continued operations are discussed in Appendix B.

E.3.3.1 Continued Operations Accident

The dominant continued operations accident is the "mispositioned jumper accident" previously discussed in the No Action alternative Section E.2.2.1 and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qts).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The probability of occurrence is based on 20 years of waste transfers to accommodate the retanking operations. Therefore, the probability was calculated to be 2.2E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.2.2 are reproduced in Table E.3.3.1.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Long-Term Management alternative, however, the LCF risk (point estimate) is not the same because of the difference in probabilities. The LCFs and the LCF risks are calculated in Table E.3.3.2.

Table E.3.3.1 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.3.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.2E-01	2.5E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.2E-01	2.5E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.2E-01	2.2E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.2E-01	1.2E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.2E-01	6.8E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.2E-01	3.2E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Chemical Consequences

For the Long-Term Management alternative, the potential acute hazards associated with the mispositioned jumper are the same as the acute hazards presented in Tables E.2.2.4 and E.2.2.5 for the No Action alternative.

Toxic Impact From Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00 and exceeds 1.0. This acute hazard index is primarily attributable to TOC (assumed to be

tributylphosphate). As discussed previously, the use of this surrogate chemical for total organic carbon provides a conservative estimate of the potential acute health hazards. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons, indicating that no health effects would be expected.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00 and exceeds the ratio of 1.0. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard) and would present only minor irritations. The acute hazard index for the MEI general public was less than 1.0 for comparison to ERPG-1 values.

E.3.3.2 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows:

Source Term - The source term resulting from a hydrogen burn in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 100 years of operation was therefore estimated to be 2.25E-03.

Radiological Consequences - The radiological consequences presented in Table E.2.1.5 are reproduced in Table E.3.3.3.

Table E.3.3.3 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.18E+05
MEI Worker	2.18E+04
Noninvolved workers (1,835) [1]	2.45E+04
MEI noninvolved worker	1.74E+03
General public (114,734) [1]	3.70E+03
MEI general public	4.23E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk

The LCFs calculated in Section E.2.2.2.4 are reproduced in Table E.3.3.4.

Table E.3.3.4 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	2.3E-03	2.3E-03[2]
MEI worker	2.2E+04	N/A	N/A	2.3E-03	2.3E-03[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	2.3E-03	2.2E-02
MEI noninvolved worker	1.7E+03	N/A	N/A	2.3E-03	2.3E-03[2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	2.3E-03	4.2E-03
MEI general public	4.2E+00	5.0E-04	2.1E-03	2.3E-03	4.8E-06

Notes:
[1] Total number of fatal cancers if the accident occurs
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = LCF do not apply for a lethal dose

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

The potential acute hazards associated with the hydrogen burn in a waste storage tank are summarized in Table E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the worker because all workers would receive a lethal radiation dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);

- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.3.3.3 Occupational Injuries and Fatalities from Operations

The number of operation personnel was estimated at 1.04E+05 person-years (Jacobs 1996) during 100 years of routine operations. The total recordable injuries or illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (1.04E+05 person-years) · (2.2E+00 incidences/100 person-years) = 2.29E+03

Lost Workday Cases = (1.04E+05 person-years) · (1.1E+00 incidences/100 person-years) = 1.14E+03

Fatalities = (1.04E+05 person-years) · (3.2E-03 fatalities/100 person-years) = 3.33E+00

E.3.4 POST-REMEDIATION ACCIDENT

The post remediation accident for the Long-Term Management alternative would be the tanks collapsing due to an earthquake, as discussed in Section E.2.3. The onsite population of 183 people living downwind from the acute release would potentially die from a radiological dose of 1.79E+04 person-rem and exposure to toxic chemicals that would exceed the ERPG-3 threshold values by a factor of 1.16E+01.

The acute downwind offsite population radiological dose and the chronic population radiological dose of 3.64E+04 person-rem would result in 1.82E+01 LCFs. The population living closest to the Hanford Site would receive an exposure to toxic chemicals that would exceed the ERPG-2 threshold value by a factor of 8.41E+00, indicating they would suffer from reversible health effects.

E.4.0 IN SITU FILL AND CAP ALTERNATIVE

Under this alternative, all excess liquid from the DSTs would be evaporated at the 242-A Evaporator. The tanks would then be backfilled with gravel and a Hanford Barrier would be constructed over the tanks. The waste in the MUSTs would be grouted in situ.

E.4.1 CONSTRUCTION ACCIDENTS

Although construction activities are limited for the In Situ Fill and Cap alternative, the potential exists for accidents. The construction activities are discussed in Appendix B of the EIS.

The number of construction personnel was estimated at 7.25E+02 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities were calculated using the incidence rates from Table E.1.2.1 as follows.

Total Recordable Cases = (7.25E+02 person-years) · (9.75E+00 incidences/100 person-years) = 7.07E+01
Lost Workday Cases = (7.25E+02 person-years) · (2.45E+00 incidences/100 person-years) = 1.78E+01
Fatalities = (7.25E+02 person-years) · (3.20E-03 fatalities/100 person-years) = 2.32E-02

E.4.2 TRANSPORTATION ACCIDENTS

Transporting activities associated with this alternative include:

- Transporting construction material from offsite for the waste transfer system upgrade (W-314);
- Transporting cement from offsite to grout MUSTs;
- Transporting sand and gravel from the Pit 30 borrow site to grout MUSTs;
- Transporting earthen material from onsite borrow sites for the Hanford Barrier; and
- Employees commuting to work each day.

E.4.2.1 Radiological Cancer Risk

All operations would be conducted within established operating parameters for the tanks and would not involve transporting radioactive materials by container. Therefore, there would be no radiological cancer risks from transportation.

E.4.2.2 Chemical Exposure

Because there would be very limited transportation of toxic materials (e.g., lubricants for routine operations), it is extremely unlikely there would be any accidents resulting in chemical exposures. Therefore, transportation accidents involving chemical exposures were not quantified.

E.4.2.3 Occupational Injuries and Fatalities

Truck Transport Accidents

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Truck transportation activities to transport materials and supplies to the Hanford Site for this alternative were estimated (Jacobs 1996) and are summarized in Table E.4.2.1.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.4.2.2 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

The expected injuries and fatalities resulting from transportation accidents associated with the In Situ Fill and Cap alternative are summarized in Table E.4.2.3.

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck, site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 2.61E+04 (Jacobs 1996). Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:

(2.61E+04 person-years) · (260 days/year) · (140 km/day) · (1/1.35) = 7.05E+08 km (4.37E+08 mi)

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (7.05E+08 km) · (7.14E-07 injuries/km) = 5.03E+02
Fatalities = (7.05E+08 km) · (8.98E-09 fatalities/km) = 6.33E+00

Table E.4.2.1 Summary of Transportation Activities for the In Situ Fill and Cap Alternative

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - Onsite	Borrow	1.38E+03	1.00E+01 [1]	1.38E+04	N/A	N/A	N/A
Offsite	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [3]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02 [3]	N/A	N/A	7.42E+03	N/A
Grout Fill MUSTs							
Truck - Onsite	Sand/gravel	2.20E+03	1.00E+01[1]	2.20E+04	N/A	N/A	N/A
Offsite	Cement	4.63E+02	1.40E+02[3]	N/A	N/A	6.48E+04	N/A
Closure							
Truck - Onsite	Gravel (tank fill)	9.03E+04	1.00E+01[1]	9.03E+05	N/A	N/A	N/A
	Silt	4.93E+04	3.00E+01 [4]	1.48E+06	N/A	N/A	N/A
	Riprap	8.34E+04	3.20E+01 [5]	2.67E+06	N/A	N/A	N/A
	Aggregate	5.43E+04	1.00E+01 [1]	5.43E+05	N/A	N/A	N/A
			Total	5.63E+06	N/A	1.29E+05	0

Notes:
[1] Round trip distance from Pit 30 borrow site.
[2] Round trip distance from Portland/Seattle area.
[3] Round trip distance from Tri-Cities area.
[4] Round trip distance from McGee Ranch borrow site.
[5] Round trip distance from Vernita Quarry borrow site.
MUSTs = Miscellaneous underground storage tanks
N/A = Not Applicable

Table E.4.2.2 Distance Traveled in Population Zones for the In Situ Fill and Cap Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	6.43E+03	5.64E+06	1.16E+05

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.4.2.1.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.4.2.1.
[3] Rural represents 90 percent of total offsite distance from Table E.4.2.1.

Table E.4.2.3 Injuries and Fatalities Resulting from Truck Transportation Accidents for the In Situ Fill and Cap Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	4.82E-05	7.33E-02	6.14E-03	7.94E-02	N/A
	Injury	2.38E-03	2.14E+00	9.26E-02	N/A	2.23E+00
				Total	7.95E-02	2.24E+00

Notes:
N/A = Not Applicable

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck transport and employee vehicle accidents. The results are summarized in Table E.4.2.4.

Table E.4.2.4 Cumulative Injuries and Fatalities from Traffic Impacts for the In Situ Fill and Cap Alternative

Mode	Fatalities	Injuries
Truck transport	7.95E-02	2.24E+00
Employee vehicle	6.33E+00	5.03E+02
Total	6.41E+00	5.06E+02

E.4.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities. The operations are discussed in Appendix B.

This analysis separates and analyzes operations according to the following modes of operation:

- Continued operations - These operations have been previously discussed in No Action alternative; and
- Treatment - After excess liquid has been removed from the tank waste the tanks are filled with gravel.

The dominant accident scenarios analyzed in the following subsections were selected from the Accident Screening Table (Table E.4.3.1). The accidents listed in Table E.4.3.1 were taken from the Accident Analysis Data Package (Shire et al. 1995). The methodology of screening was previously discussed in Section 1.1.2.

Table E.4.3.1 Accident Screening Table for the In Situ Fill and Cap Alternative

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
Mode - Treatment					
In Situ Fill and Cap	Over Pressurization	4.4.2.1 Ferrocyanide reaction	Low	BDBA	2
		4.4.2.2 Organic reaction	Low	BDBA	2
	Fire	4.4.2.3 Flammable gas burn	Low	BDBA	2
	Tank Collapse	4.4.1.1 Partial tank dome collapse due to live load	Moderate	BDBA	3
	Deflagration	Jacobs 1996 Rock slinger ignites gas plume in tank	Moderate	EU	6

Notes:
A = Anticipated 1E-2 to 1 (value = 4)
BDBA = Beyond design basis accident 1E-7 to 1E-6 (value = 1)
EU = Extremely unlikely 1E-6 to 1E-4 (value = 2)
High = Onsite fatalities, offsite exposure >1E-1 rem (value = 4)
Low = Onsite exposure < 5 rem, offsite exposure insignificant (value = 2)
Moderate = Onsite exposure > 5 rem, offsite exposure < 1E-1 rem (value = 3)
No = Negligible onsite and offsite impacts; <0.005 rem onsite, < 0.0001 rem offsite (value = 1)
U = Unlikely 1E-4 to 1E-2 (value = 3)

E.4.3.1 Continued Operation Accident

The dominant continued operations accident is the mispositioned jumper accident previously discussed in the No Action alternative (Section E.2.2.1) and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The In Situ Fill and Cap alternative was based on 15 years of operations. Therefore, the probability was calculated to be 1.7E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 were reproduced in Table E.4.3.2.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the In Situ Fill and Cap alternative however, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.4.3.3. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper accident are summarized in Tables E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Table E.4.3.2 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.4.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	1.7E-01	1.9E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	1.7E-01	1.9E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	1.7E-01	1.7E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	1.7E-01	8.8E-03
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	1.7E-01	5.1E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	1.7E-01	2.4E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00 and exceeds 1.0. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate and provides a conservative estimate of the acute hazard. The acute hazard indices for the MEI noninvolved worker and general public was less than 1.0 for ERPG-1 comparisons and is not indicative of acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00 and exceeds the ratio of 1.0. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the

MEI general public was less than 1.0 for ERPG-1 comparisons and would not be indicative of acute effects.

E.4.3.2 Treatment Accident

The treatment accidents identified in the accident engineering data package (Shire et al. 1995) are summarized in Table E.4.3.1. The rock slinger ignites gas plume in tank accident, which would lead to a partial tank dome collapse, was identified as the dominant accident.

E.4.3.2.1 Scenario and Source-Term Development for Deflagration In Tank During Fill and Cap

It was postulated that hydrogen deflagration could occur while filling the tank with gravel using a rock slinger. A spark from the gravel ignites a hydrogen gas plume, which is suddenly released from the solids or salt cake causing the tank to overpressurize. This in turn causes the HEPA filters to blow out (in the case of DST) or the dome to collapse (in the case of SST). The impact of the postulated accident would result in an airborne release of radionuclides and chemical constituents in the tank.

For this event to occur, the following conditions must exist.

- Flammable gases must be generated from the waste.
- The concentration of the flammable gas must exceed the lower flammability limit.
- There must be an ignition source.
- The deflagration would have to generate enough energy to blow out the HEPA filters or collapse the tank dome.

Generation of Flammable Gas

All 177 waste tanks produce flammable gases at the molecular level such as hydrogen, ammonia, and methane due to radiolysis and organic degradation. The generation of flammable gas has been demonstrated in all the tanks and has resulted in 25 tanks being included on the Watchlist for hydrogen buildup. These 25 tanks consists of 19 SSTs and 6 DSTs.

Gas Concentration

Gases that are constantly being released into the headspace, and subsequently removed from the tank through the tank ventilation system, are unable to reach the lower flammability limits and do not pose a potential hydrogen deflagration event. Active ventilation systems can be engineered to provide removal of flammable gases and prevent gas concentrations from reaching 25 percent of the LFL.

Of concern are conditions in which the gas is not readily released from the waste leading to retention of substantial volumes of gas in the waste matrix. These trapped pockets of gas could be triggered into an instant release by pressure from the fill material on the tank waste. This would result in a gas plume in the head space. Studies made on the flammable gas Watchlist tanks (LANL 1995) have shown the potential for concentrations of hydrogen in these gas pockets to exceed the LFL. The composition of the mixture is important. If the mixture is hydrogen and air, it takes a relatively small ignition source (0.01 mJ - equivalent to pieces of fabric rubbing together or stray radio waves) to ignite the mixture.

Ignition of Gas

As the gravel is thrown into the tank by the rock slinger, it has the potential to create a spark by striking against metal inside the tank or against the gravel in the tank. The spark could ignite the sudden release of a plume of gas if hydrogen concentration exceeds the LFL. The probability of these events occurring at the same instant is low, however. At this time, it cannot be ruled out that the hydrogen concentration in the gas plume will exceed the LFL. The time it would take for the plume to diffuse and drop the hydrogen concentration to below the LFL by dilution from the ventilation system depends on the size and concentration of the plume, which cannot be accurately estimated at this time. Therefore, it may be assumed that the plume occurs and ignites.

The probability of the plume igniting could be reduced substantially by using wet sand or soil and possibly grout as fill instead of gravel.

Loss of Containment

The pressure necessary to cause failure in a SST varies from 11 psi for a 1,000,000- gal tank to 14 psi for a 500,000-gal tank (Julyk 1994). The pressure necessary to cause failure in a DST is 60 psi because it has a steel liner. The pressure generated by the ignited plume is dependent on the plume size, head space, heat transfer, and ventilation. A plume of flammable gas (16 m^3 [570 ft^3]) sufficiently concentrated, if ignited, will cause an overpressure of 15 psi, which is more than enough to collapse the dome of a SST (Fox-Stepnewski 1994). For the DST, 15 psi may not breach the dome but would blow out the HEPA filters. These potential overpressures do not take into account the 42-in. risers that penetrate the tank dome, which would absorb some of the pressure from a deflagration.

Additional saltwell pumping of the SSTs is expected to reduce the probability of hydrogen burps by removing liquids, which tend to trap gases in the saltcake. Additional saltwell pumping also would be expected to remove organic materials, such as complexants, which degrade to form flammable gases. The risk of a plume burn could also be reduced by filling the 25 Watchlist tanks last. It has been shown in tank waste that hydrogen generation rates drop by about one-half every 15 years. By waiting approximately 15 years to fill the 25 Watchlist tanks, the hydrogen generation rate of these tanks would drop by about 50 percent.

Source Term for SST Dome Collapse

It was conservatively assumed that all radiological and chemical contaminants in the headspace are available for release. The collapse of a portion of the dome and overburden compresses the vapor in the headspace as it descends, enhancing the vapor release rate by sudden pressure difference. Assuming a respirable concentration of contaminants in the headspace of 100 mg/m^3, a liquid SpG of 1.5, and a headspace volume of 1,000 m^3, the potential source term contribution from the headspace release was calculated as follows:

$$(100\ mg/m^3) \cdot (1\ g/L\ 1{,}000\ mg) \cdot (1\ L/1{,}000\ g) \cdot (1{,}000\ m^3) \cdot (1/1.5) = 7.0E\text{-}02\ L\ (7.4E\text{-}02\ qt)$$

It was assumed that gravel fill takes place after saltwell pumping that has reduced the liquid in the SSTs to less than 0.5 percent. It was conservatively assumed the surface was dry and crumbly and the MAR

was 2,500 L. It was postulated that the fall of the objects generated a substantial air movement to suspend a fraction the MAR.

Assuming the respirable release fraction to be 2.0E-03, the potential source term contribution from entrainment was calculated as follows:

(2,500 L) · (2.0E-03) = 5.0E+00 L (5.3E+00 qt)

It was postulated that prevailing winds resuspend a respirable fraction of the MAR (2,500 L). A respirable release fraction of 4.0E-05/hr for 24 hours was assumed. The potential source term contribution from resuspension was calculated as follows:

(2,500 L) · (4.0E-05/h) · (24 h) = 2.4E+00 L (2.5E+00 qt)

The combined source term of the potential SST accident is calculated as follows:

(0.07 L) + (5.0 L) + (2.4 L) = 7.47E+00 L (7.9E+00 qt)

Source Term for the DSTs

For the DSTs, a consequence analysis was performed (LANL 1995) based on a dome space loading of 0.39 L in the vapor space plus 3.30 L entrained by the deflagration. It was assumed that the HEPA filter was destroyed by the pressure pulse generated by the ignited gases. The amount of material on the filter was assumed to be 0.45 L. Therefore, the amount of inventory released from the tank would be 4.14 L. The bounding source term or respirable amount released from a DST and made airborne was 2.0 L for tank 241-SY-101 (LANL 1995).

E.4.3.2.2 Probability of the Event

The probability of a plume burn is assumed to be a likely event due to the gas pockets that exist in the waste and the available ignition source. However, the magnitude of the deflagration is uncertain. It is more likely that the gas burn would be small and would not have sufficient energy to blow out the HEPA filters or breach the tank. It is therefore assumed to be an extremely unlikely event, and for the purpose of this analysis, a probability of 1E-04 is used to calculate the point estimates.

E.4.3.2.3 Radiological Consequence for Tank Dome Collapse

The tank dome collapse would be bounding so the radiological dose to the receptors was calculated from the source term for the SST by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section E.1.1.6. The results (Shire et al. 1995) are summarized in Table E.4.3.4.

E.4.3.2.4 Radiological Cancer Risk for Tank Dome Collapse

All 10 workers and the MEI noninvolved worker potentially would receive a lethal dose. The LCFs and LCF point estimate risk were calculated for the receptors and presented in Table E.4.3.5.

Table E.4.3.4 Dose Consequence for Tank Dome Collapse

Receptor	Dose (person-rem)
Workers (10) [1]	6.2E+04
MEI worker	6.2E+03
Noninvolved workers (1,835) [1]	2.3E+04
MEI noninvolved worker	1.5E+03
General public (114,734) [1]	3.7E+03
MEI general public	3.9E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.4.3.5 Latent Cancer Fatality Risk from Tank Dome Collapse

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	6.2E+04	N/A	N/A	1.0E-04	1.0E-04 [3]
MEI worker	6.2E+03	N/A	N/A	1.0E-04	1.0E-04 [3]
Noninvolved workers (1,835) [2]	2.3E+04	4.0E-04	9.2E+00	1.0E-04	9.2E-04
MEI noninvolved worker	1.5E+03	N/A	N/A	1.0E-04	1.0E-04 [3]
General public (114,734) [2]	3.7E+03	5.0E-04	1.9E+00	1.0E-04	1.9E-04
MEI general public	3.9E+00	5.0E-04	2.0E-03	1.0E-04	2.0E-07

Notes:
[1] Total number of fatal cancers in the population if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose; therefore, LCFs are not included

In addition to all 10 workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be 9 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

E.4.3.2.5 Chemical Consequences of Tank Dome Collapse

The chemical exposure to the receptors from the postulated accident are similar to those summarized in the exposure column in Table E.2.2.8 and Table E.2.2.9 for toxic and corrosive/irritant effects, respectively. The consequences are summarized as follows:

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m (951 ft) from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m (5,838 ft) from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00, which exceeds 1.0 and indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m (951 ft) from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and would be indicative of only minor, transient effects. For the noninvolved worker population located 1,780 m (5,383 ft) from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.4.3.2.6 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and summarized as follows:

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 19 years of operation was therefore estimated to be 4.28E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.4.3.6.

Table E.4.3.6 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are reproduced in Table E.4.3.7.

In addition to all 10 workers, and the MEI noninvolved worker dying directly following the lethal exposure the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively. Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose, as discussed previously.

Table E.4.3.7 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	4.3E-04	4.3E-04[2]
MEI worker	2.2E+04	N/A	N/A	4.3E-04	4.3E-04 [2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	4.3E-04	4.2E-03
MEI noninvolved worker	1.7E-+03	N/A	N/A	4.3E-04	4.3E-04 [2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	4.3E-04	7.9E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	4.3E-04	9.0E-07

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.4.3.2.7 Occupation Injuries, Illnesses, and Fatalities from Operations

The number of operation personnel to support the In Situ Fill and Cap alternative is summarized as follows:

- Continued operations - 2.39E+04 person-years
- Treatment operations - 1.51E+03 person-years

Therefore, there would be a total of 2.54E+04 person-years for the In Situ Fill and Cap alternative. The total recordable injuries and illnesses lost workday cases and fatalities were calculated as follows:

Total Recordable Cases = (2.54E+04 person-years) · (2.2E+00 incidences/100 person-years) = 5.59E+02

Lost Workday Cases = (2.54E+04 person-years) · (1.1E+00 incidences/100 person-years) = 2.80E+02

Fatalities = (2.54E+04 person-years) · (3.2E-03 fatalities/100 person-years) = 8.13E-01

E.4.4 POST-REMEDIATION ACCIDENT

E.4.4.1 Deflagration in Storage Tank

After the tanks have been filled with gravel, the dome sealed off, and the Hanford Barrier placed over the tank farms, it was postulated that hydrogen builds up in the tank, reaches the LFL, and ignites. The probable sequence of events is that the tank would breach and possibly the asphalt layer in the Hanford Barrier would crack allowing an increased movement of the residual tank waste into the groundwater from increased infiltration. An explosion that could breach the dome, displace 23 m (7 ft) of overburden, and displace an additional 50 m (15 ft) of the Hanford Barrier, is considered to be incredible.

For this event to occur, the following conditions must exist:

- Flammable gases must be generated from the waste;
- The concentration of the flammable gas must exceed the lower flammability limit;
- There must be an ignition source; and
- The deflagration would have to generate enough energy to breach the tank and crack the asphalt liner.

Generation of Flammable Gas

All 177 waste tanks produce flammable gases at the molecular level such as hydrogen, ammonia, and methane along with nitrous oxide (an oxidizer) due to radiolysis, organic degradation, and corrosion.

Gas Concentration

Gases generated from the residual tank waste would diffuse and accumulate in the voids within the gravel and the tank headspace created by the waste settling under the pressure of the fill. If the hydrogen is not allowed to escape from the tank through leaks or cracks in the tank, the hydrogen concentration will continue to increase as long as the potential for radiolysis, organic degradation, or corrosion exists.

It has been shown in tank waste that hydrogen generation rates may drop by approximately one-half every 15 years. Therefore, the gas concentration potential could be reduced by allowing the tanks to vent for 100 years (during institutional controls) through vent pipes passing up through the Hanford Barrier. The vents could then be sealed off. Allowing the tanks to vent for 100 years would reduce the probability of hydrogen reaching the LFL in the tank. Hydrogen gas concentration could be retarded by placing catalytic recombiners in the tank that would recombine hydrogen and oxygen. The buildup of hydrogen could be mitigated over the long-term by engineering permanent measures to allow the gas to escape into the atmosphere. This may include cutting small openings in the tanks domes and the asphalt layer within the Hanford Barrier.

Ignition of Gas

If the gas concentrations in the tank manage to exceed the LFL, the ignition sources are limited. Possible ignition sources would include a lightning strike, an earthquake, or heat produced by reactions taking place in the materials remaining in the tank. If the gas was ignited, the propagation of the burn through the gravel is dependent on the size of the voids in the gravel matrix. Flames will not propagate in a porous material if the pore size is less than a critical value.

Consequences of Deflagration

The probable sequence of events is that the tank would breach and possibly the asphalt layer in the Hanford Barrier would crack allowing an increased leaching of the residual tank waste into the groundwater.

Consequences of Gas Building Up Under the Asphalt Barrier

If the hydrogen gas generated in the tanks was able to permeate from the tank through leaks and cracks, it could potentially build up under the asphalt layer of the Hanford Barrier if the permeation rate through the asphalt is slower than the rate in which it reaches the asphalt. Because hydrogen is highly diffusible, it is extremely unlikely that this would be the case. However, if hydrogen did build up under the asphalt layer, the worst credible consequences would result in the asphalt cracking allowing an increased movement of the residual tank waste into the groundwater. This event could be mitigated by placing catalytic recombiners under the asphalt that would recombine hydrogen and oxygen or venting the asphalt layer.

E.4.4.2 Seismic Induced Rupture of Stabilized Tanks

An evaluation was performed to determine if displacement on a fault could increase exposure to the waste after remediation was completed. For this to occur, a capable fault (a fault on which displacement can occur) would have to intersect one or more tanks and cause displacement equal to the thickness of the soil cover on the tank and the Hanford Barrier, a total of 6.4 m (21 ft).

The seismicity of the area was studied extensively when the area was a potential candidate site for a potential geologic repository (Rockwell 1983). This report concludes that earthquakes in the central Columbia Plateau indicate the stress regime that exists today has been relatively unchanged for more than 14 million years, and no change of this stress regime is anticipated over the next 100,000 years. Deformation was in progress in the late Grande Ronde time (approximately 14.5 million years before present) and continued at an average low rate of uplift (vertical strain) from 14.5 to 10.5 million years before present as determined from the aerial and thickness distribution of basalt flows.

Strain appears to be concentrated in steeply dipping strata and on major structures. New first-order structures do not appear to have developed in the Quaternary, nor are they anticipated to develop in the next 10,000 to 100,000 years (Rockwell 1983).

Seismicity in the central Columbia Plateau is confined to a thin, 28-km (8.5-ft) crust and is characterized by temporally and spatially limited swarms of low magnitude (magnitude ≤3.5), shallow (≤6 km [2 ft]) earthquakes that may be characteristic of brittle deformation in basalt.

Earthquakes in the central Columbia Plateau presently are not associated with mapped geologic faults, nor in a manner that suggests the presence of unmapped faults. Swarms have occurred on the flanks of the Saddle Mountains, a first-order structure which is faulted, but the events do not correspond with mapped faults. However, swarms also have occurred elsewhere where there are no mapped geologic structures. Some small alignments are indicated by the migration of swarm events in the Saddle Mountains.

An average displacement rate of 0.03 to 0.06 mm/yr (0.0012 to 0.0024 in/yr) was calculated. While a fault model has been assumed, this estimate could represent the total deformation associated with a wider zone north and south of the crest of the Saddle Mountains structure.

Because the average deformation rate of the region is 0.06 mm/yr (0.0024 in./yr), there would be 0.6 m (1.97 ft) of deformation in 10,000 years. This is much less than the 6.4 m (21 ft) of cover over the tanks. Therefore, even if all displacement in the region were concentrated on 1 fault and that fault intersected a tank, there would be only 0.6 m (1.97 ft) of displacement over 10,000 years and therefore, waste would not be displaced to the surface. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.5.0 IN SITU VITRIFICATION ALTERNATIVE

This section analyses the risk resulting from potential accidents associated with the In Situ Vitrification alternative.

The In Situ Vitrification alternative would involve the following activities:

- Construct and operate a Tank Farm Confinement Facility that would support in situ vitrification of tank waste including MUSTs;
- Waste transfer system upgrade construction (W-314);
- Continue evaporating liquid through the 242-A Evaporator;
- Fill tank voids with sand prior to in situ vitrification; and
- Construct Hanford Barriers over tank farms.

E.5.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the In Situ Vitrification alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated as follows.

The number of construction personnel was estimated at an average 2.25E+04 person-years (Jacobs 1996). The total recordable injuries and illnesses, lost workday cases, and fatalities during the 22 years of construction were calculated using the incidence rates from Table E.1.2.1 of this Appendix as follows:

Total Recordable Cases = (2.25E+04 person-years) · (9.75E+00 incidences/100 person-years) = 2.19E+03

Lost Workday Cases = (2.25E+04 person-years) · (2.45E+00 incidences/100 person-years) = 5.51E+02

Fatalities = (2.25E+04 person-years) · (3.2E-03 fatalities/100 person-years) = 7.19E-01

E.5.2 TRANSPORTATION ACCIDENTS

Transporting activities associated with this alternative include:

- Transporting construction material from offsite for the Tank Farms Confinement Facility and the waste transfer system upgrade;
- Transporting earthen material from onsite borrow site for the waste transfer system upgrade and to fill tank voids;

- Transporting aggregate from onsite borrow site for concrete;
- Transporting process chemicals for off-gas treatment;
- Transporting earthen material from onsite borrow site for the Hanford Barrier; and
- Employees commuting to work each day.

E.5.2.1 Radiological Cancer Risk

All operations would be conducted within established operating parameters for the tanks and would not involve transporting radioactive materials by container. Therefore, there would be no radiological cancer risks from transportation.

E.5.2.2 Chemical Exposure

Anhydrous ammonia would be transported to the Hanford Site by rail to support the off-gas treatment process. The toxicological impacts of anhydrous ammonia were analyzed in Green (Green 1995). The annual quantities and annual shipments for in situ vitrification are similar to those analyzed in Green (Green 1995). The toxicological impacts are summarized in Table E.5.2.1. Table E.5.2.1 compares the concentration of the postulated chemical release to exposure limits discussed in Section 1.1.7. The general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 and propane would exceed the ratio of exposure to ERPG-1 by 3.67E+00 for corrosive/irritant chemicals. Based on the magnitude of the anhydrous ammonia exceedance, potential lethal effects would be expected.

Table E.5.2.1 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the In Situ Vitrification Alternative

Analyte (Threshold values are presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Anhydrous Ammonia [1]	Threshold Value		1.77E+01	1.42E+02	7.10E+02
			Ratio of Exposure to ERPG		
	MEI General Public	8.77E+03	4.95E+02	6.18E+01	1.24E+01
Propane [2]	Threshold Value		1.80E+03	N/D	3.61E+04
			Ratio of Exposure to ERPG		
	MEI General Public	6.60E+03	3.67E+00	N/D	1.83E-01

Notes:
[1] AIHA ERPGs were used for anhydrous ammonia.
[2] Propane is a simple asphyxiant with no listed ERPGs. The TWA (1,800 mg/m³) was used as a surrogate value for the ERPG-1. The IDLH (36,100 mg/m³) was used as a surrogate value for the ERPG-3.
N/D = No data were available to establish an ERPG-2 with any certainty.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

E.5.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Truck and rail transportation activities to transport materials and supplies to the Site for this alternative were estimated in the In Situ Vitrification engineering data package (WHC 1995f) and are summarized in Table E.5.2.2. The total distance was calculated by multiplying the number of trips by the round-trip distance.

The number of fatalities and injuries were calculated by multiplying the total distance traveled in each zone, shown in Table E.5.2.3, by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3. The expected injuries and fatalities resulting from transportation accidents associated with the In Situ Vitrification alternative are summarized in Table E.5.2.4.

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 4.88E+04 (Jacobs 1996).

Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-City area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total personnel vehicle distance was therefore calculated to be 1.32E+09 km (8.2E+09 mi).

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section 1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents was calculated as follows:

Injuries = (1.32E+09 km) · (7.14E-7 injuries/km) = 9.40E+02
Fatalities = (1.32 E+09 km) · (8.98E-9 fatalities/km) = 1.18 E+01

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts is the sum of the truck, rail, and employee vehicle accidents. The results are summarized in Table E.5.2.5.

E.5.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities. The operations are discussed in Appendix B.

Table E.5.2.2 Summary of Transportation Activities for the In Situ Vitrification Alternative

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - Onsite	Borrow	1.38E+03	1.00E+01 [1]	1.38E+04	N/A	N/A	N/A
Offsite	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [3]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02	N/A	N/A	7.42E+03	N/A
Vitrification							
Construction Truck - onsite	Earthen borrow	2.12E+05	1.00E+01 [1]	2.12E+06	N/A	N/A	N/A
Truck - offsite	Miscellaneous	5.20E+03/year (19 year)	1.40E+02 [2]	N/A	N/A	1.38E+07	N/A
Rail - offsite	Steel	1.30E+02	8.00E+02 [3]	N/A	N/A	N/A	1.04E+05
	Cement	8.5E+01	8.00E+02 [3]	N/A	N/A	N/A	6.80E+04
Processing Truck - offsite	Miscellaneous	5.20E+03/year (12year)	1.40E+02 [2]	N/A	N/A	8.74E+06	N/A
Rail - offsite	Chemical	4.00E+00/year (12 year)	8.00E+02 [3]	N/A	N/A	N/A	3.84E+04
Grout Fill MUSTs Outside Tank Farm Areas							
Truck - Onsite	Sand/gravel	7.70E+02	1.00E+01 [1]	7.70E+03	N/A	N/A	N/A
Offsite	Cement	1.60E+02	1.40E+02 [3]	N/A	N/A	2.24E+04	N/A
Closure							
Truck - onsite	Silt	4.93E+04	3.00E+01 [4]	1.48E+06	N/A	N/A	N/A
	Riprap	8.34E+04	3.20E+01 [5]	2.67E+06	N/A	N/A	N/A
	Aggregate/ sand	5.43E+04	1.00E+01 [1]	5.43E+05	N/A	N/A	N/A
			Total	6.83E+06	N/A	2.27E+07	2.10E+05

Notes:
[1] Round-trip distance from Pit 30 borrow site.
[2] Round-trip distance from Tri-Cities area.
[3] Round-trip distance from Portland/Seattle area.
[4] Round-trip distance from McGee Ranch borrow site.
[5] Round-trip distance from Vernita Quarry borrow site.
N/A = Not Applicable

Table E.5.2.3 Distance Traveled in Population Zones for the In Situ Vitrification Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	1.13E+06 km	7.94E+06 km	2.03E+07 km
Rail	1.05E+04 km	1.05E+04 km	1.89E+05 km

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.5.2.2.
[2] Suburban represents 5 percent of total offsite distance and 100 percent of total onsite distance from Table E.5.2.2.
[3] Rural represents 90 percent of total offsite distance from Table E.5.2.2.

Table E.5.2.4 Injuries/Fatalities Resulting from Truck and Rail Transportation Accidents for the In Situ Vitrification Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatality	Total Injury
Truck	Fatality	8..46E-03	1.03E-01	1.08E+00	1.19E+00	N/A
	Injury	4.18E-01	3.02E+00	1.62E+01	N/A	1.97E+01
Rail	Fatality	1.79E-04	1.79E-04	3.22E-03	2.40E-03	N/A
	Injury	3.47E-04	3.47E-04	6.25E-03	N/A	4.80E-03
				Total	1.20E+00	1.98E+01

Notes:
N/A = Not Applicable

Table E.5.2.5 Cumulative Injuries and Fatalities from Traffic Impacts for the In Situ Vitrification Alternative

Mode	Fatalities	Injuries
Truck and Rail	1.20E+00	1.98E+01
Employee Vehicle	1.18E+01	9.40E+02
Total	1.30E+01	9.60E+02

This analysis separates and analyzes operations according to the following modes of operation:

- Continued operations - These operations have been previously discussed in the No Action alternative;
- Treatment - An off-gas hood would be placed over the tank and a confinement enclosure installed over the hood and the tank farm. The void space in the tank is filled with sand from the Hanford Site. Electrodes are positioned in the tank and surrounding the tank, and the tank waste is vitrified in place as well as the soil column surrounding the tanks.
- Hanford Barrier - After vitrification, the off-gas hood and confinement enclosure are removed. A multi-layer barrier of earthen material would be placed over the tank farms.

The dominant accident scenarios analyzed in the following subsections were selected from the Accident Screening Table (Table E.5.3.1). The accidents listed in Table E.5.3.1 were taken from the accident analysis data package (Shire et al. 1995). The methodology of screening was previously discussed in Section 1.1.2.

E.5.3.1 Continued Operation Accidents

The dominant continued operations accident is the "mispositioned jumper accident" previously discussed in the No Action alternative in Section E.2.2.1 and is summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The In Situ Vitrification alternative is based on 15 years of operations. Therefore, the probability for the In Situ Vitrification alternative was calculated to be 1.7E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.5.3.2.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the In Situ Vitrification alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.5.3.3. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper accident are summarized in Table E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, exceeds 1.0, and would be indicative of reversible acute effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). This is conservative in that the TOC was assumed to be tributylphosphate, which provides a conservative estimate of potential acute hazard. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons and would not be indicative of acute effects.

9613409.1409

Table E.5.3.1 Accident Screening Table for the In Situ Vitrification Alternative

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
Mode - Continued Operations					
Waste Transfer	Spray	4.1.3 Ruptured SST submersible pump line in valve pit with cover on - 80 psi	No	A	4
		4.1.4 Mispositioned jumper in SST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.5 Mispositioned jumper in DST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.6 Mispositioned jumper in SST valve pit with cover off - 80 psi	Low	A	8
		4.1.7 Mispositioned jumper in SST DCRT pump pit with cover off - 207 psi	**High**	**U**	**12**
		4.1.8 Mispositioned jumper in DST DCRT pump pit with cover off - 207 psi	High	U	12
		4.1.12 Valve stem seal leak in cross-site transfer line - 1500 psi	No	EU	2
	Leak	4.1.9 Aging waste pipeline break due to excavation activities	Low	EU	4
		4.1.10 DST pipeline break due to excavation activities	Low	EU	4
		4.1.11 Cross-site transfer line break due to excavation activities	Low	EU	4
Evaporator Operations	Leak	4.2.1 Corroded underground slurry line leak during emergency dump	Low	BDBA	2
		4.2.4 Underground slurry line leak due to excavation activity	Low	EU	4
	Spray	4.2.2 Leak at connection between jumper and wall nozzle in P-B-2 Pump Room with filtration - 240 psi	No	A	4
		4.2.3 Leak at connection between jumper and wall nozzle in P-B-2 Pump Room with filter damage - 240 psi	No	A	4
	Fire/deflagration	4.2.5 Red oil compound deflagrate or burn under elevated temperature in evaporator	No	BDBA	1
		4.2.6 Flammable compounds ignite under elevated temperature in evaporator	No	BDBA	1

Table E.5.3.1 Accident Screening Table for the In Situ Vitrification Alternative (cont'd)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
	Ventilation failure	4.2.7 Second-phase organics compounds ignite under elevated temperature in evaporator collection tank	No	BDBA	1
		4.2.8 Earthquake spills slurry in evaporator vessel and ruptures building ventilation	Moderate	U	9
Mode - Treatment					
In situ vitrification	Mechanical impact	4.4.4.1 Confinement collapse due to dropped machine	No	U	3
		4.4.4.2 Dropped electrode	No	U	3
	Ventilation failure	**4.4.4.3 Rupture of off-gas duct**	**Low**	**U**	**6**
		4.4.4.8 Loss of filtration - off-gas system	No	A	4
	confinement failure	4.4.4.4 Earthquake ruptures confinement	Low	EU	4
	Fire	4.4.4.5 Flammable gas burps accumulate and burn	No	U	3
	Explosion	4.4.4.6 Steam explosion during melt process	No	U	3
	Organic reaction	4.4.4.7 Organic reaction	No	U	3
Mode - Disposal/Storage					
Vitrified tank storage	Leak	Breach of vitrified tanks	No	BDBA	1

Notes:
A = Anticipated 1E-2 to 1 (value = 4)
BDBA = Beyond design basis accident 1E-7 to 1E-6 (value = 1)
DCRT = Double contained receiver tank
EU = Extremely unlikely 1E-6 to 1E-4 (value = 2)
High = Onsite fatalities, offsite exposure >1E-1 rem (value = 4)
Low= Onsite exposure < 5 rem, offsite exposure insignificant (value = 2)
Moderate= Onsite exposure > 5 rem, offsite exposure < 1E-1 rem (value = 3)
No = Negligible onsite and offsite impacts; <0.005 rem onsite, < 0.0001 rem offsite (value = 1)
SST = Single-shell tank
U = Unlikely 1E-4 to 1E-2 (value = 3)

Table E.5.3.2 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved worker (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.5.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	1.7E-01	1.9E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	1.7E-01	1.9E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	1.7E-01	1.7E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	1.7E-01	8.8E-03
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	1.7E-01	5.1E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	1.7E-01	2.4E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, exceeds 1.0, and would be indicative of reversible acute effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparisons and would not be indicative of acute effects.

E.5.3.2 Treatment Accidents

Types of potential accidents with treatment include ventilation failure, fire, explosion, exothermic reactions, mechanical impacts, and criticality. From Table E.5.3.1 the credible accident identified as having the highest risk was Accident 4.4.4.3, "rupture off-gas duct". It was postulated that a

double-ended break occurs in the off-gas line between the off-gas hood and the off-gas treatment facility. The initiating event was postulated to be an earthquake.

E.5.3.2.1 Scenario and Source Term Development for Off-Gas Rupture

Most radionuclides are volatilized at the vitrifying temperature and would be drawn into the off-gas hood and ventilation system by exhaust flow. The break would result in a release directly to the environment without the benefit of off-gas treatment.

The normal off-gas flow was calculated to be 300 m^3/min. A respirable airborne concentration of 200 mg/m^3 was assumed in the tank headspace because of the high temperature associated with the vitrification process. The airborne concentration was assumed to be less than 30 percent radioactive waste because of the presence of a frit. A specific gravity (SpG)=1.00 was assumed for the tank waste. The exposure time was assumed to be 16 hours. The respirable source term was calculated as follows:

$$(300\ m^3/min) \cdot (200\ mg/m^3) \cdot (30\ percent) \cdot (1.0E\text{-}06\ L/mg) \cdot (960\ min) = 17.3\ L\ (1.8\ qt)$$

E.5.3.2.2 Probability of Off-Gas Duct Rupture

The annual frequency of the earthquake was assumed to be 7.0E-04 in the accident data package (Shire et al. 1995). The probability for this scenario based on 9 years of operation was therefore estimated to be 6.3E-03.

E.5.3.2.3 Radiological Consequence of Off-Gas Duct Rupture

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section 1.1.6. The results are presented in Table E.5.3.4.

Table E.5.3.4 Dose Consequence for Off-Gas Duct Rupture

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.5E+04
MEI worker	2.5E+03
Noninvolved workers (1,835) [1]	4.5E+04
MEI noninvolved worker	1.2E+03
General public (114,734) [1]	1.1E+04
MEI general public	5.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent.
MEI = Maximally-exposed individual.

E.5.3.2.4 Radiological Cancer Risk for Off-Gas Duct Rupture

All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. A dose-to-risk conversion factor of 8.0E-04 LCF per person-rem for the noninvolved workers was used because the individual doses were greater than 20 rem. A dose-to risk conversion factor of 5.0E-04 LCF per person-rem for the general public was used. The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.5.3.5.

Table E.5.3.5 Latent Cancer Fatality Risk from Off-Gas Duct Rupture

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	2.5E+04	N/A	N/A	6.3E-03	6.3E-03 [3]
MEI Worker	2.5E+03	N/A	N/A	6.3E-03	6.3E-03 [3]
Noninvolved workers (1,835) [2]	4.5E+04	8.0E-04	3.6E+01	6.3E-03	2.3E-01
MEI noninvolved worker	1.2E+03	N/A	N/A	6.3E-03	6.3E-03 [3]
General public (114,734) [2]	1.1E+04	5.0E-04	5.5E+00	6.3E-03	3.5E-02
MEI general public	5.2E+00	5.0E-04	2.6E-03	6.3E-03	1.6E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] Risk of receiving lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose

In addition to all 10 workers and the MEI noninvolved worker dying from the lethal dose, the calculations show there would be 36 fatal cancers to the noninvolved worker population and 5 fatal cancers to the general public population attributable to this exposure.

E.5.3.2.5 Chemical Consequences of Off-Gas Duct Rupture

The chemical consequences to the receptors from the postulated accident were calculated in Appendix A of the accident data package (Shire et al.1995) and are summarized in the exposure column in Table E.5.3.6 and Table E.5.3.7. The tables compare the concentration of the postulated chemical releases to acute exposure criteria (ERPGs) discussed in Section 1.1.7.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose, as discussed previously.

Table E.5.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Off-Gas Duct Rupture

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Antimony [1]	Threshold Value		2.00E+00	4.00E+01	7.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	5.17E-05	2.59E-05	1.29E-06	7.39E-07
	MEI General Public	1.25E-07	6.25E-08	3.13E-09	1.79E-09
Arsenic [2]	Threshold Value		1.00E-01	7.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	5.89E-02	5.89E-01	8.41E-03	5.89E-03
	MEI General Public	1.43E-04	1.43E-03	2.04E-05	1.43E-05
Beryllium [3]	Threshold Value		6.00E-03	2.50E-02	1.00E-01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.45E-03	2.42E-01	5.80E-02	1.45E-02
	MEI General Public	3.51E-06	5.85E-04	1.40E-04	3.51E-05
Cadmium [4]	Threshold Value		2.00E-01	1.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.69E-01	1.35E+00	2.69E-01	2.69E-02
	MEI General Public	6.51E-04	3.26E-03	6.51E-04	6.51E-05
Cerium [5]	Threshold Value		7.00E+01	5.00E+02	7.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.69E-02	3.84E-04	5.38E-05	3.84E-05
	MEI General Public	6.51E-05	9.30E-07	1.30E-07	9.30E-08
Cobalt [6]	Threshold Value		5.00E-02	2.00E-01	8.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	6.72E-03	1.34E-01	3.36E-02	8.40E-04
	MEI General Public	1.63E-05	3.26E-04	8.15E-05	2.04E-06
Cyanide [7]	Threshold Value		5.00E+00	4.10E+01	2.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	4.86E-03	9.72E-04	1.19E-04	2.43E-05
	MEI General Public	1.18E-05	2.36E-06	2.88E-07	5.90E-08

Table E.5.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Off-Gas Duct Rupture (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Mercury [8]	Threshold Value		7.50E-02	1.00E-01	1.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.14E-03	1.52E-02	1.14E-02	8.14E-05
	MEI General Public	2.76E-06	3.68E-05	2.76E-05	1.97E-07
Neodymium [9]	Threshold Value		7.20E+01	5.04E+02	7.20E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.23E-02	1.00E-03	1.43E-04	1.00E-04
	MEI General Public	1.75E-04	2.43E-06	3.47E-07	2.43E-07
Oxalate [10]	Threshold Value		4.00E+00	2.00E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.84E+00	7.10E-01	1.42E-01	7.10E-02
	MEI General Public	6.89E-03	1.72E-03	3.45E-04	1.72E-04
Selenium [11]	Threshold Value		2.00E-01	4.00E-01	2.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.48E-03	1.24E-02	6.20E-03	1.24E-03
	MEI General Public	6.01E-06	3.01E-05	1.50E-05	3.01E-06
Tellurium [12]	Threshold Value		1.30E-01	3.00E-01	1.40E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	9.61E-03	7.39E-02	3.20E-02	6.86E-03
	MEI General Public	2.33E-05	1.79E-04	7.77E-05	1.66E-05
Thallium [13]	Threshold Value		3.00E-01	2.00E+00	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.34E-01	4.47E-01	6.70E-02	6.70E-03
	MEI General Public	3.26E-04	1.09E-03	1.63E-04	1.63E-05
Uranium [14]	Threshold Value		1.00E+00	1.00E+01	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	4.55E-01	4.55E-01	4.55E-02	2.28E-02
	MEI General Public	1.10E-03	1.10E-03	1.10E-04	5.50E-05

Table E.5.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Off-Gas Duct Rupture (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Vanadium [15]	Threshold Value		1.20E+00	1.10E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.55E-04	1.29E-04	1.41E-05	3.88E-06
	MEI General Public	3.76E-07	3.13E-07	3.42E-08	9.40E-09
Total Organic Carbon (as tributyl phosphate) [16]	Threshold Value		3.00E+00	1.50E+01	5.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.75E-01	2.58E-01	5.17E-02	1.55E-02
	MEI General Public	1.88E-03	6.27E-04	1.25E-04	3.76E-05
	Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
	Total MEI Noninvolved Worker Ratios		**4.28E+00**	**7.25E-01**	**1.72E-01**
	Total MEI General Public Ratios		**1.04E-02**	**1.76E-03**	**4.18E-04**

Notes:
[1] Guidelines are based on total antimony content.
[2] Guidelines are based on total arsenic content.
[3] Guidelines are based on total beryllium content and were developed by PNL.
[4] Guidelines are based on total cadmium content and were developed by HEHF.
[5] ERPGs for cerium were developed by HEHF using data for cerium chloride.
[6] Guidelines are based on total cobalt content and were developed by HEHF.
[7] Guidelines are based on total cyanide content and were developed by HEHF.
[8] Guidelines are based on total mercury content. ERPG-2 is the EPA Level of Concern. The ERPG-3 is the NIOSH IDLH f mercury vapor.
[9] Guidelines are based on total neodymium content and were based on neodymium chloride.
[10] Guidelines are based on oxalic acid and adjusted by ERPG (oxalic acid) · molecular weight compound/molecular weight oxalic acid.
[11] Guidelines are based on the toxicity of sodium selenate.
[12] Guidelines are based on sodium selenate and were developed by HEHF.
[13] ERPGs were developed by HEHF.
[14] ERPGs were based on soluble uranium compounds.
[15] ERPGs were based on vanadium pentoxide and were developed by HEHF.
[16] ERPGs were based on toxicity of tributylphosphate.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure exposed individual does not apply for a lethal radiological dose

Table E.5.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Off-Gas Duct Rupture

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Ammonia [1]	Threshold Value		4.60E-01	9.20E+00	2.30E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	6.72E-02	1.46E-01	7.30E-03	2.92E-03
	MEI General Public	1.63E-04	3.54E-04	1.77E-05	7.09E-06
Barium [2]	Threshold Value		6.80E+00	1.38E+02	3.44E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.00E-02	4.41E-03	2.17E-04	8.72E-05
	MEI General Public	7.26E-05	1.07E-05	5.26E-07	2.11E-07
Calcium [3]	Threshold Value		1.00E+00	2.20E+01	5.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.69E-01	2.69E-01	1.22E-02	4.98E-03
	MEI General Public	6.51E-04	6.51E-04	2.96E-05	1.21E-05
Chromium [4]	Threshold Value		2.60E+00	5.15E+01	1.29E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.03E-01	2.70E-01	1.37E-02	5.45E-03
	MEI General Public	1.70E-03	6.54E-04	3.30E-05	1.32E-05
Dysprosium [5]	Threshold Value		8.00E+01	6.00E+02	8.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	8.58E-04	1.07E-05	1.43E-06	1.07E-06
	MEI General Public	2.08E-06	2.60E-08	3.47E-09	2.60E-09
Lanthanum [6]	Threshold Value		6.90E+00	1.37E+02	3.43E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.10E-01	4.49E-02	2.26E-03	9.04E-04
	MEI General Public	7.51E-04	1.09E-04	5.48E-06	2.19E-06
Sodium Hydroxide	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.38E+00	1.19E+00	5.95E-02	2.38E-02
	MEI General Public	5.76E-03	2.88E-03	1.44E-04	5.76E-05

Table E.5.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Off-Gas Rupture(cont'd)

Analyte (Threshold Values are Presented in mg/m³)	Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Total MEI Worker Ratios		N/A	N/A	N/A
Total MEI Noninvolved Worker Ratios		1.92E+00	9.52E-02	3.81E-02
Total MEI General Public Ratios		4.66E-03	2.30E-04	9.23E-05

Notes:
[1] Guidelines were based on ammonium hydroxide normalized to sodium hydroxide.
[2] Guidelines were based on barium hydroxide normalized to sodium hydroxide.
[3] ERPGs were normalized to sodium hydroxide.
[4] Guidelines were based on chromium hydroxide normalized to sodium hydroxide.
[5] Guidelines were based on cerous hydroxide and were developed by HEHF.
[6] Guidelines were based on lanthanum fluoride normalized to sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure does not apply for a lethal radiological dose

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.28E+00, exceeds 1.0, and would be indicative of mild transient effects. This acute hazard index is primarily attributable to:

- Cadmium (approximately 31 percent of the total hazard);
- Oxalate (approximately 17 percent of the total hazard);
- Arsenic (approximately 14 percent of the total hazard);
- Uranium (approximately 11 percent of the total hazard);
- Thallium (approximately 10 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard);
- Beryllium (approximately 6 percent of the total hazard); and
- Cobalt (approximately 3 percent of the total hazard).

The acute hazard index for the general public MEI was less than 1.0 and would not be indicative of any acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.92E+00 and exceeds 1.0. This acute hazard index is primarily

attributable to sodium hydroxide (approximately 62 percent of the total hazard) and would be indicative of mild, transient effects. The acute hazard index for the MEI general public was less than 1.0 and would not be indicative of any acute effects.

E.5.3.3 Beyond Design Basis Accidents

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows:

Source Term - The source term resulting from a hydrogen burn in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 19 years of operation was therefore estimated to be 4.28E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.5.3.8.

Table E.5.3.8 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are reproduced in Table E.5.3.9.

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Table E.5.3.9 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	4.3E-04	4.3E-04 [2]
MEI worker	2.2E+04	N/A	N/A	4.3E-04	4.3E-04 [2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	4.3E-04	4.2E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	4.3E-04	4.3E-04 [2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	4.3E-04	7.9E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	4.3E-04	9.0E-07

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied

Chemical Consequences

The potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively. Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and would indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.5.3.4 Occupational Injuries and Fatalities from Operations

The number of operation personnel was estimated at approximately 2.64E+04 person-years (Jacobs 1996). The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (2.64E+04 person-years) · (2.2E+00 incidences/100 person-years) = 5.80E+02
Lost Workday Cases = (2.64E+04 person-years) · (1.1E+00 incidences/100 person-years) = 2.90E+02
Fatalities = (2.64E+04 person-years) · (3.2E-03 fatalities/100 person-years) =8.43E-01

E.5.4 POST-REMEDIATION ACCIDENT

E.5.4.1 Deflagration in Storage Tank

After the tank waste was vitrified in-place and the organics destroyed in the process, the probability of a tank generating enough hydrogen to exceed the LFL is considered to be incredible.

E.5.4.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault resulting in an airborne release of the waste after remediation is considered incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.6.0 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE

The Ex Situ Intermediate Separations alternative for tank waste would involve constructing and operating vitrification and support facilities, low-level vitrified waste burial vaults, and transfer lines from the tank farms and T Plant to the vitrified facilities. This alternative would also involve transporting retrieved tank waste and high-level vitrified waste to an offsite potential geologic repository, and vehicle traffic of the personnel required to support the alternative. This section analyzes the construction, operation, and transportation risks associated with this alternative.

E.6.1 CONSTRUCTION ACCIDENTS

The potential exists for accidents resulting from construction activities. The construction activities are outlined in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated as follows.

The number of construction personnel was estimated at an average 3.09E+04 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities during the 39 years of construction were calculated using the incidence rates from Table E.1.2.1 as follows:

Total Recordable Cases = (3.09E+04 person-years) · (9.75E+00 incidences/100 person-years) = 3.01E+03
Lost Workday Cases = (3.9E+04 person-years) · (2.45E+00 incidences/100 person-years) = 7.57E+02
Fatalities = (3.09E+04 person-years) · (3.2E-03 fatalities/100 person-years) = 9.88E-01

E.6.2 TRANSPORTATION ACCIDENTS

Under the Ex Situ Intermediate Separations alternative, Hanford Site tank waste would be stabilized by vitrification. The vitrified HLW would be shipped to an offsite potential geologic repository and the LAW would be buried in vaults on the Hanford Site. These waste streams would be transported by pipeline, truck, and rail. In addition to transporting the waste, construction materials and process chemicals would be transported to the Hanford Site by truck and rail. This alternative would also be supported by a work force of employees that would commute to work each day.

E.6.2.1 Radiological Cancer Risk

Radiological exposures resulting from accidents were analyzed using RADTRAN 4 (Neuhauser-Kanipe 1992). Exposures resulting from accidents from the following transportation activities were included in the analysis.

- Transporting residual waste from the SSTs to the processing facility by truck;
- Transporting waste from MUSTs to the processing facility by truck; and
- Transporting vitrified HLW from the Hanford Site to an offsite potential geological repository by rail.

The analysis addressed radiological accident impacts as both integrated population risk (i.e., accident frequencies times consequences integrated over the entire shipping campaign) and urban population risk. The analysis also addressed the consequences of a maximum credible accident using GENII computer codes (Napier et al. 1988).

The population doses calculated by RADTRAN 4 were dependent on the accident probability, release quantities, atmospheric dispersion parameters, population distribution parameters, human uptake, and dosimetry models.

Radiological exposure to the MEI was calculated for a bounding scenario accident by GENII computer code (Green 1995). The public and worker dose calculated by GENII were dependent on the release quantities of radioactive material, release duration, receptor location, and meteorology.

E.6.2.1.1 Truck Transport of Retrieved Tank Waste

The receptor dose and LCF risk resulting from the accident analysis for retrieval of MUST waste and SST residuals is presented in Table E.6.2.1 for the integrated population and Table E.6.2.2 for the MEI worker and MEI general public.

Table E.6.2.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
MUSTs	3.43E-03	4.0E-04	1.37E-06
SSTs	1.58E-02	4.0E-04	6.32E-06

Notes:
LCF = Latent cancer fatalities
MUST = Miscellaneous underground storage tank
SST = Single-shell tank

Table E.6.2.2 MEI Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
MUSTs			
Worker MEI	3.5E-01	4.0E-04	1.4E-04
General public MEI	1.5E-03	5.0E-04	7.5E-07
SSTs			
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual
MUST = Miscellaneous underground storage tank
SST = Single-shell tank

There would be no LCFs resulting from an accident while transporting retrieved waste on site.

E.6.2.1.2 Rail Transport of Vitrified High-Level Waste

The receptor dose, LCF risk resulting from the RADTRAN 4 accident analysis for transporting vitrified HLW to an offsite potential geologic repository is presented in Table E.6.2.3 for the integrated population, urban population, MEI worker, and MEI general public. The calculations show there would be no LCFs.

Table E.6.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated population	9.25E-02	5.0E-04	4.6E-05
Urban population	2.52E-02	5.0E-04	1.3E-05
MEI worker	6.9E+00	4.0E-04	2.8E-03
MEI general public	3.0E-02	5.0E-04	1.5E-05

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

E.6.2.2 Chemical Exposure

Chemicals transported to the Hanford Site to support the pretreatment and vitrification processes would have the greatest chemical impact. An analysis was performed to 1) identify the hazardous chemicals that could result in the largest toxicological impacts; and 2) evaluate the toxicological impacts of the maximum credible accidents involving the highest hazard chemicals (Green 1995). A preliminary screening analysis was performed to identify the chemicals representing the highest potential toxicological hazard. The highest hazard chemicals in terms of toxicity were determined to be nitric acid, sodium hydroxide, anhydrous ammonia, and dicyclopentadiene. The chemical concentrations resulting from the maximum credible accident at 100 m (328 ft) and the frequency of the accidents (Green 1995) are summarized in Table E.6.2.4.

Table E.6.2.4 Chemical Releases from Postulated Accidents for the Ex Situ Intermediate Separations Alternative

Chemical	Concentration	Frequency
Nitric Acid	0.28 mg/m^3	5.0E-08/yr
Sodium Hydroxide	4.9 mg/m^3	2.0E-07/yr
Anhydrous Ammonia	8,770 mg/m^3	2.0E-07/yr
Dicyclopentadiene	1.02 mg/m^3	1.0E-8/yr

Table E.6.2.5 compares the respirable concentration of the postulated chemical releases to exposure limits discussed in Section E.1.1.7.

Table E.6.2.5 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Ex Situ Intermediate Separations Alternative

Analyte (Threshold values are presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Anhydrous Ammonia [1]	Threshold Value		1.77E+01	1.42E+02	7.10E+02
			Ratio of Exposure to ERPG		
	MEI General Public	8.77E+03	4.95E+02	6.18E+01	1.24E+01
Dicyclopentadiene [2]	Threshold Value		2.20E+01	1.10E+02	1.10E+04
			Ratio of Exposure to ERPG		
	MEI General Public	1.02E+00	4.64E-02	9.27E-03	9.27E-05
Nitric Acid [3]	Threshold Value		5.20E+00	6.55E+01	1.31E+02
			Ratio of Exposure ERPG		
	MEI General Public	2.80E-01	5.38E-02	4.27E-03	2.14E-03
Sodium Hydroxide [4]	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI General Public	4.90E+00	2.45E+00	1.23E-01	4.90E-02

Notes:
[1] AIHA ERPGs were used for anhydrous ammonia.
[2] The OSHA permissible exposure limit-time weighted average (PEL-TWA) concentration for dicyclopentadiene (27 mg/m3) was similar to the PEL-TWA for 1,3-butadiene (22 mg/m3). Therefore, the ERPGs for 1,3-butadiene were conservatively used as surrogate values.
[3] AIHA ERPGs were used for nitric acid.
[4] AIHA ERPGs were used for sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure exposed individual does not apply for a lethal radiological dose

Table E.6.2.5 shows the general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 and sodium hydroxide would exceed the ratio of exposure to ERPG-1 by 2.45E+00 for corrosive/irritant chemicals. The magnitude of the anhydrous ammonia exceedance indicates potential lethal effects for the MEI general public.

E.6.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the Site for this alternative were estimated (WHC 1995j) and are summarized in Table E.6.2.6.

Table E.6.2.6 Summary of Transportation Activities for the Ex Situ Intermediate Separations Alternative

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Retrieval							
Construction Truck - offsite	Concrete	4.80E+02/year (20 year)	1.40E+02 [1]	N/A	N/A	1.34E+06	N/A
	Raw material	4.50E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	7.20E+05	N/A
	Equipment	2.50E+01/year (20 year)	1.00E+04 [3]	N/A	N/A	5.00E+06	N/A
	Miscellaneous	5.20E+03/year (20 year)	1.40E+02 [1]	N/A	N/A	1.46E+07	N/A
Rail - offsite	Raw material	1.00E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	N/A	1.60E+05
Waste Transport Truck - onsite	Inactive miscellaneous underground storage tank waste	6.25E+02	2.0E+01	1.25E+04	N/A	N/A	N/A
Waste Transfer System Upgrade (W-314)							
Truck - onsite	Borrow	1.38E+03	1.00E+01 [4]	1.38E+04	N/A	N/A	N/A
Truck - offsite	Steel	5.3E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
Vitrification							
Construction Truck - onsite	Borrow	1.69E+05	1.00E+01 [4]	1.69E+06	N/A	N/A	N/A
Truck - offsite	Concrete	5.45E+04	1.40E+02 [1]	N/A	N/A	7.63E+06	N/A
	Steel	1.51E+04	8.00E+02 [2]	N/A	N/A	1.21E+07	N/A
	Miscellaneous	7.54E+03/year (10 year)	1.40E+02 [1]	N/A	N/A	1.06E+07	N/A
Processing Truck - offsite	Process material	2.30E+03/year (19 year)	8.00E+02 [2]	N/A	N/A	3.50E+07	N/A
	Miscellaneous	6.70E+03/year (19 year)	1.40E+02 [1]	N/A	N/A	1.78E+07	N/A
Rail - offsite	Process material	2.74E+02/year (19 year)	8.00E+02 [2]	N/A	N/A	N/A	4.16E+06

Table E.6.2.6 Summary of Transportation Activities for the Ex Situ Intermediate Separations Alternative (cont'd)

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Vitrified High-Level Waste Transport							
Rail - offsite	Vitrified glass	8.35E+02	4.28E+03 [5]	N/A	N/A	N/A	3.57E+06
Grout Fill MUSTs							
Truck - onsite	Sand/Gravel	2.20+03	1.00E+01 [4]	2.20E+04	N/A	N/A	N/A
Truck - offsite	Cement	4.63E+02	1.40E+02 [1]	N/A	N/A	6.48E+04	N/A
Closure							
Truck - onsite	Silt [8]	8.53E+04	3.00E+01 [6]	2.56E+06	N/A	N/A	N/A
	Tank fill [9]	9.86E+04	1.00E+01 [4]	9.86E+05	N/A	N/A	N/A
	Riprap [8]	1.22E+05	3.20E+01 [7]	3.90E+06	N/A	N/A	N/A
	Sand [8]	1.00E+05	1.00E+01 [4]	1.00E+06	N/A	N/A	N/A
			Total	1.02E+07	N/A	1.05E+08	7.90E+06

Notes:
[1] Round-trip distance from Tri-Cities area.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from East Coast.
[4] Round-trip distance from Pit 30 borrow site.
[5] Round-trip distance to Yucca Mountain.
[6] Round-trip distance from McGee Ranch borrow site.
[7] Round-trip distance from Vernita Quarry borrow site.
[8] For Hanford Barrier.
[9] For tank fill.
N/A= Not Applicable

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.6.2.7 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3. The expected injuries and fatalities resulting from transportation accidents associated with the Ex Situ Intermediate Separations alternative are summarized in Table E.6.2.8.

Table E.6.2.7 Distance Traveled in Population Zones for the Ex Situ Intermediate Separations Alternative

Mode	Urban	Suburban	Rural
Truck	5.24E+06	1.54E+07	9.43E+07
Rail	3.95E+05	3.95E+05	7.11E+06

Table E.6.2.8 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ Intermediate Separations Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	3.93E-02	2.01E-01	5.00E+00	5.24E+00	N/A
	Injury	1.94E+00	5.86E+00	7.55E+01	N/A	8.33E+01
Rail	Fatality	6.71E-03	6.71E-03	1.21E-01	1.34E-01	N/A
	Injury	1.30E-02	1.30E-02	2.35E-01	N/A	2.61E-01
				Total	5.37E+00	8.35E+01

Notes:
N/A = Not Applicable

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, Site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 8.57E+04.

Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:
(8.57E+04 person-years) · (260 days/year) · (140 km/day) · (1/1.35) = 2.31E+09 km (1.44E+09 mi)

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (2.31E+09 km) · (7.14E-07 injuries/km) = 1.65E+03
Fatalities = (2.31E+09 km) · (8.98E-09 fatalities/km) = 2.07E+01

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.6.2.9.

Table E.6.2.9 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ Intermediate Separations Alternative

Mode	Fatalities	Injuries
Truck and rail transport	5.37E+00	8.35E+01
Employee vehicle	2.07E+01	1.65E+03
Total	2.61E+01	1.73E+03

9613409.1419

This page intentionally left blank.

APPENDIX E
RISK FROM ACCIDENTS

E.6.3 OPERATION ACCIDENTS

Operations are discussed in Appendix B. The operations are separated and analyzed according to the following modes of operation:

- Continued operations - Previously discussed in the No Action alternative.
- Retrieval operations - DST waste would be extracted from tanks using slurry pumping. Hydraulic sluicing would be used to remove SST waste. If hydraulic sluicing did not meet waste retrieval goals, robotic arm-based retrieval methods would be used. Pipelines would transfer waste from the tank farms to a pretreatment facility.
- Pretreatment - Pretreatment would consist of sludge washing and chemical processes to separate the waste into HLW and LAW streams. The solids in the tank would be washed to dissolve salts to the extent practical and those salts bearing liquid would be added to the supernatant stream going to Cs removal. The sludge remaining in the tanks would be washed to remove additional solids and to minimize the feed to the HLW vitrification facility.
- Treatment - LAW would be pumped into a LAW vitrification facility where it would be mixed with feed material and vitrified into glass. Vitrification is a high-temperature process where waste is blended with additives and fused into a glass-like form suitable for disposal. The HLW would be routed from a lag storage facility, where it would be temporarily stored before treatment, to a HLW vitrification facility where it would be mixed with feed material (such as glass formers) and then fused into glass.
- Disposal - The LAW glass would be placed into a near-surface retrievable disposal facility on the Hanford Site. A Hanford Barrier would be constructed over the retrievable LAW disposal site to inhibit migration of contaminants or intrusion by humans or animals. The high-level vitrification waste glass would be placed in aboveground storage facility at the Hanford Site. It would then be shipped by rail to an offsite potential geologic repository for permanent disposal.

The potential for accidents exists during the operation of these activities. The dominant accident scenarios analyzed in the following subsections were selected from the Accident Screening Table (Table E.6.3.1). The methodology of the table was previously discussed in Section E.1.1.2.

E.6.3.1 Routine Operation Accidents

The dominant routine operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The Ex Situ Intermediate Separations routine operation activity was based on 23 years of operations, therefore, the probability was calculated to be 2.5E-01.

Table E.6.3.1 Accident Screening Table for the Ex Situ Intermediate Separations Alternative

Activity	Hazard	Cause		Severity	Annual Frequency	Risk
Mode - Continued Operations						
Waste Transfer	Spray	4.1.3	Ruptured SST submersible pump line in valve pit with cover on - 80 psi	No	A	4
		4.1.4	Mispositioned jumper in SST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.5	Mispositioned jumper in DST DCRT pump pit with cover on - 207 psi	No	A	4
		4.1.6	Mispositioned jumper in SST valve pit with cover off - 80 psi	Low	A	8
		4.1.7	**Mispositioned jumper in SST DCRT pump pit with cover off - 207 psi**	**High**	**U**	**12**
		4.1.8	Mispositioned jumper in DST DCRT pump pit with cover off - 207 psi	High	U	12
		4.1.12	Valve stem seal leak in cross-site transfer line - 1,500 psi	No	EU	2
	Leak	4.1.9	Aging waste pipeline break due to excavation activities	Low	EU	4
		4.1.10	DST pipeline break due to excavation activities	Low	EU	4
		4.1.11	Cross-site transfer line break due to excavation activities	Low	EU	4
Evaporator Operations	Leak	4.2.1	Corroded underground slurry line leak during emergency dump	Low	BDBA	2
		4.2.4	Underground slurry line leak due to excavation activity	Low	EU	4
	Spray	4.2.2	Leak at connection between jumper and wall nozzle in P-B-2 pump room with filtration - 240 psi	No	A	4
		4.2.3	Leak at connection between jumper and wall nozzle in P-B-2 pump room with filter damage - 240 psi	No	A	4
	Fire/deflagration	4.2.5	Red oil compound deflagrate or burn under elevated temperature in evaporator	No	BDBA	1
		4.2.6	Flammable compounds ignite under elevated temperature in evaporator	No	BDBA	1
		4.2.7	Second-phase organics compounds ignite under elevated temperature in evaporator collection tank	No	BDBA	1
	Ammonia release	4.2.9	Ammonia release from the evaporator due to a blending error	High	EU	8

9613409.1421

Table E.6.3.1 Accident Screening Table for the Ex Situ Intermediate Separations Alternative (cont'd)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
Evaporator operations	Ventilation failure	4.2.8 Earthquake spills slurry in evaporator vessel and ruptures building ventilation	Moderate	U	9
Retrieval					
Mechanical retrieval	Mechanical impact	4.3.1.1 Tank dome collapse when retrieval equipment is inadvertently dropped	Moderate	EU	6
		4.3.1.6 Container transport truck crashes spilling content of container	No	A	4
	Fire/deflagration	4.3.1.2 Ferrocyanide and oxidizer mix and ignite from spark	Low	BDBA	2
		4.3.1.4 Generated hydrogen in tank is ignited	Low	BDBA	2
		4.3.1.9 Power loss to ventilation allows flammable gas buildup	Low	EU	4
	Criticality	4.3.1.3 Waste in tank reaches criticality state	Low	BDBA	2
	Ventilation failure	4.3.1.5 Earthquake causes double-ended rupture of ventilation recirculation duct	Low	U	6
		4.3.1.7 SST steam explosion surge overcomes tank ventilation negative pressure	Low	U	6
		4.3.1.10 HEPA filter plug and blowout due to ventilation heater failure	Low	EU	4
	Leak	4.3.1.8 Retrieval activity creates leaks from existing corrosion holes	No	A	4
Hydraulic retrieval	Mechanical impact	4.3.2.1 Tank dome collapse due to overload	Low	BDBA	2
	Spray	4.3.2.2 Pressurized spray leak at slurry pump outlet with cover on - 195 psi	No	A	4
		4.3.2.3 Pressurized spray leak at supernate/sluice pump inlet cover on - 195 psi	No	A	4
		4.3.2.14 Pressurized spray release inside tank	No	EU	2
	Leak	4.3.2.4 Seismic rupture of slurry pump outlet waste transfer line	Low	U	6
		4.3.2.5 Seismic rupture of supernate pump inlet waste transfer line	Low	U	6
		4.3.2.7 Break in slurry transfer piping	Low	EU	4
		4.3.2.10 SST leakage to the soil column	No	A	4

Table E.6.3.1 Accident Screening Table for the Ex Situ Intermediate Separations Alternative (cont'd)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
Hydraulic retrieval	Ventilation failure	4.3.2.6 Seismic rupture of ventilation recirculation duct	Low	U	6
		4.3.2.9 Loss of filtration	Low	EU	4
		4.3.2.8 SST steam explosion surge overcomes tank ventilation negative pressure	Low	U	6
	Fire/deflagration	4.3.2.11 Ferrocyanide reaction	Low	BDBA	2
		4.3.2.13 Hydrogen burn	Low	EU	4
		4.3.2.15 Loss of services or power - factor for flammable gas build up	Low	EU	4
	Criticality	4.3.2.12 Criticality	Low	BDBA	2
Mode - Pretreatment					
Waste staging and sampling facility	Spill/spray	4.5.1.1.1 Process tank spill due to earthquake	No	EU	2
	Spray	**4.5.1.1.2 Line break occurs within vault due to earthquake**	**Low**	**U**	**6**
Separations facility	Spill	4.5.2.1 Process tank spill due to earthquake	Low	EU	4
	Explosion	4.5.2.2 Cs ion exchange is exposed to concentrated HNO_3 and ignites	Low	EU	4
Mode - Treatment					
LAW vitrification facility	Spill/spray	4.5.3.1 Process tank spill due to earthquake	Low	BDBA	2
	Fire/deflagration	4.5.3.2 Kerosene/oxygen line ruptures due to dropped melter cell cover block	Low	BDBA	2
		4.5.3.3 Dicyclopentadiene\cyclopentadiene feed line rupture by crane load during maintenance activity	No	EU	2

9613409.1422

Table E.6.3.1 Accident Screening Table for the Ex Situ Intermediate Separations Alternative (cont'd)

Activity	Hazard	Cause	Severity	Annual Frequency	Risk
HLW vitrification facility	Spill	4.5.4.1 Melter, process tanks spill due to earthquake	Low	BDBA	2
	Fire/deflagration	4.5.4.2 Hydrogen buildup due to air sweep failure	High	BDBA	4
	Mechanical impact	4.5.4.4 Canister dropped due to mechanical or human failure	No	A	4
	Leak	4.5.4.5 Canister storage cask leaks	Low	BDBA	2
Mode - Disposal/Storage					
LAW repository	Leak	4.7.1 Breach of LAW vault	No	BDBA	1
HLW temporary storage	Leak	4.8.1 Breach of HLW storage container	No	BDBA	1
HLW transport offsite	Mechanical impact	Rail accident			

Notes:

A = Anticipated 1.0E-02 to 1 (value = 4)
BDBA = Beyond design basis accident 1.0E-07 to 1.0E-06 (value = 1)
DCRT = Double-contained tank receiver
EU = Extremely unlikely 1.0E-06 to 1.0E-04 (value = 2)
HEPA = High-efficiency particulate air
High = Onsite fatalities, offsite exposure >1E-1 rem (value = 4)
HLW = High-level waste
LAW = Low-activity waste
Low = Onsite exposure < 5 rem, offsite exposure <0.0001 rem (value = 2)
Moderate = Onsite exposure > 5 rem, offsite exposure <1.0E-01 (value = 3)
No = Negligible onsite and offsite impact, <0.005 rem onsite, < 0.0001 rem offsite (value = 1)
SST = Single-shell tank
U = Unlikely 1.0E-04 to 1.0E-02 (value = 3)

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.6.3.2.

Table E.6.3.2 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Ex Situ Intermediate Separations alternative. However, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.6.3.3.

Table E.6.3.3 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.5E-01	2.8E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.5E-01	2.8E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.5E-01	2.5E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.5E-01	1.4E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.5E-01	7.8E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.5E-01	3.7E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper accident are summarized in Table E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 and would be indicative of reversible acute effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC was assumed to be tributylphosphate which provides a conservative estimate of the potential acute hazard. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons and would not be indicative of any acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, which exceeds the ratio of 1.0 and would be indicative of reversible, acute health effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.1E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard) and would be indicative of transient effects. The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparisons and would not be indicative of any acute effects.

E.6.3.2 Retrieval Accidents

The types of potential accidents associated with retrieval are leaks, sprays, ventilation failure, fire/deflagration, mechanical impacts, and criticality. From the Accident Screening Table (Table E.6.3.1), the accident within design basis identified as having the highest risk was Accident E.4.3.1.10, "loss of filtration."

A tank dome collapse analysis (Shire et al. 1995) concluded that the annual frequency of the event would be incredible depending on barrier configuration and administrative controls. The collapse of a tank dome would require a heavy vehicle on the dome. Large objects such as the tank 101-SY mixer pump do not represent sufficient weight to cause damage to the tank dome because they are suspended from a support structure in the central pit. Mechanical barriers such as posts spaced closely together would prevent large vehicles from driving on top of the domes without removing the posts. Post removal would be administratively controlled through a controlled locking system. Failure of the barrier configuration and the administrative control system was calculated to be 1.0E-07/year.

E.6.3.2.1 Scenario and Source Term Development for Loss of Filtration

It was postulated that a ventilation heater failure could occur due to an electrical fault resulting in humid air plugging the HEPA filter and filter blowout. A condenser maintenance backflush error could also result in plugging the HEPA filter and filter blowout. Loss of both stages of filtration would allow an unfiltered release LPF of 1.00 for the bounding scenario.

The impact of the postulated accident during retrieval of tank waste would result in an airborne release of the radionuclides in the headspace of the tank. Assuming a respirable concentration of radionuclides in the headspace of 100 mg/m^3 (based on a partition fraction between liquid and aerosol of 1.0E-07), a liquid SpG of 1, and a headspace volume of 2,500 m^3, the potential source term from the headspace release was calculated as follows:

$$(100\ mg/m^3) \cdot (2{,}500\ m^3) \cdot (1\ g/1{,}000\ mg) \cdot (1\ L/1{,}000\ g) \cdot (1) = 0.25\ L\ (0.26\ qt)$$

E.6.3.2.2 Probability of Loss of Filtration

The annual frequency of the event was calculated in the potential accident data package (Shire et al. 1995) as follows:

> The failure rate of an electrically powered air heater was calculated to be 8.8E-03/yr based on an hourly failure rate of 1.0E-06. The HEPA filtration system would have a monitoring and alarm system that could detect the change in the differential pressure caused by a filter plug or filter blowout. This system was given a failure rate of 1.0E-03/yr. The annual frequency of this event was therefore calculated to be 8.8E-06. Based on 23 years of operation, the probability was calculated to be 2.0E-04.

E.6.3.2.3 Radiological Consequence from Loss of Filtration

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section E.1.1.6. The results (Shire et al. 1995) are summarized in Table E.6.3.4.

Table E.6.3.4 Dose Consequence from Loss of Filtration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.7E+04
MEI worker	3.7E+03
Noninvolved workers (1,835) [1]	1.04E+03
MEI noninvolved worker	2.42E+01
General public (114,734) [1]	1.56E+02
MEI general public	1.04E-01

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

E.6.3.2.4 Radiological Cancer Risk from Loss of Filtration

All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. Based on a dose-to-risk conversion factor of 4.0E-04 LCF per person-rem for the noninvolved workers and 5.0E-04 LCF per person-rem for the general public, the LCFs and the LCF point estimate risk were calculated for the receptors and are presented in Table E.6.3.5.

Table E.6.3.5 Latent Cancer Fatality Risk from Loss of Filtration

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.7E+04	N/A	N/A	2.0E-04	2.0E-04 [3]
MEI worker	3.7E+03	N/A	N/A	2.0E-04	2.0E-04 [3]
Noninvolved workers (1,835) [2]	1.0E+03	4.0E-04	4.2E-01	2.0E-04	8.4E-05
MEI noninvolved worker	2.4+01	8.0E-04	1.9E-02	2.0E-04	3.9E-06
General public (114,734) [2]	1.6E+02	5.0E-04	7.8E-02	2.0E-04	1.6E-05
MEI general public	1.0E-01	5.0E-04	5.2E-05	2.0E-04	1.1E-08

Notes:
[1] Total number of fatal cancers if the accident occurs
[2] Number of people in exposed population
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not included.

Aside from all 10 workers dying from a lethal dose, the calculations show there would be less than 1 LCF attributed to the exposure to the noninvolved workers and the general public if the accident occurred.

E.6.3.2.5 Chemical Consequences from Loss of Filtration

The chemical exposure to the receptors from the postulated accident was calculated using the same methodology found in Appendix A of the accident data package (Shire et al. 1995) and summarized in the exposure column in Table E.6.3.6 and Table E.6.3.7 for toxic and corrosive/irritant effects, respectively. The tables compare the concentration of the postulated chemical released to acute exposure criteria (ERPGs) discussed in Section 1.1.7.

Chemical impacts were not evaluated for the MEI worker because all workers would receive a lethal radiation dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 6.60E+01, which and exceeds 1.0 and would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Uranium (approximately 52 percent of the total hazard);
- Oxalate (approximately 26 percent of the total hazard);
- Selenium (approximately 7 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard); and
- Mercury (approximately 5 percent of the total hazard).

Table E.6.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Loss of Filtration Accident

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Antimony [1]	Threshold Value		2.00E+00	4.00E+01	7.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.69E+00	1.85E+00	9.23E-02	5.27E-02
	MEI Noninvolved Worker at 290 m	1.30E-02	6.50E-03	3.25E-04	1.86E-04
	MEI Noninvolved Worker at 1,780 m	1.80E-04	9.00E-05	4.50E-06	2.57E-06
	MEI General Public	1.47E-04	7.35E-05	3.68E-06	2.10E-06
Arsenic [2]	Threshold Value		1.00E-01	7.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.96E+00	2.96E+01	4.23E-01	2.96E-01
	MEI Noninvolved Worker at 290 m	1.07E-02	1.07E-01	1.53E-03	1.07E-03
	MEI Noninvolved Worker at 1,780 m	1.44E-04	1.44E-03	2.06E-05	1.44E-05
	MEI General Public	1.18E-04	1.18E-03	1.69E-05	1.18E-05
Beryllium [3]	Threshold Value		6.00E-03	2.50E-02	1.00E-01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.40E-02	1.07E+01	2.56E+00	6.40E-01
	MEI Noninvolved Worker at 290 m	2.32E-04	3.87E-02	9.28E-03	2.32E-03
	MEI Noninvolved Worker at 1,780 m	3.12E-06	5.20E-04	1.25E-04	3.12E-05
	MEI General Public	2.55E-06	4.25E-04	1.02E-04	2.55E-05
Cadmium [4]	Threshold Value		2.00E-01	1.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	4.19E+00	2.09E+01	4.19E+00	4.19E-01
	MEI Noninvolved Worker at 290 m	1.52E-02	7.59E-02	1.52E-02	1.52E-03
	MEI Noninvolved Worker at 1,780 m	2.04E-04	1.02E-03	2.04E-04	2.04E-05
	MEI General Public	1.67E-04	8.35E-04	1.67E-04	1.67E-05
Cerium [5]	Threshold Value		7.00E+01	5.00E+02	7.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.12E+00	3.03E-02	4.24E-03	3.03E-03
	MEI Noninvolved Worker at 290 m	7.68E-03	1.10E-04	1.54E-02	1.10E-05
	MEI Noninvolved Worker at 1,780 m	1.03E-04	1.47E-06	2.06E-07	1.47E-07
	MEI General Public	8.43E-05	1.20E-06	1.69E-07	1.20E-07
Cobalt [6]	Threshold Value		5.00E-02	2.00E-01	8.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.33E+00	2.66E+01	6.65E+00	1.66E-01
	MEI Noninvolved Worker at 290 m	4.82E-03	9.64E-05	2.41E-02	6.03E-04
	MEI Noninvolved Worker at 1,780 m	6.48E-05	1.30E-03	3.24E-04	8.10E-06
	MEI General Public	5.29E-05	1.06E-03	2.65E-04	6.61E-06

Table E.6.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Loss of Filtration Accident (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Cyanide [7]	Threshold Value		5.00E+00	4.10E+01	2.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.94E+01	7.88E+00	9.61E-01	1.97E-01
	MEI Noninvolved Worker at 290 m	1.43E-01	2.86E-02	3.48E-03	7.14E-04
	MEI Noninvolved Worker at 1,780 m	1.92E-03	3.84E-04	4.68E-05	9.60E-06
	MEI General Public	1.57E-03	3.14E-04	3..82E-05	7.84E-06
Mercury [8]	Threshold Value		7.50E-02	1.00E-01	1.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	4.93E+01	6.57E+02	4.93E+02	3.52E+00
	MEI Noninvolved Worker at 290 m	1.79E-01	2.38E+00	1.79E+00	1.28E-02
	MEI Noninvolved Worker at 1,780 m	2.40E-03	3.20E-02	2.40E-02	1.71E-04
	MEI General Public	1.96E-03	2.61E-02	1.96E-02	1.40E-04
Neodymium [9]	Threshold Value		7.20E+01	5.04E+02	7.20E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.71E-01	3.76E-03	5.37E-04	3.76E-04
	MEI Noninvolved Worker at 290 m	9.82E-04	1.36E-05	1.95E-06	1.36E-06
	MEI Noninvolved Worker at 1,780 m	1.32E-05	1.83E-07	2.62E-08	1.83E-08
	MEI General Public	1.08E-05	1.50E-07	2.14E-08	1.50E-08
Oxalate [10]	Threshold Value		4.00E+00	2.00E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.90E+02	1.72E+02	3.45E+01	1.72E+01
	MEI Noninvolved Worker at 290 m	2.50E+00	6.25E-01	1.25E-01	6.25E-02
	MEI Noninvolved Worker at 1,780 m	3.36E-02	8.40E-03	1.68E-03	8.40E-04
	MEI General Public	2.74E-02	6.86E-03	1.37E-03	6.86E-04
Selenium [11]	Threshold Value		2.00E-01	4.00E-01	2.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	8.62E+00	4.31E+01	2.15E+01	4.31E+00
	MEI Noninvolved Worker at 290 m	3.12E-02	1.56E-01	7.81E-02	1.56E-02
	MEI Noninvolved Worker at 1,780 m	4.20E-04	2.10E-03	1.05E-03	2.10E-04
	MEI General Public	3.43E-04	1.72E-03	8.58E-04	1.72E-04

Table E.6.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Loss of Filtration Accident (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Tellurium [12]	Threshold Value		1.30E-01	3.00E-01	1.40E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	4.93E-01	3.79E+00	1.64E+00	3.52E-01
	MEI Noninvolved Worker at 290 m	1.79E-03	1.37E-02	5.95E-03	1.28E-03
	MEI Noninvolved Worker at 1,780 m	2.40E-05	1.85E-04	8.00E-05	1.71E-05
	MEI General Public	1.96E-05	1.51E-04	6.53E-05	1.40E-05
Thallium [13]	Threshold Value		3.00E-01	2.00E+00	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.23E+01	4.10E+01	6.16E+00	6.16E-01
	MEI Noninvolved Worker at 290 m	4.46E-02	1.49E-01	2.23E-02	2.23E-03
	MEI Noninvolved Worker at 1,780 m	6.00E-04	2.00E-03	3.00E-04	3.00E-05
	MEI General Public	4.90E-04	1.63E-03	2.45E-04	2.45E-05
Uranium [14]	Threshold Value		1.00E+00	1.00E+01	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	6.90E+02	6.90E+02	6.90E+01	3.45E+01
	MEI Noninvolved Worker at 290 m	2.50E+00	2.50E+00	2.50E-01	1.25E-01
	MEI Noninvolved Worker at 1,780 m	3.36E-02	3.36E-02	3.36E-03	1.68E-03
	MEI General Public	2.74E-02	2.74E-02	2.74E-03	1.37E-03
Vanadium [15]	Threshold Value		1.20E+00	1.10E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.20E-01	2.67E-01	2.91E-02	8.00E-03
	MEI Noninvolved Worker at 290 m	1.16E-03	9.67E-04	1.05E-04	2.90E-05
	MEI Noninvolved Worker at 1,780 m	1.56E-05	1.32E-05	1.42E-06	3.90E-07
	MEI General Public	1.27E-05	1.06E-05	1.15E-06	3.18E-07
Total Organic Carbon (as tributyl phosphate) [16]	Threshold Value		3.00E+00	1.50E+01	5.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.85E+02	6.16E+01	1.23E+01	3.69E+00
	MEI Noninvolved Worker at 290 m	6.69E-01	2.23E-01	4.46E-02	1.34E-02
	MEI Noninvolved Worker at 1,780 m	9.00E-03	3.00E-03	6.00E-04	1.80E-04
	MEI General Public	7.35E-03	2.45E-03	4.90E-04	1.47E-04

Table E.6.3.6 Comparison of Chemical Concentrations to Toxic Concentration Limits for Loss of Filtration Accident (cont'd)

Analyte (Threshold Values are Presented in mg/m³)	Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
Total MEI Noninvolved Worker at 100 m Ratios		**1.77E+03**	**6.52E+02**	**6.60E+01**
Total MEI Noninvolved Worker at 290 m Ratios		**6.40E+00**	**2.36E+00**	**2.39E-01**
Total MEI Noninvolved Worker at 1,780 m Ratios		**8.60E-02**	**3.18E-02**	**3.22E-03**
Total MEI General Public Ratios		**7.03E-02**	**2.60E-02**	**2.63E-03**

Notes:
[1] Guidelines are based on total antimony content.
[2] Guidelines are based on total arsenic content.
[3] Guidelines are based on total beryllium content and were developed by PNL.
[4] Guidelines are based on total cadmium content and were developed by HEHF.
[5] ERPGs for cerium were developed by HEHF using data for cerium chloride.
[6] Guidelines are based on total cobalt content and were developed by HEHF.
[7] Guidelines are based on total cyanide content and were developed by HEHF.
[8] Guidelines are based on total mercury content. ERPG-2 is the EPA Level of Concern. The ERPG-3 is the NIOSH IDLH for mercury vapor.
[9] Guidelines are based on total neodymium content and were based on neodymium chloride.
[10] Guidelines are based on oxalic acid and adjusted by ERPG (oxalic acid) · molecular weight compound/molecular weight oxalic acid.
[11] Guidelines are based on the toxicity of sodium selenate.
[12] Guidelines are based on sodium selenate and were developed by HEHF.
[13] ERPGs were developed by HEHF.
[14] ERPGs were based on soluble uranium compounds.
[15] ERPGs were based on vanadium pentoxide and were developed by HEHF.
[16] ERPGs were based on toxicity of tributylphosphate.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure does not apply to a lethal radiological dose

Table E.6.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Loss of Filtration Accident

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Ammonia [1]	Threshold Value		4.60E-01	9.20E+00	2.30E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	3.69E+00	8.03E+00	4.01E-01	1.61E-01
	MEI Noninvolved Worker at 290 m	1.34E-02	2.91E-02	1.46E-03	5.82E-04
	MEI Noninvolved Worker at 1,780 m	1.80E-04	3.91E-04	1.96E-05	7.83E-06
	MEI General Public	1.47E-04	3.20E-04	1.60E-05	6.39E-06
Barium [2]	Threshold Value		6.80E+00	1.38E+02	3.44E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	9.85E+01	1.45E+01	7.14E-01	2.86E-01
	MEI Noninvolved Worker at 290 m	3.57E-01	5.25E-02	2.59E-03	1.04E-03
	MEI Noninvolved worker at 1,780 m	4.80E-03	7.06E-04	3.48E-05	1.40E-05
	MEI General Public	3.92E-03	5.76E-04	2.84E-05	1.14E-05
Calcium [3]	Threshold Value		1.00E+00	2.20E+01	5.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	2.34E+02	2.34E+02	1.06E+01	4.33E+00
	MEI Noninvolved Worker at 290 m	8.48E-01	8.48E-01	3.85E-02	1.57E-02
	MEI Noninvolved Worker at 1,780 m	1.14E-02	1.14E-02	5.18E-04	2.11E-04
	MEI General Public	9.31E-03	9.31E-03	4.23E-04	1.72E-04
Chromium [4]	Threshold Value		2.60E+00	5.15E+01	1.29E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.70E+02	6.54E+01	3.30E+00	1.32E+00
	MEI Noninvolved Worker at 290 m	6.16E-01	2.37E-01	1.20E-02	4.77E-03
	MEI Noninvolved Worker at 1,780 m	8.28E-03	3.18E-03	1.61E-04	6.42E-05
	MEI General Public	6.76E-03	2.60E-03	1.31E-04	5.24E-05
Dysprosium [5]	Threshold Value		8.00E+01	6.00E+02	8.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	1.65E-01	2.06E-03	2.75E-04	2.06E-04
	MEI Noninvolved Worker at 290 m	5.98E-04	7.48E-06	9.97E-07	7.48E-07
	MEI Noninvolved Worker at 1,780 m	8.04E-06	1.01E-07	1.34E-08	1.01E-08
	MEI General Public	6.57E-06	8.21E-08	1.10E-08	8.21E-09

Table E.6.3.7 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Loss of Filtration Accident (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Lanthanum [6]	Threshold Value		6.90E+00	1.37E+02	3.43E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	8.31E+01	1.18E+01	5.93E-01	2.37E-01
	MEI Noninvolved Worker at 290 m	2.95E-01	4.27E-02	2.15E-03	8.59E-01
	MEI Noninvolved Worker at 1,780 m	3.96E-03	5.74E-04	2.89E-05	1.15E-05
	MEI General Public	3.23E-03	4.69E-04	2.36E-05	9.43E-06
Sodium Hydroxide	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker at 100 m	5.66E+02	2.83E+02	1.42E+01	5.66E+00
	MEI Noninvolved Worker at 290 m	2.05E+00	1.03E+00	5.13E-02	2.05E-02
	MEI Noninvolved worker at 1,780 m	2.76E-02	1.38E-02	6.90E-04	2.76E-04
	MEI General Public	2.25E-02	1.13E-02	5.64E-04	2.25E-04
	Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
	Total MEI Noninvolved Worker at 100 m Ratios		**6.17E+02**	**2.98E+01**	**1.20E+01**
	Total MEI Noninvolved Worker at 290 m		**2.24E+00**	**1.08E-01**	**4.35E-02**
	Total MEI Noninvolved Worker at 1,780 m		**3.01E-02**	**1.45E-03**	**5.85E-04**
	Total MEI General Public Ratios		**2.45E-02**	**1.19E-03**	**4.77E-04**

Notes:
[1] Guidelines were based on ammonium hydroxide normalized to sodium hydroxide.
[2] Guidelines were based on barium hydroxide normalized to sodium hydroxide.
[3] ERPGs were normalized to sodium hydroxide.
[4] Guidelines were based on chromium hydroxide normalized to sodium hydroxide.
[5] Guidelines were based on cerous hydroxide and were developed by HEHF.
[6] Guidelines were based on lanthanum fluoride normalized to sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure does not apply to a lethal radiological dose.

The nearest noninvolved worker population consists of 335 people and is located 290 m (951 ft) from the accident. The cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 2.36E+00, which exceeds the ratio of 1.0 and indicates reversible acute health effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m (5,840 ft) from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 8.60E-02 (5,840 ft), which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.2E+01, which exceeds 1.0 and indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 47 percent of the total hazard);
- Calcium (approximately 36 percent of the total hazard); and
- Chromium (approximately 11 percent of the total hazard).

For the noninvolved worker population located 290 m (951 ft) from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.24E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 3.01E-02, which does not exceed the ratio of 1.0 and would indicate no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.45E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.6.3.3 Pretreatment

Types of potential accidents associated with pretreatment are spills, sprays, and explosions. From the Accident Screening Table (Table E.6.3.1), the DBA accident identified as having the highest risk was a pressurized spray release, Accident 4.5.1.1.2, "line break occurs within vault due to earthquake".

It was postulated that a line break could occur within a ventilated vault because of a DBE. The vault would be located between the separations facility and the HLW vitrification facility. The pump pressure to the line would be 207 psi.

E.6.3.3.1 Scenario and Source Term Development for Seismic Induced Line Break in Vault

It was determined a maximum respirable spray release from the ruptured line with a pump pressure of 207 psi would be approximately 7.6 L/minute (Shire et al. 1995). The total released quantity would be drawn through a double-stage HEPA filter before being released to the environment.

Assumptions were as follows:

- The spray was limited to 16 hours (960 minutes).
- HEPA filters provided an assumed LPF of 1.0E-05.

The source term was calculated as follows:

(7.6 L/minutes) · (960 minutes) · (1.0E-05) = 7.3E-02 L (7.7E-02 qt)

E.6.3.3.2 Probability of Seismic Induced Line Break in Vault

The annual frequency of the event was assumed to be 6.0E-05 (Shire et al. 1995). This is the frequency of a 0.23 g DBE at the Hanford Site. It is assumed the leak would occur given the probability of the DBE. Based on 20 years of pretreatment operation the probability was calculated to be 1.2E-03.

E.6.3.3.3 Radiological Consequences of Seismic Reduced Line Break in Vault

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code using the methodology discussed in Section E.1.1.4. The results (Shire et al. 1995) are summarized in Table E.6.3.8.

Table E.6.3.8 Dose Consequence for Seismic Reduced Line Break in Vault

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.4E+01
MEI worker	3.4E+00
Noninvolved workers (5,500) [1]	7.1E+00
MEI noninvolved worker	2.9E-01
General public (114,734) [1]	2.7E+00
MEI general public	4.5E-04

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI= Maximally-exposed individual

E.6.3.3.4 Radiological Cancer Risk of Seismic Induced Line Break in Vault

Based on a dose-to-risk conversion factor of 4.0E-04 LCF per person-rem for the workers and noninvolved workers and 5.0E-04 per person-rem for the general public, the LCFs and the LCF risk (point estimate) were calculated for the receptors and presented in Table E.6.3.9. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

E.6.3.3.5 Chemical Consequences of Seismic Induced Line Break in Vault

The chemical exposure to the receptors from the postulated pretreatment spray release were calculated in Appendix A of Shire (Shire et al. 1995) and are summarized in the exposure column in Table E.6.3.10 and Table E.6.3.11 for toxic and corrosive/irritant effects, respectively. The tables compare the concentration of the postulated chemical releases to acute exposure criteria (ERPGs) discussed in Section 1.17.

Table E.6.3.9 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.4E+01	4.0E-04	1.4E-02	1.2E-03	1.6E-05
MEI worker	3.4E+00	4.0E-04	1.4E-03	1.2E-03	1.6E-06
Noninvolved workers (5,500) [2]	7.1E+00	4.0E-04	2.8E-03	1.2E-03	3.4E-06
MEI noninvolved worker	2.9E-01	4.0E-04	1.2E-04	1.2E-03	1.4E-07
General public (114,734) [2]	2.7E+00	5.0E-04	1.4E-03	1.2E-03	1.6E-06
MEI general public	4.5E-04	5.0E-04	2.3E-07	1.2E-03	2.7E-10

Notes:
[1] Total number of fatal cancer in the population if the accident occurs.
[2] Number of people in exposed population.
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

Table E.6.3.10 Comparison of Chemical Concentrations to Toxic Concentration Limits for Pretreatment Spray Release

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Antimony [1]	Threshold Value		2.00E+00	4.00E+01	7.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.07E-06	3.54E-06	1.77E-07	1.01E-07
	MEI General Public	4.63E-09	2.32E-09	1.16E-10	6.61E-11
Arsenic [2]	Threshold Value		1.00E-01	7.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.84E-07	3.84E-06	5.49E-08	3.84E-08
	MEI General Public	2.51E-10	2.51E-09	3.59E-11	2.51E-11
Beryllium [3]	Threshold Value		6.00E-03	2.50E-02	1.00E-01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.51E-08	1.25E-05	3.00E-06	7.51E-07
	MEI General Public	4.91E-11	8.18E-09	1.96E-09	4.91E-10
Cadmium [4]	Threshold Value		2.00E-01	1.00E+00	1.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.09E-06	1.55E-05	3.09E-06	3.09E-07
	MEI General Public	2.02E-09	1.01E-08	2.02E-09	2.02E-10
Cerium [5]	Threshold Value		7.00E+01	5.00E+02	7.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.73E-05	1.10E-06	1.55E-07	1.10E-07
	MEI General Public	5.06E-08	7.23E-10	1.01E-10	7.23E-11
Cobalt [6]	Threshold Value		5.00E-02	2.00E-01	8.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.89E-07	7.78E-06	1.95E-06	4.86E-08
	MEI General Public	2.54E-10	5.08E-09	1.27E-09	3.18E-11
Cyanide [7]	Threshold Value		5.00E+00	4.10E+01	2.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.34E-04	4.68E-05	5.71E-06	1.17E-06
	MEI General Public	1.53E-07	3.06E-08	3.73E-09	7.65E-10

Table E.6.3.10 Comparison of Chemical Concentrations to Toxic Concentration Limits for Pretreatment Spray Release (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Mercury [8]	Threshold Value		7.50E-02	1.00E-01	1.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.71E-06	4.95E-05	3.71E-05	2.65E-07
	MEI General Public	2.43E-09	3.24E-08	2.43E-08	1.74E-10
Neodymium [9]	Threshold Value		7.20E+01	5.04E+02	7.20E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	6.19E-06	8.60E-08	1.23E-08	8.60E-09
	MEI General Public	4.05E-09	5.63E-11	8.04E-12	5.63E-12
Oxalate [10]	Threshold Value		4.00E+00	2.00E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	MEI General Public	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Selenium [11]	Threshold Value		2.00E-01	4.00E-01	2.00E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.54E-06	1.77E-05	8.85E-06	1.77E-06
	MEI General Public	2.31E-09	1.16E-08	5.78E-09	1.16E-09
Tellurium [12]	Threshold Value		1.30E-01	3.00E-01	1.40E+00
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.46E-07	1.12E-06	4.87E-07	1.04E-07
	MEI General Public	1.00E-10	7.69E-10	3.33E-10	7.14E-11
Thallium [13]	Threshold Value		3.00E-01	2.00E+00	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	6.36E-01	2.12E+00	3.18E-01	3.18E-02
	MEI General Public	4.16E-04	1.39E-03	2.08E-04	2.08E-05
Uranium [14]	Threshold Value		1.00E+00	1.00E+01	2.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	6.19E-05	6.19E-05	6.19E-06	3.10E-06
	MEI General Public	4.05E-08	4.05E-08	4.05E-09	2.03E-09

Table E.6.3.10 Comparison of Chemical Concentrations to Toxic Concentration Limits for Pretreatment Spray Release (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Vanadium [15]	Threshold Value		1.20E+00	1.10E+01	4.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.81E-07	1.51E-07	1.65E-08	4.53E-09
	MEI General Public	1.19E-10	9.92E-11	1.08E-11	2.98E-12
Total Organic Carbon (as tributyl phosphate) [16]	Threshold Value		3.00E+00	1.50E+01	5.00E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	1.77E-03	5.90E-04	1.18E-04	3.54E-05
	MEI General Public	1.16E-06	3.87E-07	7.73E-08	2.32E-08
	Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
	Total MEI Noninvolved Worker Ratios		**2.12E+00**	**3.18E-01**	**3.18E-02**
	Total MEI General Public Ratios		**1.39E-03**	**2.08E-04**	**2.08E-05**

Notes:
[1] Guidelines are based on total antimony content.
[2] Guidelines are based on total arsenic content.
[3] Guidelines are based on total beryllium content and were developed by PNL.
[4] Guidelines are based on total cadmium content and were developed by HEHF.
[5] ERPGs for cerium were developed by HEHF using data for cerium chloride.
[6] Guidelines are based on total cobalt content and were developed by HEHF.
[7] Guidelines are based on total cyanide content and were developed by HEHF.
[8] Guidelines are based on total mercury content. ERPG-2 is the EPA Level of Concern. The ERPG-3 is the NIOSH IDLH for mercury vapor.
[9] Guidelines are based on total neodymium content and were based on neodymium chloride.
[10] Guidelines are based on oxalic acid and adjusted by ERPG (oxalic acid) · molecular weight compound/molecular weight oxalic acid.
[11] Guidelines are based on the toxicity of sodium selenate.
[12] Guidelines are based on sodium selenate and were developed by HEHF.
[13] ERPGs were developed by HEHF.
[14] ERPGs were based on soluble uranium compounds.
[15] ERPGs were based on vanadium pentoxide and were developed by HEHF.
[16] ERPGs were based on toxicity of tributylphosphate.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure does not apply to a lethal radiological dose

Table E.6.3.11 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Pretreatment Spray Release

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Ammonia [1]	Threshold Value		4.60E-01	9.20E+00	2.30E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.14E-04	6.83E-04	3.41E-05	1.37E-05
	MEI General Public	2.05E-07	4.46E-07	2.23E-08	8.91E-09
Barium [2]	Threshold Value		6.80E+00	1.38E+02	3.44E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	2.34E-06	3.44E-07	1.70E-08	6.80E-09
	MEI General Public	1.53E-09	2.25E-10	1.11E-11	4.45E-12
Calcium [3]	Threshold Value		1.00E+00	2.20E+01	5.40E+01
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	5.75E-05	5.75E-05	2.61E-06	1.06E-06
	MEI General Public	3.76E-08	3.76E-08	1.71E-09	6.96E-10
Chromium [4]	Threshold Value		2.60E+00	5.15E+01	1.29E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	7.07E-04	2.72E-04	1.37E-05	5.48E-06
	MEI General Public	4.63E-07	1.78E-07	8.99E-09	3.59E-09
Dysprosium [5]	Threshold Value		8.00E+01	6.00E+02	8.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	3.93E-08	4.91E-10	6.55E-11	4.91E-11
	MEI General Public	2.57E-11	3.21E-13	4.28E-14	3.21E-14
Lanthanum [6]	Threshold Value		6.90E+00	1.37E+02	3.43E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	4.42E-05	6.41E-06	3.23E-07	1.29E-07
	MEI General Public	2.89E-08	4.19E-09	2.11E-10	8.43E-11
Sodium Hydroxide	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI Worker	N/A			
	MEI Noninvolved Worker	8.93E-03	4.47E-03	2.23E-04	8.93E-05
	MEI General Public	5.84E-06	2.92E-06	1.46E-07	5.84E-08

Table E.6.3.11 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Pretreatment Spray Release (cont'd)

Analyte (Threshold Values are Presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
	Total MEI Worker Ratios		**N/A**	**N/A**	**N/A**
	Total MEI Noninvolved Worker Ratios		**5.48E-03**	**2.74E-04**	**1.10E-04**
	Total MEI General Public Ratios		**3.59E-06**	**1.79E-07**	**7.17E-08**

Notes:
[1] Guidelines were based on ammonium hydroxide normalized to sodium hydroxide.
[2] Guidelines were based on barium hydroxide normalized to sodium hydroxide.
[3] ERPGs were normalized to sodium hydroxide.
[4] Guidelines were based on chromium hydroxide normalized to sodium hydroxide.
[5] Guidelines were based on cerous hydroxide and were developed by HEHF.
[6] Guidelines were based on lanthanum fluoride normalized to sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual
N/A = Chemical exposure does not apply to a lethal radiological dose

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.12E+00, which exceeds 1.0 and would be indicative of minor transient effects. This acute hazard index is primarily attributable to thallium (approximately over 99 percent of the total hazard). The acute hazard index for the general public was less than 1.0, and because the accident takes place within a vault the emissions are from a stack and the worker does not receive an exposure.

Corrosive/Irritant Impact from Chemical Exposure

For all receptors, the cumulative ratio of exposure to ERPG values for corrosive/irritant chemicals was less than 1.0 and not indicative of any acute effects.

E.6.3.4 Treatment Accidents

The treatment section of the Accident Screening Table (Table E.6.3.1) shows the radiological consequences to be insignificant for all credible accidents. The dominant accident was identified as Accident 4.5.4.4 "A Canister Dropped Due to Mechanical Failure or Human Error".

E.6.3.4.1 Source Term for Breached Canister

The source term for a 24-hour release through a two-stage HEPA filter was calculated in Shire (Shire et al. 1995) to be 2.5E-06 grams (8.8E-08 ounces).

E.6.3.4.2 Radiological Consequences of Immobilization Accident

Accident 4.5.4.4, "a canister dropped due to mechanical failure or human error," has the highest dose consequences. As calculated in the accident data package (Shire et al. 1995) the radiological dose to the receptors are shown in Table E.6.3.12.

Table E.6.3.12 Dose Consequence for Breached Canister

Receptor	Dose CEDE (person-rem)
Worker (10) [1]	1.5E-04
MEI worker	1.5E-05
Noninvolved workers (5,500) [1]	5.8E-08
MEI noninvolved worker	4.0E-09
General public (114,734) [1]	1.5E-08
MEI general public	2.4E-12

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

E.6.3.4.3 Probability of Breached Canister

The annual frequency of the accident was considered in the accident data package (Shire et al. 1995) to be 6.0E-01. This was based on the frequency of a canister being dropped during transfer of 3.0E-04 per transfer and 2,000 transfers per year. Based on 20 years of operation the probability was calculated to be 1.0E+00.

E.6.3.4.4 Radiological Cancer Risk of Breached Canister

Based on a dose-to-risk conversion factor of 4.0 E-04 LCF per person-rem for the worker/noninvolved worker and 5.0 E-04 LCF per person-rem for the general public, the LCFs and the LCF risk (point estimate) were calculated for the receptors and presented in Table E.6.3.13.

The calculations show there would be no LCFs attributable to this exposure.

E.6.3.4.5 Chemical Consequences of Breached Canister

No chemical consequences were evaluated in (Shire et al. 1995) since the release would first pass through a two-stage HEPA filters that would reduce the source term to a very small amount, well below the cumulative ratio of exposure to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.6.3.5 Disposal/Storage Accidents

No DBA accidents resulting in a radiological or chemical consequences to the receptors were identified. This is largely due to the vitrified waste form of the material and the engineered structural packaging of the vitrified LAW in burial vaults and vitrified HLW in shipping containers.

Table E.6.3.13 Latent Cancer Fatality Risk from Breached Canister

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Worker (10) [2]	1.5E-04	4.0E-04	5.8E-08	1.0E+00	5.8E-08
MEI worker	1.5E-05	4.0E-04	5.8E-09	1.0E+00	5.8E-09
Noninvolved worker (5,500) [2]	5.8E-08	4.0E-04	2.3E-11	1.0E+00	2.3E-11
MEI noninvolved worker	4.0E-09	4.0E-04	1.6E-12	1.0E+00	1.6E-12
General public (114,734) [2]	1.5E-08	5.0E-04	7.5E-12	1.0E+00	7.5E-12
MEI general public	2.4E-12	5.0E-04	1.2E-15	1.0E+00	1.2E-15

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

E.6.3.6 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows.

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 23 years of operation was therefore estimated to be 5.18E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.6.3.14.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are the same for the Ex Situ Intermediate Separations alternative. However, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCR and the LCF risk are calculated in Table E.6.3.15.

In addition to all 10 workers, and the MEI noninvolved worker dying directly following the exposure the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a postulated hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively. Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose as discussed previously.

Table E.6.3.14 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.6.3.15 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	5.2E-04	5.2E-04 [2]
MEI worker	2.2E+04	N/A	N/A	5.2E-04	5.2E-04 [2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	5.2E-04	5.1E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	5.2E-04	5.2E-04 [2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	5.2E-04	9.6E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	5.2E-04	1.1E-06

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. The next nearest noninvolved worker population consists of 1500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was .06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.6.3.7 Occupational Injuries and Fatalities

The number of operation personnel to support the Ex Situ Intermediate Separations alternative was estimated (Jacobs 1996) and is summarized as follows:

- Retrieval operations - 3.74E+04 person-years; and
- Vitrification operations - 1.73E+04 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (5.47E+04 person-years) · (2.2E+00 incidences/100 person-years) = 1.20E+03

Lost Workday Cases = (5.47E+04 person-years) · (1.1E+00 incidences/100 person-years) = 6.02E+02

Fatalities = (5.47E+04 person-years) · 3.2E-03 fatalities/100 person-years) = 1.75E+00

E.6.4 POST-REMEDIATION ACCIDENT

E.6.4.1 Deflagration in Storage Tank

After 99 percent of the tank waste has been removed from each tank, the probability of a tank generating enough hydrogen to exceed the LFL is considered to be incredible.

E.6.4.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault that would increase exposure to the waste after remediation is considered incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.7.0 EX SITU NO SEPARATIONS ALTERNATIVE

The Ex Situ No Separations alternative would not separate waste into LAW and HLW streams. The SST and DST waste would be blended and vitrified (as HLW) into glass cullet. The cullet would be packed into canisters, placed into concrete overpack shielding casks, and held on interim site storage pads to await shipment to a permanent potential geologic repository for final disposal. This section analyzes and compares the construction, operation, and transportation risks associated with this alternative.

E.7.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Ex Situ No Separations alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated in the following text.

The number of construction personnel to support the Ex Situ No Separations alternative was estimated (Jacobs 1996) and summarized as follows:

- Waste transfer system upgrade - 1.63E+02 person-years;
- Retrieval construction - 1.06E+04 person-years;
- Vitrification construction - 1.48E+04 person-years; and
- Grout fill MUSTs and closure - 4.62E+02 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (2.60E+04 person-years) · (9.75E+00 incidences/100 person-years) = 2.54E+03.
Lost Workday Cases = (2.60E+04 person-years) · (2.45E+00 incidences/100 person-years) = 6.38E+02.
Fatalities = (2.60E+04 person-years) · (3.20E-03 fatalities/100 person-years) = 8.33E-01.

E.7.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are:

- Transporting MUSTs waste to vitrification facility;
- Transporting vitrified HLW to an offsite potential geologic repository;
- Transporting earthen material from onsite borrow site to fill tank voids;
- Transporting earthen material from onsite borrow site for Hanford Barrier;
- Transporting construction material to the Hanford Site; and
- Employees commuting to work each day.

E.7.2.1 Radiological Consequences

The methodology for determining radiological consequences from accidents while transporting vitrified HLW to an offsite potential geologic repository was previously discussed in Section E.6.2.1. The results are presented in the following subsection.

E.7.2.1.1 Truck Transport of Retrieved Tank Waste

The receptor dose and LCF risk resulting from the accident analysis for retrieval of MUST waste and SST residuals is presented in Table E.7.2.1 for the integrated population and Table E.7.2.2 for the MEI worker and MEI general public. There would be no LCFs resulting from an accident while transporting retrieved waste onsite.

Table E.7.2.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
MUSTs	3.43E-03	4.0E-04	1.37E-06
SSTs	1.58E-02	4.0E-04	6.32E-06

Notes:
LCF = Latent cancer fatalities
MUSTs =Miscellaneous underground storage tanks

Table E.7.2.2 MEI Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
MUSTs			
Worker MEI	3.5E-01	4.0E-04	1.4E-04
General public MEI	1.5E-03	5.0E-04	7.5E-07
SSTs			
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual
MUSTs = Miscellaneous underground storage tanks

E.7.2.1.2 Rail Transport of Vitrified High-Level Waste

The receptor dose and LCF risk resulting from the RADTRAN 4 accident analysis for transporting vitrified HLW to an offsite potential geologic repository is presented in Table E.7.2.3 for the integrated population, urban population MEI worker and MEI general public. The calculations show there would be no LCFs.

Table E.7.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated population	1.2E-01	5.0E-04	6.0E-05
Urban population	3.2E-02	5.0E-04	1.6E-05
MEI worker	4.5E+00	4.0E-04	1.8E-03
MEI general public	1.9E-02	5.0E-04	9.5E-06

Notes:
LCF = Latent cancer fatalities

E.7.2.1.3 Chemical Consequences

The chemical exposure for the Ex Situ No Separations alternative is the same as that previously discussed in Section 6.2.2 for the Ex Situ Intermediate Separations alternative with the exclusion of the dicyclopentadiene. The results are reproduced in Table E.7.2.4. The general public's exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 for corrosive/irritant chemicals. Consequently, this exposure to the MEI general public could result in potential lethal effects.

E.7.2.2 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the site for this alternative were estimated in the No Separations data package (WHC 1995c) and summarized in Table E.7.2.5.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.7.2.6 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

The expected injuries and fatalities resulting from transportation accidents associated with the Ex Situ No Separations alternative are summarized in Table E.7.2.7.

9613409.1435

Table E.7.2.4 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Ex Situ No Separations Alternative

Analyte (Threshold values are presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Anhydrous Ammonia [1]	Threshold Value		1.77E+01	1.42E+02	7.10E+02
			Ratio of Exposure to ERPG		
	MEI General Public	8.77E+03	4.95E+02	6.18E+01	1.24E+01
Nitric Acid [2]	Threshold Value		5.20E+00	6.55E+01	1.31E+02
			Ratio of Exposure to ERPG		
	MEI General Public	1.77E-01	3.40E-02	2.70E-03	1.35E-03
Sodium Hydroxide [3]	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure ERPG		
	MEI General Public	1.37E+00	6.85E-01	3.43E-02	1.37E-02

Notes:
[1] AIHA ERPGs were used for anhydrous ammonia.
[2] AIHA ERPGs were used for nitric acid.
[3] AIHA ERPGs were used for sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

Table E.7.2.5 Summary of Transportation Activities for the Ex Situ No Separations Alternative

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - Onsite Offsite	Borrow	1.38E+03	1.00E+01 [4]	1.38E+04	N/A	N/A	N/A
	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02 [1]	N/A	N/A	7.42E+03	N/A
Grout Fill MUSTs							
Truck - onsite	Sand/gravel	2.20E+03	1.00E+01 [4]	2.20E+04	N/A	N/A	N/A
offsite	Cement	4.63E+02	1.40E+02 [1]	N/A	N/A	6.48E+04	N/A
Retrieval							
Construction Truck - offsite	Concrete	4.80E+02/year (20 year)	1.40E+02 [1]	N/A	N/A	1.34E+06	N/A
	Raw material	4.50E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	7.20E+05	N/A
	Equipment	2.50E+01/year (20 year)	1.00E+04 [3]	N/A	N/A	5.00E+06	N/A
	Miscellaneous	5.20E+03/year (20 year)	1.40E+02 [1]	N/A	N/A	1.46E+07	N/A
Rail - offsite	Raw material	1.00E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	N/A	1.60E+05
Waste transport Truck - onsite	MUST waste	6.25E+02	2.0E+01	1.25E+04	N/A	N/A	N/A
Vitrification							
Construction Truck - onsite	Borrow	1.18E+05	1.00E+01 [4]	1.18E+06	N/A	N/A	N/A
Truck - offsite	Construction material	4.38E+04	1.40E+02 [1]	N/A	N/A	6.13E+06	N/A
	Construction material	4.34E+04	8.00E+02 [2]	N/A	N/A	3.47E+07	N/A
	Miscellaneous	5.20E+03/year (5.5 year)	1.40E+02 [1]	N/A	N/A	4.00E+06	N/A

9613409.1436

Table E.7.2.5 Summary of Transportation Activities for the Ex Situ No Separations Alternative

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Processing Truck - offsite	Miscellaneous	6.85E+03/year (15 year)	1.40E+02 [1]	N/A	N/A	1.44E+07	N/A
	Process material	4.17E+02/year (15 year)	8.00E+02 [2]		N/A	5.0E+06	N/A
Rail - offsite	Process material	1.03E+02/year (15 year)	8.00E+02 [2]	N/A	N/A	N/A	1.24E+06
Vitrified High-Level Waste Transport							
Rail - offsite	Vitrified glass	1.47E+04	4.28E+03 [5]	N/A	N/A	N/A	6.29E+07
Closure							
Truck - onsite	Silt [8]	4.93E+04	3.00E+01 [6]	1.48E+06	N/A	N/A	N/A
	Riprap [8]	8.35E+04	3.20E+01 [7]	2.67E+06	N/A	N/A	N/A
	Sand [8]	5.43E+04	1.00E+01 [4]	5.43E+05	N/A	N/A	N/A
	Sand [9]	9.86E+04	1.00E+01 [4]	9.86E+05	N/A	N/A	N/A
			Total	6.91E+06	N/A	8.60E+07	6.43E+07

Notes:
[1] Round-trip distance from Tri-Cities area.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from East Coast.
[4] Round-trip distance from Pit 30 borrow site.
[5] Round-trip distance to Yucca Mountain.
[6] Round-trip distance from McGee Ranch borrow site.
[7] Round-trip distance from Vernita Quarry borrow site.
[8] For Hanford Barrier.
[9] For tank fill.
MUSTs =Miscellaneous underground storage tanks
N/A = Not Applicable

Table E.7.2.6 Distance Traveled in Population Zones for the Ex Situ No Separations Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	4.3E+06	1.12E+07	7.74E+07
Rail	3.22E+06	3.22E+06	5.79E+07

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.7.2.5.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.7.2.5.
[3] Rural represents 90 percent of total offsite distance from Table E.7.2.5.

Table E.7.2.7 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ No Separations Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	3.22E-02	1.46E-01	4.10E+00	4.28E+00	N/A
	Injury	1.59E+00	4.26E+00	6.19E+01	N/A	6.78E+01
Rail	Fatality	5.47E-02	5.47E-02	9.84E-01	1.09E+00	N/A
	Injury	1.06E-01	1.06E-01	1.91E+00	N/A	2.12E+00
				Total	5.37E+00	6.99E+01

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 6.73E+04 (Jacobs 1996). Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:
(6.73E+04 person-years) · (260 days/year) · (140 km/day) · (1/1.35) =1.82E+09 km (1.1E+09 mi)

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (1.82E+09 km) · (7.1E-07 injuries/km) = 1.30E+03
Fatalities = (1.82E+09 km) · (8.98E-09 fatalities/km) = 1.63E-01

Cumulative Transportation Injuries and Fatalities

The cumulative, nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts is the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.7.2.8.

Table E.7.2.8 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ No Separations Alternative

Mode	Fatalities	Injuries
Truck and rail transport	5.37E+00	6.99E+01
Employee vehicle	1.63E+01	1.30E+03
Total	2.17E+01	1.37E+03

E.7.3 OPERATION ACCIDENTS

The radiological and chemical operation accidents, consequences, and risk for the Ex Situ No Separations alternative are summarized in the following text.

E.7.3.1 Continued Operation - Mispositioned Jumper Accident

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The Ex Situ No Separations continued operation activity was based on 18 years of operations, therefore, the probability was calculated to be 2.0E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.7.3.1.

Table E.7.3.1 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

The dominant continued operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and summarized as follows:

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Ex Situ No Separations alternative, however, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.7.3.2. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Table E.7.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF[1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.0E-01	2.2E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.0E-01	2.2E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.0E-01	2.0E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.0E-01	1.1E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.0E-01	6.1E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.0E-01	2.9E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper accident are summarized in Tables E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 but would only be associated with reversible effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate which provides a conservative estimate of the potential acute health effects. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, which exceeds 1.0 and would be associated with reversible effects.
The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00 and mild, transient effects would be anticipated. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparisons and no acute effects would be anticipated.

E.7.3.2 Retrieval - Loss of Filtration Accident

The dominant retrieval operations accident is the loss of filtration accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.2 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.2.1 was calculated to be 2.5E-01L (2.6E-01 qt).

Probability - The frequency of a loss of filtration in Section E.6.3.2.2 was 8.8E-06 per year. The Ex Situ No Separations retrieval activity was based on 18 years of operations, therefore, the probability was calculated to be 1.6E-04.

Radiological Consequences - The radiological consequences presented in Section 6.3.2.3 are reproduced in Table E.7.3.3.

Table E.7.3.3 Dose Consequence from Loss of Filtration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.7E+04
MEI worker	3.7E+03
Noninvolved workers (1,835) [1]	1.0E+03
MEI noninvolved worker	2.4E+02
General public (114,734) [1]	1.6E+02
MEI general public	1.0E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. The LCFs and the LCF point estimate risk were calculated for the receptors and are presented in Table E.7.3.4.

Table E.7.3.4 Latent Cancer Fatality Risk from Loss of Filtration

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF[1]	Probability	LCF Risk (point estimate)
Workers (10)[2]	3.7E+04	N/A	N/A	1.6E-04	1.6E-04
MEI worker	3.7E+03	N/A	N/A	1.6E-04	1.6E-04
Noninvolved workers (1,835) [2]	1.0E+03	4.0E-04	4.2E-01	1.6E-04	6.6E-05
MEI noninvolved worker	2.4E+01	8.0E-04	1.9E-02	1.6E-04	3.1E-06
General public (114,734) [2]	1.6E+02	5.0E-04	7.8E-02	1.6E-04	1.2E-05
MEI general public	1.0E-01	5.0E-04	5.2E-05	1.6E-04	8.2E-09

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not included

In addition to all ten workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be less than one LCFs attributed to the exposure to the noninvolved workers and the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a loss of filtration are summarized in Tables E.6.3.6 and E.6.3.7 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 6.60E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Uranium (approximately 52 percent of the total hazard);
- Oxalate (approximately 26 percent of the total hazard);
- Selenium (approximately 7 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard); and
- Mercury (approximately 5 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 2.36E+00, which exceeds the ratio of 1.0 and indicates reversible, acute health effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 8.60E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.2E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 47 percent of the total hazard);
- Calcium (approximately 36 percent of the total hazard); and
- Chromium (approximately 11 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.24E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located

1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 3.01E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.45E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.7.3.3 Treatment - Canister of Vitrified High-Level Waste Inadvertently Drops and Ruptures

The dominant immobilization operations accident is the "canister of vitrified HLW inadvertently drops and ruptures" accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.4 and summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.4.1 was calculated to be 2.5E-06 g (8.8E-08 oz) based on a solid glass form in the canister. The canisters for the Ex Situ No Separations alternative are filled with glass cullet, therefore it was assumed that the MAR would be increased by a factor of two. This increase would result in a source term of 5.0E-06 g (1.8E-07 oz).

Probability - The frequency of the accident in Section E.6.3.4.2 was 6.0E-01 per year. The Ex Situ No Separation treatment activity was based on 15 years of operations, therefore, the probability was calculated to be 1.0E+00.

Radiological Consequences - The radiological consequences in Section 6.3.4.3 were increased by a factor of two, based on the increased inventory, and are presented in Table E.7.3.5.

Table E.7.3.5 Dose Consequence from Breached Canister

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.5E-04
MEI worker	1.5E-05
Noninvolved workers (5,500) [1]	5.8E-08
MEI noninvolved worker	4.0E-09
General public (114,734) [1]	1.5E-08
MEI general public	2.4E-12

Notes:
[1] Number of people in exposed population
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and are presented in Table E.7.3.6. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.7.3.6 Latent Cancer Fatality Risk from Breached Canister

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.5E-04	4.0E-04	5.8E-08	1.0E+00	5.8E-08
MEI worker	1.5E-05	4.0E-04	5.8E-09	1.0E+00	5.8E-09
Noninvolved workers (5,500) [2]	5.8E-08	4.0E-04	2.3E-11	1.0E+00	2.3E-11
MEI noninvolved worker	4.0E-09	4.0E-04	1.6E-12	1.0E+00	1.6E-12
General public (114,734) [2]	1.5E-08	5.0E-04	7.5E-12	1.0E+00	7.5E-12
MEI general public	2.4E-12	5.0E-04	1.2E-15	1.0E+00	1.2E-15

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - No chemical consequences were evaluated (Shire et al. 1995) since the release would first pass through two-stage HEPA filters that would reduce the source term to a very small amount, well below the cumulative ratio of exposure to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.7.3.4 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and summarized as follows:

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The Ex Situ No Separations alternative was based on 25 flammable gas Watchlist tanks and 18 years of operation, therefore the probability was calculated to be 4.05E-0.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.7.3.7

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are the same for the Ex Situ No Separations alternative. However, the LCF point estimate risk is not the same due to the difference in probabilities. The LCF and the LCF risk are calculated in Table E.7.3.8.

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Table E.7.3.7 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.7.3.8 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	4.1E-04	4.1E-04[2]
MEI worker	2.2E+04	N/A	N/A	4.1E-04	4.1E-04[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	4.1E-04	4.0E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	4.1E-04	4.1E-04[2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	4.1E-04	7.5E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	4.1E-04	8.6E-07

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied

Chemical Consequences

Potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively. Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiological dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential

irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.7.3.5 Occupation Injuries, Illnesses, and Fatalities from Operations

The number of operation personnel to support the Ex Situ No Separations alternative was estimated (Jacobs 1996) and is summarized as follows:

- Retrieval operations - 3.15E+04 person-years.
- Vitrification operations - 9.78E+03 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (4.13E+04 person-years) · (2.2E+00 incidences/100 person-years) = 9.08E+02
Lost Workday Cases = (4.13E+04 person-years) · (1.1E+00 incidences/100 person-years) = 4.54+02
Fatalities = (4.13E+04 person-years) · (3.20E-03 fatalities/100 person-years) = 1.32E+00

E.7.4 CALCINATION SUBALTERNATIVE

A subalternative to vitrification for the No Separations alternative is calcination. Rather than vitrifying the waste stream, it would be calcined. The difference in the accident analysis between vitrification and calcination would be in transporting the treated waste. There would be no change in the construction and operation accidents.

E.7.4.1 Transportation

Transportation activities associated with this alternative are:

- Transporting MUSTs waste to vitrification facility;
- Transporting vitrified HLW to an offsite potential geologic repository;
- Transporting earthen material from borrow sites to fill tank voids and for Hanford Barrier;
- Transporting construction material to Hanford Site; and
- Employees commuting to work each day.

E.7.4.1.1 Radiological Consequences

The methodology for determining radiological consequences from accidents while transporting vitrified HLW to an offsite potential geologic repository was previously discussed in Section E.6.2.1. The results are presented in the following text:

Truck Transport of Retrieved Tank Waste

The receptor dose and LCF risk resulting from the accident analysis for retrieval of MUST waste and SST residuals is presented in Table E.7.4.1 for the integrated population and Table E.7.4.2 for the MEI worker and MEI general public.

There would be no LCFs resulting from an accident while transporting retrieved waste onsite.

Table E.7.4.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
MUSTs	3.43E-03	4.0E-04	1.37E-06
SSTs	1.58E-02	4.0E-04	6.32E-06

Notes:
LCF = Latent cancer fatalities

Table E.7.4.2 MEI Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
MUSTs			
Worker MEI	3.5E-01	4.0E-04	1.4E-04
General public MEI	1.5E-03	5.0E-04	7.5E-07
SSTs			
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
SST = Single-shell tank

Rail Transport of Vitrified High-Level Waste

The receptor dose and LCF risk resulting from the accident analysis for transporting vitrified HLW to an offsite potential geologic repository is presented in Table E.7.4.3 for the integrated population, urban population, MEI worker, and MEI general public. the calculations show there would be no LCFs.

Table E.7.4.3 Radiological Impact from Transport Accidents While Transporting Calcined HLW to a Potential Geologic Repository

Receptor	Dose (Person-rem)	LCF/rem	LCF Risk
Integrated population	3.6E-01	5.0E-04	1.8E-04
Urban population	6.8E-02	5.0E-04	3.4E-05
MEI worker	4.5E+00	4.0E-04	1.8E-03
MEI general public	1.9E-02	5.0E-04	9.5E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

E.7.4.1.2 Chemical Exposure

The chemical exposure for calcination would be the same as that previously discussed for vitrification in Section E.7.2.1.3. The general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 for corrosive/irritant chemicals and could potentially result in lethal effects.

E.7.4.1.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the site for this alternative were estimated in the No Separations data package (WHC 1995c) and summarized in Table E.7.4.4.

Table E.7.4.4 Summary of Transportation Activities for the Ex Situ No Separations Alternative (Calcination)

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - Onsite Offsite	Borrow	1.38E+03	1.00E+01 [4]	1.38E+04	N/A	N/A	N/A
	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02 [1]	N/A	N/A	7.42E+03	N/A
Grout Fill MUSTs							
Truck - onsite	Sand/gravel	2.20E+03	1.00E+01 [4]	2.20E+04	N/A	N/A	N/A
offsite	Cement	4.63E+02	1.40E+02 [1]	N/A	N/A	6.48E+04	N/A
Retrieval							
Construction Truck - offsite	Concrete	4.80E+02/year (20 year)	1.40E+02 [1]	N/A	N/A	1.34E+06	N/A
	Raw material	4.50E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	7.20E+05	N/A
	Equipment	2.50E+01/year (20 year)	1.00E+04 [3]	N/A	N/A	5.00E+06	N/A
	Miscellaneous	5.20E+03/year (20 year)	1.40E+02 [1]	N/A	N/A	1.46E+07	N/A
Rail - offsite	Raw material	1.00E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	N/A	1.60E+05
Waste transport Truck - onsite	MUST waste	6.25E+02	2.0E+01	1.25E+04	N/A	N/A	N/A
Calcination							
Construction Truck - onsite	Borrow	3.30E+04	1.00E+01 [4]	3.30E+05	N/A	N/A	N/A

Table E.7.4.4 Summary of Transportation Activities for the Ex Situ No Separations Alternative (Calcination) (cont'd)

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Truck - offsite	Construction material	3.40E+04	1.40E+02 [1]	N/A	N/A	4.76E+06	N/A
	Construction material	1.07E+04	8.00E+02 [2]	N/A	N/A	8.56E+06	N/A
	Miscellaneous	5.20E+03/year (5.5 years)	1.40E+02 [1]	N/A	N/A	4.00E+06	N/A
Processing Truck - offsite	Miscellaneous	5.20E+03/year (15 year)	1.40E+02 [1]	N/A	N/A	1.09E+07	N/A
	Process material	8.87E+02/year (15 year)	8.00E+02 [2]		N/A	1.06E+07	N/A
Rail - offsite	Process material	1.03E+02/year (15 year)	8.00E+02 [2]	N/A	N/A	N/A	1.24E+06
Calcined High-Level Waste Transport							
Rail - offsite	Calcined HLW	4.15E+03	4.28E+03 [5]	N/A	N/A	N/A	1.78E+07
Closure							
Truck - onsite	Silt [8]	4.93E+04	3.00E+01 [6]	1.48E+06	N/A	N/A	N/A
	Riprap [8]	8.35E+04	3.20E+01 [7]	2.67E+06	N/A	N/A	N/A
	Sand [8]	5.43E+04	1.00E+01 [4]	5.43E+05	N/A	N/A	N/A
	Sand [9]	9.86E+04	1.00E+01 [4]	9.86E+05	N/A	N/A	N/A
			Total	6.06E+06	N/A	6.06E+07	1.92E+07

Notes:
[1] Round-trip distance from Tri-Cities area.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from East Coast.
[4] Round-trip distance from Pit 30 borrow site.
[5] Round-trip distance to Yucca Mountain.
[6] Round-trip distance from McGee Ranch borrow site.
[7] Round-trip distance from Vernita Quarry borrow site.
[8] For Hanford Barrier.
[9] For tank fill.
MUSTs = Miscellaneous underground storage tanks
N/A = Not Applicable

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.7.4.5 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

Table E.7.4.5 Distance Traveled in Population Zones for the Calcination Subalternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	3.03E+06	9.09E+06	5.46E+07
Rail	9.58E+05	9.58E+05	1.72E+07

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.7.4.3.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.7.4.3.
[3] Rural represents 90 percent of total offsite distance from Table E.7.4.3.

The expected injuries and fatalities resulting from transportation accidents associated with the Ex Situ No Separations alternative are summarized in Table E.7.4.6.

Table E.7.4.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Calcination Subalternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	2.27E-02	1.18E-01	2.89E+00	3.03E+00	N/A
	Injury	1.12E+00	3.45E+00	4.37E+01	N/A	4.83E+01
Rail	Fatality	1.63E-02	1.63E-02	2.93E-01	3.26E-01	N/A
	Injury	3.16E-02	3.16E-02	5.69E-01	N/A	6.32E-01
				Total	3.36E+00	4.89E+01

Employee Traffic

Employee Traffic would be the same as for Vitrification, as calculated in Section E.7.2.2, which would result in 1.30E+03 injuries and 1.63E-01 fatalities.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.7.4.5 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

The expected injuries and fatalities resulting from transportation accidents associated with the calcination subalternative are summarized in Table E.7.4.6.

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The employee impacts from calcination would remain the same as vitrification. The results are summarized in Table E.7.4.7.

Table E.7.4.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Calcination Subalternative

Mode	Fatalities	Injuries
Truck and rail transport	3.36E+00	4.89E+01
Employee vehicle	1.63E+01	1.30E+03
Total	1.97E+01	1.35E+03

E.7.5 POST-REMEDIATION ACCIDENT

E.7.5.1 Deflagration in Storage Tank

After 99 percent of the tank waste has been removed from each tank, the probability of a tank generating enough hydrogen to exceed the LFL is considered to be incredible.

E.7.5.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault that would increase exposure to the waste after remediation is considered to be incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.8.0 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE

The Ex Situ Extensive Separations alternative would separate waste into LAW and HLW streams. This alternative is very similar to the Ex Situ Intermediate Separations alternative except that the extensive separations process would reduce the amount of vitrified HLW that would be transported to an offsite potential geologic repository. This section analyzes and compares the construction, operation, and transportation risks associated with this alternative.

E.8.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Ex Situ Extensive Separations alternative are discussed in Appendix B of the EIS. It should be noted that there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated in the following text.

The number of construction personnel to support the Ex Situ Extensive Separations alternative was estimated (Jacobs 1996) and is summarized as follows:

- Retrieval construction - 1.06E+04 person-years;
- Vitrification construction - 2.58E+04 person-years; and
- Closure - 4.90E+02 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (3.69E+04 person-years) · (9.75E+00 incidences/100 person-years) = 3.60E+03

Lost Workday Cases = (3.69E+04 person-years) · (2.45E+00 incidences/100 person-years) = 9.04E+02

Fatalities = (3.69E+04 person-years) · (3.20E-03 fatalities/100 person-years) = 1.18E+00

E.8.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are:

- Transport construction material to the site;
- Transporting MUST waste to vitrification facility;
- Transporting vitrified HLW to an offsite potential geologic repository;
- Transporting earthen material from onsite borrow site to fill tank voids;
- Transporting earthen material from onsite borrow site for Hanford Barrier; and
- Employees commuting to work each day.

E.8.2.1 Radiological Consequences

The methodology for determining radiological consequences from accidents while transporting vitrified HLW to an offsite potential geologic repository was previously discussed in Section E.6.2.1. The results are presented in the following text:

E.8.2.1.1 Truck Transport of Retrieved Tank Waste

The receptor dose and LCF risk resulting from the accident analysis for retrieval of MUST waste and SST residuals are presented in Table E.8.2.1 for the integrated population and Table E.8.2.2 for the MEI worker and MEI general public.

There would be no LCFs resulting from an accident while transporting retrieved waste onsite.

E.8.2.1.2 Rail Transport of Vitrified High-Level Waste

The receptor dose and LCF risk resulting from the accident analysis for transporting vitrified HLW to an offsite potential geologic repository are presented in Table E.8.2.3 for the integrated population, urban population, MEI worker, and MEI general public. The calculations show there would be no LCFs.

E.8.2.2 Chemical Exposure

There would be no change from the Ex Situ Intermediate Separations alternative discussed in Section 6.2.2. The general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 and sodium hydroxide would exceed the ratio of exposure to ERPG-1 by 2.45E+00 for corrosive/irritant chemicals. Based on the magnitude of the exceedance for anhydrous ammonia, this exposure could potentially result in lethal effects.

Table E.8.2.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
MUSTs	3.43E-03	4.0E-04	1.37E-06
SSTs	1.58E-02	4.0E-04	6.32E-06

Notes:
LCF = Latent cancer fatalities
MUSTs = Miscellaneous underground storage tanks
SST = Single-shell tank

Table E.8.2.2 Maximally-Exposed Individual Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
MUSTs			
Worker MEI	3.5E-01	4.0E-04	1.4E-04
General public MEI	1.5E-03	5.0E-04	7.5E-07
SSTs			
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual
MUSTs =Miscellaneous underground storage tanks
SST = Single-shell tank

Table E.8.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated population	6.6E-02	5.0E-04	3.3E-05
Urban population	2.0E-03	5.0E-04	1.0E-06
MEI worker	3.7E+00	4.0E-04	1.5E-03
MEI general public	1.6E-02	5.0E-04	8.0E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

E.8.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the site for this alternative were estimated in the Extensive Separations engineering data package (WHC 1995e) and summarized in Table E.8.2.4.

Table E.8.2.4 Summary of Transportation Activities for the Ex Situ Extensive Separations Alternative

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - Onsite	Borrow	1.38E+03	1.00E+01 [5]	1.38E+04	N/A	N/A	N/A
Offsite	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02 [1]	N/A	N/A	7.42E+03	N/A
Grout Fill MUSTs							
Truck - onsite	Sand/gravel	2.20E+03	1.00E+01 [5]	2.20E+04	N/A	N/A	N/A
offsite	Cement	4.63E+02	1.40E+02 [1]	N/A	N/A	6.48E+04	N/A
Retrieval							
Construction Truck - offsite	Concrete	4.80E+02/year (20 year)	1.40E+02 [1]		N/A	1.34E+06	N/A
	Raw material	4.50E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	7.20E+05	N/A
	Equipment	2.50E+01/year (20 year)	1.00E+04 [3]	N/A	N/A	5.00E+06	N/A
	Miscellaneous	5.20E+03/year (20 year)	1.40E+02 [1]	N/A	N/A	1.46E+07	N/A
Rail - offsite	Raw material	1.00E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	N/A	1.60E+05
Waste transport Truck - onsite	Inactive miscellaneous underground storage tank waste	6.25E+02	2.0E+01	1.25E+04[d]	N/A	N/A	N/A
Vitrification							
Construction Truck - onsite	Borrow	2.12E+05	1.00E+01 [5]	2.12E+06	N/A	N/A	N/A
Truck - offsite	Construction material	1.07E+05	1.40E+02 [1]	N/A	N/A	1.50E+07	N/A
	Construction material	2.62E+04	8.00E+02 [2]	N/A	N/A	2.10E+07	N/A
	Miscellaneous	5.20E+03/year (9 year)	1.40E+02 [1]	N/A	N/A	6.55E+06	N/A

Table E.8.2.4 Summary of Transportation Activities for the Ex Situ Extensive Separations Alternative (cont'd)

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Processing Truck - offsite	Process material	2.17E+03/year (19 year)	8.00E+02 [2]	N/A	N/A	3.30E+07	N/A
	Miscellaneous	5.20E+03/year (19 year)	1.40E+02 [1]	N/A	N/A	1.38E+07	N/A
Rail - offsite	Process material	6.77E+02/year (19 year)	8.00E+02 [2]	N/A	N/A	N/A	1.03E+05
Vitrified HLW Transport							
Rail - offsite	Vitrified glass	4.00E+01	4.28E+03 [6]	N/A	N/A	N/A	1.71E+05
Closure							
Truck - onsite	Silt [9]	8.53E+04	3.00E+01 [7]	2.56E+06	N/A	N/A	N/A
	Riprap [9]	1.22E+05	3.20E+01 [8]	3.90E+06	N/A	N/A	N/A
	Sand [9]	1.00E+05	1.00E+01 [5]	1.00E+06	N/A	N/A	N/A
	Sand [10]	9.86E+04	1.00E+01 [5]	9.86E+05	N/A	N/A	N/A
			Total	1.06E+07	N/A	1.11E+08	1.06E+07

Notes:
[1] Round-trip distance from Tri-Cities area.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from the East Coast.
[4] Total distance from Green (Green 1995).
[5] Round-trip distance from Pit 30 borrow site.
[6] Round-trip distance to Yucca Mountain.
[7] Round-trip distance from McGee Ranch borrow site.
[8] Round-trip distance from Vernita Quarry borrow site.
[9] For Hanford Barrier.
[10] For tank fill.
HLW = High-level waste
MUSTs =Miscellaneous underground storage tanks
N/A = Not Applicable

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.8.2.5 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

The expected injuries and fatalities resulting from transportation accidents associated with the Ex Situ Extensive Separations alternative are summarized in Table E.8.2.6.

Table E.8.2.5 Distance Traveled in Population Zones for the Ex Situ Extensive Separations Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	5.55E+06	1.62E+07	1.00E+08
Rail	5.31E+05	5.31E+05	9.56E+06

Notes:
[1] Urban represent 5 percent of total offsite distance from Table E.8.2.4.
[2] Suburban represent 5 percent of total offsite distance and 100 percent of total onsite distance from Table E.8.2.4.
[3] Rural represent 90 percent of total offsite distance from Table E.8.2.4.

Table E.8.2.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Ex Situ Extensive Separations Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	4.16E-02	2.10E-01	5.30E+00	5.55E+00	
	Injury	2.05E+00	6.14E+00	8.00E+01		8.82E+01
Rail	Fatality	9.03E-03	9.03E-03	1.63E-01	1.81E-01	
	Injury	1.75E-02	1.75E-02	3.15E-01		3.50E-01
				Total	5.73E+00	8.85E+01

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, site workers and other personnel required to perform the various activities would be driving to work in their vehicles. The total person-years to perform the activities was estimated at 8.12E+04 (Jacobs 1996). Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:

$$(8.12E+04 \text{ person-years}) \cdot (260 \text{ days/year}) \cdot (140 \text{ km/day}) \cdot (1/1.35) = 2.19E+09 \text{ km}$$

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

$$\text{Injuries} = (2.19E+09 \text{ km}) \cdot (7.1E-07 \text{ injuries/km}) = 1.56E+03$$
$$\text{Fatalities} = (2.19E+09 \text{ km}) \cdot (8.98E-09 \text{ fatalities/km}) = 1.97E+01$$

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.8.2.7.

Table E.8.2.7 Cumulative Fatalities and Injuries from Traffic Impacts for the Ex Situ Extensive Separations Alternative

Mode	Fatalities	Injuries
Truck and rail transport	5.73E+00	8.85E+01
Employee vehicle	1.97E+01	1.56E+03
Total	2.54E+01	1.65E+03

E.8.3 OPERATION ACCIDENTS

The radiological and chemical operation accidents, consequences, and risk for the Ex Situ Extensive Separations alternative are analyzed in the following subsections.

E.8.3.1 Continued Operation Accident

The dominant continued operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The Ex Situ Extensive Separations continued operation accident was based on 23 years of operations, therefore, the probability was calculated to be 2.5E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.2.1 are reproduced in Table E.8.3.1.

Table E.8.3.1 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Ex Situ Extensive Separations alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.8.3.2. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Table E.8.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.5E-01	2.8E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.5E-01	2.8E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.5E-01	2.5E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.5E-01	1.4E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.5E-01	7.8E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.5E-01	3.7E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper are summarized in Table E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 and would be indicative of reversible acute effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate and provides a conservative estimate of the potential acute exposure. The acute hazard indices for the MEI noninvolved worker and general public was less than 1.0 for ERPG-1 comparisons.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, which exceeds 1.0 and would be indicative of reversible, acute effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.1E+00 and would be indicative of minor transient effects. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparison.

E.8.3.2 Retrieval Accidents

The dominant retrieval operations accident is the loss of filtration accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.2 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.2.1 was calculated to be 2.5E-01 L (2.6E-01 qt).

Probability - The frequency of a loss of filtration in Section E.6.3.2.2 was 8.8E-06 per year. The Ex Situ Extensive Separations retrieval activity was based on 23 years of operations, therefore, the probability was calculated to be 2.02E-04.

Radiological Consequences - The radiological consequences presented in Section 6.3.2.3 are reproduced in Table E.8.3.3.

Radiological Cancer Risk - All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.8.3.4.

9613409.1448

Table E.8.3.3 Dose Consequence from Loss of Filtration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.7E+04
MEI worker	3.7E+03
Noninvolved workers (1,835) [1]	1.0E+03
MEI noninvolved worker	2.4E+01
General public (114,734) [1]	1.6E+02
MEI general public	1.0E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.8.3.4 Latent Cancer Fatality Risk from Loss of Filtration

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.7E+04	N/A	N/A	2.0E-04	2.0E-04[3]
MEI worker	3.7E+03	N/A	N/A	2.0E-04	2.0E-04[3]
Noninvolved workers (1,835) [2]	1.0E+03	4.0E-04	4.2E-01	2.0E-04	8.4E-05
MEI noninvolved worker	2.4E+01	8.0E-04	1.9E-02	2.0E-04	3.9E-06
General public (114,734) [2]	1.6E+02	5.0E-04	7.8E-02	2.0E-04	1.6E-05
MEI general public	1.0E-01	5.0E-04	5.2E-05	2.0E-04	1.1E-08

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose; therefore LCFs are not included

In addition to all 10 workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be nine LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a tank dome collapse are summarized in Tables E.6.3.6 and E.6.3.7 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiological dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 6.60E+01 and exceeds 1.0, which would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Uranium (approximately 52 percent of the total hazard);
- Oxalate (approximately 26 percent of the total hazard);
- Selenium (approximately 7 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard); and
- Mercury (approximately 5 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 2.36E+00, which exceeds the ratio of 1.0 and indicates reversible, acute health effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 8.60E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.45E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.2E+01 and exceeds 1.0, which would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 47 percent of the total hazard);
- Calcium (approximately 36 percent of the total hazard); and
- Chromium (approximately 11 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.24E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 3.01E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.8.3.3 Pretreatment Accidents

The dominant pretreatment operations accident is the seismic induced line break in vault accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.3 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.3.1 was calculated to be 7.3E-02 L (7.7E-02 qt).

Probability - The frequency of the accident in Section E.6.3.3.2 was 6.0E-05 per year. The Ex Situ Extensive Separations alternative was based on 20 years of operations, therefore, the probability was calculated to be 1.2E-03.

Radiological Consequences - The radiological consequences presented in Section 6.3.3.3 are reproduced in Table E.8.3.5.

Table E.8.3.5 Dose Consequence from Seismic Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.4E+01
MEI worker	3.4E+00
Noninvolved workers (5,500) [1]	7.1E+00
MEI noninvolved worker	2.9E-01
General public (114,734) [1]	2.7E+00
MEI general public	4.5E-04

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.8.3.6. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.8.3.6 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.4E+01	4.0E-04	1.4E-02	1.2E-03	1.6E-05
MEI worker	3.4E+00	4.0E-04	1.4E-03	1.2E-03	1.6E-06
Noninvolved workers (5,500) [2]	7.1E+00	4.0E-04	2.8E-03	1.2E-03	3.4E-06
MEI noninvolved worker	2.9E-01	4.0E-04	1.2E-04	1.2E-03	1.4E-07
General public (114,734) [2]	2.7E+00	5.0E-04	1.4E-03	1.2E-03	1.6E-06
MEI general public	4.5E-04	5.0E-04	2.3E-07	1.2E-03	2.7E-10

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.12E+00, which exceeds 1.0 and would be indicative of mild, transient effects. This acute hazard index is primarily attributable to thallium (approximately over 99 percent of the total hazard). The acute hazard index for the general public was less than 1.0, and because the accident takes place within a vault the emissions are from a stack and the worker does not receive a dose.

For all receptors, the cumulative ratio of exposure to ERPG values for corrosive/irritant chemicals was less than 1.0.

E.8.3.4 Treatment Accidents

The dominant treatment operations accident is the "canister of vitrified HLW inadvertently drops and ruptures" accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.4 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.4.1 was calculated to be 2.5E-06 g (8.8E-08 oz).

Probability - The frequency of the accident in Section E.6.3.4.2 was 6.0E-01 per year. The Ex Situ Extensive Separations alternative was based on 20 years of operations, therefore, the probability was calculated to be 1.0E+00.

Radiological Consequences - The radiological consequences presented in Section 6.3.4.3 are reproduced in Table E.8.3.7.

Table E.8.3.7 Dose Consequence from Breached Canister

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.5E-04
MEI worker	1.5E-05
Noninvolved workers (5,500) [1]	5.8E-08
MEI noninvolved worker	4.0E-09
General public (114,734) [1]	1.5E-08
MEI general public	2.4E-12

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.8.3.8. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.8.3.8 Latent Cancer Fatality Risk from Breached Canister

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.5E-04	4.0E-04	5.8E-08	1.0E+00	5.8E-08
MEI worker	1.5E-05	4.0E-04	5.8E-08	1.0E+00	5.8E-09
Noninvolved workers (5,500) [2]	5.8E-08	4.0E-04	2.3E-11	1.0E+00	2.3E-11
MEI noninvolved worker	4.0E-09	4.0E-04	1.6E-12	1.0E+00	1.6E-12
General public (114,734) [2]	1.5E-08	5.0E-04	7.5E-12	1.0E+00	7.5E-12
MEI general public	2.4E-12	5.0E-04	1.2E-15	1.0E+00	1.2E-15

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - No chemical consequences were evaluated (Shire et al. 1995) since the release would pass through two-stage HEPA filters that would reduce the source term to a very small amount, well below the cumulative ratio of exposure to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.8.3.5 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows:

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 23 years of operation was therefore estimated to be 5.18E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.8.3.9.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are the same for the Ex Situ Extensive Separations alternative. However, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCF and LCF risk are calculated in Table E.8.3.10.

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Table E.8.3.9 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.8.3.10 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	5.2E-04	5.2E-04[2]
MEI worker	2.2E+04	N/A	N/A	5.2E-04	5.2E-04[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	5.2E-04	5.1E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	5.2E-04	5.2E-04[2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	5.2E-04	9.6E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	5.2E-04	1.1E-06

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied

Chemical Consequences

Potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive lethal radiological dose as discussed previously.

Toxic Impacts for Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential

irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00 which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.8.4 OCCUPATION INJURIES, ILLNESSES, AND FATALITIES FROM OPERATIONS

The number of operation personnel to support the Ex Situ Extensive Separations alternative was estimated (Jacobs 1996) and summarized as follows:

- Retrieval operations - 3.74E+04 person-years; and
- Vitrification operations - 6.95E+03 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (4.44E+04 person-years) · (2.2E+00 incidences/100 person-years) = 9.76E+02
Lost Workday Cases = (4.44E+04 person-years) · (1.1E+00 incidences/100 person-years) = 4.88E+02
Fatalities = (4.44E+04 person-years) · (3.20E-03 fatalities/100 person-years) = 1.42E+00

E.8.5 POST-REMEDIATION ACCIDENT

E.8.5.1 Deflagration in Storage Tank

After 99 percent of the tank waste has been removed from each tank, the probability of a tank generating enough hydrogen to exceed the LFL is considered to be incredible.

Consequences of Gas Building Up Under the Asphalt Barrier

If the hydrogen gas generated in the tanks was able to permeate from the tank through leaks and cracks, it could potentially build up under the asphalt layer of the Hanford Barrier if the permeation rate through the asphalt is slower than the rate in which it reaches the asphalt. Because hydrogen is highly diffusible, it is extremely unlikely that this would be the case. However, if hydrogen did build up under the asphalt layer, the worst credible consequences would result in the asphalt cracking and allowing an increased movement of the residual tank waste into the groundwater. This event could be mitigated by placing catalytic recombiners under the asphalt that would recombine hydrogen and oxygen or venting the asphalt layer.

E.8.5.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault that would increase exposure to the waste after remediation is considered incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.9.0 EX SITU/IN SITU COMBINATION ALTERNATIVE

The Ex Situ/In Situ Combination alternative is a combination of the Ex Situ Intermediate Separations alternative and the In Situ Fill and Cap alternative. It would involve the ex situ treatment and disposal of some waste and in situ treatment of the remaining waste. This section analyzes and compares the construction, operation, and transportation risks associated with this alternative.

E.9.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Ex Situ/In Situ Combination alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated as follows.

The number of construction personnel to support the Ex Situ/In Situ Combination alternative was estimated (Jacobs 1996) and is summarized as follows:

- Waste transfer system upgrade - 1.63E+02 person-years;
- Retrieval construction - 6.36E+03 person-years;
- Vitrification construction - 1.19E+04 person-years;
- Fill tanks with gravel construction - 5.70E+01 person-years; and
- Grout fill MUSTs and closure - 5.74E+02 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated using the incidence rates from Table E.1.2.1 of this appendix as follows:

Total Recordable Cases = (1.91E+04 person-years) · (9.75E+00 incidences/100 person-years) = 1.86E+03
Lost Workday Cases = (1.91E+04 person-years) · (2.45E+00 incidences/100 person-years) = 4.67E+02
Fatalities = (1.91E+04 person-years) · (3.20E-03 fatalities/100 person-years) =6.10E-01

E.9.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are:

- Transporting high-level vitrified waste to an offsite potential geologic repository;
- Transporting earthen material from onsite borrow site to fill tank voids;
- Transporting earthen material from onsite borrow site for Hanford Barrier;
- Transporting construction material to the Hanford Site; and
- Employees commuting to work each day.

E.9.2.1 Radiological Consequences

The methodology for determining radiological consequences from accidents while transporting HLW onsite and offsite was previously discussed in Section E.6.2.1. The results are presented in the following text:

E.9.2.1.1 Truck Transport of Retrieved Tank Waste

The receptor dose and LCF risk resulting from the accident analysis for retrieval of SST residuals is presented in Table E.9.2.1 for the integrated population and Table E.9.2.2 for the MEI worker and MEI general public.

Table E.9.2.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
SSTs	1.58E-02	4.0E-04	6.3E-06

Notes:
LCF = Latent cancer fatalities
SST = Single-shell tank

Table E.9.2.2 Maximally-Exposed Individual Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

Because the MUST waste would not be retrieved and transported to the vitrification facility under this subalternative, there would be no radiological consequences from a transport accident. There would be no LCFs resulting from an accident while transporting retrieved waste onsite.

E.9.2.1.2 Rail Transport of Vitrified High-Level Waste

The receptor dose and LCF risk resulting from the accident analysis for transporting vitrified HLW to an offsite potential geologic repository is presented in Table E.9.2.3 for the integrated population, urban population, MEI worker, and MEI general public. The calculations show there would be no LCFs.

Table E.9.2.3 Radiological Impact from Transport Accidents While Transporting Vitrified HLW to a Potential Geologic Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated population	7.6E-02	5.0E-04	3.8E-05
Urban population	2.1E-02	5.0E-04	1.1E-05
MEI worker	3.7E+00	4.0E-04	1.5E-03
MEI general public	1.6E-02	5.0E-04	8.0E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

E.9.2.2 Chemical Exposure

The same chemicals would be transported to the Hanford Site by truck and rail as in the Ex Situ Intermediate Separations alternative. Therefore, the chemical exposure resulting from an accident would be the same as that shown in Table E.6.2.5 for Ex Situ Intermediate Separations alternative.

However, there would be 50 percent fewer shipments, which equates to a 50 percent reduction in the probability of an accident.

The general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 and sodium hydroxide would exceed the ratio of exposure to ERPG-1 by 2.45E+00 for corrosive/irritant chemicals. Consequently, this exposure to the MEI general public could potentially result in lethal effects.

E.9.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport material and supplies to the Site for this alternative were estimated by combining a fraction (50 percent of retrieval, 50 percent of vitrification, 50 percent of vitrified HLW transport, and 40 percent of closure) of the data values in the extensive retrieval engineering data package (WHC 1995j) with a fraction (60 percent of closure) of the data values for In Situ Fill and Cap in the in situ vitrification engineering data package (WHC 1995f). The results are summarized in Table E.9.2.4.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.9.2.5 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3.

The expected injuries and fatalities resulting from transportation accidents associated with the Ex Situ/In Situ Combination alternative are summarized in Table E.9.2.6.

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 5.28E+04. This number was estimated by combining 60 percent of the employee vehicle miles from the Ex Situ Intermediate Separations alternative with 60 percent of the employee vehicle miles from the In Situ Fill and Cap alternative.

Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). From the information listed previously the total employee vehicle distance was calculated as follows:

$$(5.28E+04 \text{ person-years}) \cdot (260 \text{ days/year}) \cdot (140 \text{ km/day}) \cdot (1/1.35 \text{ passengers per vehicle}) = 1.42E+09 \text{ km } (8.83E+8 \text{ mi})$$

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

$$\text{Injuries} = (1.42E+09 \text{ km}) \cdot (7.1E-07 \text{ injuries/km}) = 1.02E+03$$
$$\text{Fatalities} = (1.42E+09 \text{ km}) \cdot (8.98E-09 \text{ fatalities/km}) = 1.28E+01$$

Table E.9.2.4 Summary of Transportation Activities for the Ex Situ/In Situ Combination Alternative

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - onsite	Borrow	1.38E+03	1.00E+01 [5]	1.38E+04	N/A	N/A	N/A
offsite	Steel	5.30E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
	Miscellaneous	5.30E+01	1.40E+02 [1]	N/A	N/A	7.42E+03	N/A
Grout fill MUSTs							
Truck - onsite	Sand/gravel	2.20E+03	1.00E+01 [5]	2.20E+04	N/A	N/A	N/A
offsite	Cement	4.63E+02	1.40E+02[1]	N/A	N/A	6.48E+04	N/A
Retrieval							
Construction Truck - offsite	Concrete	2.40E+02/yr (20 yr)	1.40E+02 [1]	N/A	N/A	6.72E+05	N/A
	Raw material	2.25E+01/yr (20 yr)	8.00E+02 [2]	N/A	N/A	3.60E+05	N/A
	Equipment	1.25E+01/yr (20 yr)	1.00E+04 [3]	N/A	N/A	2.50E+06	N/A
	Miscellaneous	2.60E+03/yr (20 yr)	1.40E+02 [1]	N/A	N/A	7.28E+06	N/A
Rail - offsite	Raw material	5.00E+00/yr (20 yr)	8.00E+02 [2]	N/A	N/A	N/A	8.00E+04
Vitrification							
Construction Truck - onsite	Borrow	8.40E+04	1.00E+01 [5]	8.40E+05	N/A	N/A	N/A
Truck - offsite	Concrete	2.30E+04	1.40E+02 [1]	N/A	N/A	3.22E+06	N/A
	Steel	9.10E+03	8.00E+02 [2]	N/A	N/A	7.28E+06	N/A
	Miscellaneous	3.15E+03/yr (10 yr)	1.40E+02 [1]	N/A	N/A	4.41E+06	N/A
Processing Truck - offsite	Process material	1.30E+03/yr (19 yr)	8.00E+02 [2]	N/A	N/A	1.98E+07	N/A
	Miscellaneous	2.6E+03/yr (19 yr)	1.40E+02 [1]	N/A	N/A	6.92E+06	N/A
Rail - offsite	Process material	1.37E+02/yr (19 yr)	8.00E+02 [2]	N/A	N/A	N/A	2.08E+06

Table E.9.2.4 Summary of Transportation Activities for the Ex Situ/In Situ Combination Alternative (cont'd)

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Vitrified High-Level Waste Transport							
Rail - offsite	Vitrified glass	4.18E+02	4.28E+03[6]	N/A	N/A	N/A	1.79E+06
Closure							
Truck - onsite	Silt [9]	6.67E+04	3.00E+01 [7]	2.00E+06	N/A	N/A	N/A
	Riprap [9]	1.04E+05	3.20E+01 [8]	3.33E+06	N/A	N/A	N/A
	Sand [9]	7.78E+04	1.00E+01 [5]	7.78E+05	N/A	N/A	N/A
	Gravel [10]	9.36E+04	1.00E+01 [5]	9.36E+05	N/A	N/A	N/A
			Total	7.92E+06	N/A	5.25E+07	3.95E+06

Notes:
[1] Round-trip distance from Tri-Cities area
[2] Round-trip distance from Portland/Seattle area
[3] Round-trip distance from East Coast
[4] Total distance from Green (Green 1995)
[5] Round-trip distance from Pit 30 borrow site
[6] Round-trip distance to Yucca Mountain
[7] Round-trip distance from McGee Ranch borrow site
[8] Round-trip distance from Vernita Quarry borrow site
[9] For the Hanford Barrier
[10] For tank fill.
MUSTs = Miscellaneous underground storage tanks
N/A = Not Applicable

Table E.9.2.5 Distance Traveled in Population Zones for the Ex Situ/In Situ Combination Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	2.63E+06	1.05E+07	4.73E+07
Rail	1.98E+05	1.98E+05	3.56E+06

Notes:
[1] Urban represents 5 percent of the total offsite distance from Table E.9.2.4.
[2] Suburban represents 5 percent of total offsite distance and 100 percent of total onsite from Table E.9.2.4.
[3] Rural represents 90 percent of total offsite distance from Table E.9.2.4.

Table E.9.2.6 Fatalities and Injuries Resulting from Truck and Rail Transportation Accidents for the Ex Situ/In Situ Combination Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	1.97E-02	1.37E-01	2.51E+00	2.67E+00	N/A
	Injury	9.72E-01	4.01E+00	3.78E+01	N/A	4.28E+01
Rail	Fatality	3.36E-03	3.36E-03	6.05E-02	6.72E-02	N/A
	Injury	6.52E-03	6.52E-03	1.17E-01	N/A	1.30E-01
				Total	2.73E+00	4.29E+01

Notes:
N/A = Not Applicable

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.9.2.7.

Table E.9.2.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Ex Situ/In Situ Combination Alternative

Mode	Fatalities	Injuries
Truck and rail transport	2.73E+00	4.29E+01
Employee vehicle	1.28E+01	1.02E+03
Total	1.55E+01	1.06E+03

E.9.3 OPERATION ACCIDENTS

The radiological and chemical operation accidents for the Ex Situ/In Situ Combination alternative are the same as the Ex Situ Intermediate Separations alternative and the In Situ Fill and Cap alternative. The radiological cancer risk and the chemical exposure would be bound by the Ex Situ Intermediate Separations alternative presented in Section E.6.3 and are summarized as follows.

E.9.3.1 Routine Operation - Mispositioned Jumper Accident

The dominant routine operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and are summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The Ex Situ/In Situ Combination alternative was based on 23 years of operations, therefore, the probability was calculated to be 2.5E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.9.3.1.

Table E.9.3.1 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Ex Situ/In Situ Combination alternative, however, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.9.3.2. The calculations show that there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Table E.9.3.2 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.5E-01	2.8E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.5E-01	2.8E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.5E-01	2.5E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.5E-01	1.4E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.5E-01	7.8E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.5E-01	3.7E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper are summarized in Tables E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 and is indicative of potential reversible effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate which provides a conservative estimate of the potential acute hazard. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, which exceeds the ratio of 1.0 and is indicative of reversible effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.10E+00 and is indicative of mild, transient effects. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparisons.

E.9.3.2 Retrieval - Loss of Filtration Accident

The dominant retrieval operations accident is the loss of filtration accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.2 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.2.1 was calculated to be 2.5E-01 L (2.6E-01 qt).

Probability - The frequency of a loss of filtration in section E.6.3.2.2 was 8.8E-06 per year. The Ex Situ/In Situ Combination retrieval activity was based on 23 years of operations, therefore, the probability was calculated to be 2.02E-04.

Radiological Consequences - The radiological consequences presented in Section 6.3.2.3 are reproduced in Table E.9.3.3.

Radiological Cancer Risk - All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. The LCFs and the LCF point estimate risk were calculated for the receptors and are presented in Table E.9.3.4.

In addition to all 10 workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be nine LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Table E.9.3.3 Dose Consequence from Loss of Filtration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.7E+04
MEI worker	3.7E+03
Noninvolved workers (1,835) [1]	1.0E+03
MEI noninvolved worker	2.4E+01
General public (114,734) [1]	1.6E+02
MEI general public	1.0E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.9.3.4 Latent Cancer Fatality Risk from Loss of Filtration

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.7E+04	N/A	N/A	2.0E-04	2.0E-04 [3]
MEI worker	3.7E+03	N/A	N/A	2.0E-04	2.0E-04 [3]
Noninvolved workers (1,835) [2]	1.0E+03	4.0E-04	4.2E-01	2.0E-04	8.4E-05
MEI noninvolved worker	2.4E+01	8.0E-04	1.9E-02	2.0E-04	3.9E-06 [3]
General public (114,734) [2]	1.6E+02	5.0E-04	7.8E-02	2.0E-04	1.6E-05
MEI general public	1.0E-01	5.0E-04	5.2E-05	2.0E-04	1.1E-08

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not included

Chemical Consequences

Potential acute hazards associated with loss of filtration are summarized in Tables E.6.3.6 and E.6.3.7 for toxic and corrosive/irritant effects.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiological dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 6.60E+01 and exceeds 1.0, which indicates potential

irreversible health effects or death. This acute hazard index is primarily attributable to:

- Uranium (approximately 52 percent of the total hazard);
- Oxalate (approximately 26 percent of the total hazard);
- Selenium (approximately 7 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard); and
- Mercury (approximately 5 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 2.36E+00, which exceeds the ratio of 1.0 and would indicate reversible, acute health effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 8.60E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.45E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.2E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 47 percent of the total hazard);
- Calcium (approximately 36 percent of the total hazard); and
- Chromium (approximately 11 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.24E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 3.01E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.9.3.3 Pretreatment - Seismic Induced Line Break in Vault

The dominant pretreatment operations accident is the seismic-induced line break in vault accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.3 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.3.1 was calculated to be 7.3E-02 L (7.7E-02 qt).

Probability - The frequency of the accident in Section E.6.3.3.2 was 6.0E-05 per year. The Ex Situ/In Situ Combination alternative was based on 20 years of operations, therefore, the probability was calculated to be 1.2E-03.

Radiological Consequences - The radiological consequences presented in Section 6.3.3.3 are reproduced in Table E.9.3.5.

Table E.9.3.5 Dose Consequence from Seismic Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.4E+01
MEI worker	3.4E+00
Noninvolved workers (5,500) [1]	7.1E+00
MEI noninvolved worker	2.9E-01
General public (114,734) [1]	2.7E+00
MEI general public	4.5E-04

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.9.3.6. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.9.3.6 Latent Cancer Fatality Risk from Seismic-Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.4E+01	4.0E-04	1.4E-02	1.2E-03	1.6E-05
MEI worker	3.4E+00	4.0E-04	1.4E-03	1.2E-03	1.6E-06
Noninvolved workers (5,500) [2]	7.1E+00	4.0E-04	2.8E-03	1.2E-03	3.4E-06
MEI noninvolved worker	2.9E-01	4.0E-04	1.2E-04	1.2E-03	1.4E-07
General public (114,734) [2]	2.7E+00	5.0E-04	1.4E-03	1.2E-03	1.6E-06
MEI general public	4.5E-04	5.0E-04	2.3E-07	1.2E-03	2.7E-10

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.12E+00, which exceeds 1.0 and is indicative of mild, transient effects. This acute hazard index is primarily attributable to thallium (approximately over 99 percent of the total hazard). The acute hazard index for the general public was less than 1.0, and because the accident takes place within a vault the emissions are from a stack and the worker does not receive a dose. For all receptors, the cumulative ratio of exposure to ERPG values for corrosive/irritant chemicals was less than 1.0.

E.9.3.4 Treatment (Ex Situ Vitrification) - Canister of Vitrified High-Level Waste Inadvertently Drops and Ruptures

The dominant immobilization operations accident is the "canister of vitrified HLW inadvertently drops and ruptures" accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.4 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.4.1 was calculated to be 2.5E-06 g (8.8E-08 oz).

Probability - The frequency of the accident in Section E.6.3.4.2 was 6.0E-01 per year. The Ex Situ/In Situ Combination alternative was based on 20 years of operations, therefore, the probability was calculated to be 1.0E+00.

Radiological Consequences - The radiological consequences presented in Section 6.3.4.3 are reproduced in Table E.9.3.7.

Table E.9.3.7 Dose Consequence from Breached Canister

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.5E-04
MEI worker	1.5E-05
Noninvolved workers (5,500) [1]	5.8E-08
MEI noninvolved worker	4.0E-09
General public (114,734) [1]	1.5E-08
MEI general public	2.4E-12

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.9.3.8. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.9.3.8 Latent Cancer Fatality Risk from Breached Canister

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.5E-04	4.0E-04	5.8E-08	1.0E+00	5.8E-08
MEI worker	1.5E-05	4.0E-04	5.8E-09	1.0E+00	5.8E-09
Noninvolved workers (5,500) [2]	5.8E-08	4.0E-04	2.3E-11	1.0E+00	2.3E-11
MEI noninvolved worker	4.0E-09	4.0E-04	1.6E-12	1.0E+00	1.6E-12
General public (114,734) [2]	1.5E-08	5.0E-04	7.5E-12	1.0E+00	7.5E-12
MEI general public	2.4E-12	5.0E-04	1.2E-15	1.0E+00	1.2E-15

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - No chemical consequences were evaluated (Shire et al. 1995) since the release would be through two-stage HEPA filters that would reduce the source term well below the cumulative ratio of exposure to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.9.3.5 Treatment - In Situ Fill and Cap

The dominant treatment operations accident is the tank deflagration accident resulting in a tank dome collapse previously discussed in the In Situ Fill and Cap alternative in Section E.4.3.2 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.4.3.2.1 was calculated to be 7.47E+00 L (7.9E+00 qts).

Probability - The probability of a tank dome collapse in Section E.4.3.2.2 was assumed to be 1.0E-04.

Radiological Consequences - The radiological consequences presented in Section 4.3.2.3 are reproduced in Table E.9.3.9.

Radiological Cancer Risk - All 10 workers and the MEI noninvolved worker would potentially receive a lethal dose. The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.9.3.10.

In addition to all 10 workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be nine LCFs attributed to the exposure to the noninvolved workers and 2 LCFs attributed to the general public if the accident occurred.

Table E.9.3.9 Dose Consequence from Tank Dome Collapse Due to Deflagration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	6.2E+04
MEI worker	6.2E+03
Non involved workers (1,835) [1]	2.3E+04
MEI non involved worker	1.5E+03
General public (114,734) [1]	3.7E+03
MEI general public	3.9E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Table E.9.3.10 Latent Cancer Fatality Risk from Tank Dome Collapse Due to Deflagration

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	6.2E+04	N/A	N/A	1.0E-04	1.0E-04 [3]
MEI worker	6.2E+03	N/A	N/A	1.0E-04	1.0E-04 [3]
Noninvolved workers (1,835) [2]	2.3E+04	4.0E-04	9.2E+00	1.0E-04	9.2E-04
MEI noninvolved worker	1.5E+03	N/A	N/A	1.0E-04	1.0E-04 [3]
General public (114,734) [2]	3.7E+03	5.0E-04	1.9E+00	1.0E-04	1.9E-04
MEI general public	3.9E+00	5.0E-04	2.0E-03	1.0E-04	2.0E-07

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not included

E.9.3.5.1 Chemical Consequences of Tank Dome Collapse

The chemical exposure to the receptors from the postulated accident are similar to those summarized in the exposure column in Table E.2.2.8 and Table E.2.2.9 for toxic and corrosive/irritant effects, respectively. The consequences are summarized as follows.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);

- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m (951 ft) from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m (5,838 ft) from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m (328 ft) from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00, which exceeds 1.0 and would indicate potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m (951 ft) from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m (5,383 ft) from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.9.3.6 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows:

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E+00 L (2.5E+00 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 23 years of operation was therefore estimated to be 5.2E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.9.3.11.

Table E.9.3.11 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI Worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are reproduced in Table E.9.3.12.

Table E.9.3.12 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	5.2E-04	5.2E-04[2]
MEI worker	2.2E+04	N/A	N/A	5.2E-04	5.2E-04[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	5.2E-04	5.1E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	5.2E-04	5.2E-04[2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	5.2E-04	9.6E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	5.2E-04	1.1E-06

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not applied

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiological dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and would be indicative of only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.9.3.7 Occupation Injuries, Illnesses, and Fatalities from Operations

The number of operation personnel to support the Ex Situ/In Situ Combination alternative was estimated in (Jacobs 1996) and summarized as follows:

- Retrieval operations - 2.24E+04 person-years;
- Vitrification operations - 1.04E+04 person-years; and
- Fill tanks with gravel operations - 9.06E+02 person-years.

The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (3.37E+04 person-years) · (2.2E+00 incidences/100 person-years) = 7.41E+02
Lost Workday Cases = (3.37E+04 person-years) · (1.1E+00 incidences/100 person-years) = 3.71E+02
Fatalities = (3.37E+04 person-years) · (3.20E-03 fatalities/100 person-years) = 1.08E+00

E.9.4 POST-REMEDIATION ACCIDENT

E.9.4.1 Deflagration in Storage Tank

The tanks that have had 99 percent of their waste removed and filled with gravel do not pose a credible risk. However, the tanks that have been saltwell pumped and filled with gravel may. After the tanks have been filled with gravel, the dome sealed off, and the Hanford Barrier placed over the tank farms, it was postulated that hydrogen builds up in the tank, reaches the LFL, and ignites. The probable sequence of events is that the tank would breach and possibly the asphalt layer in the Hanford Barrier would crack allowing an increased movement of the residual tank waste into the groundwater. An explosion that could breach the dome, displace 2 m (7 ft) of overburden, and displace an additional 5 m (15) ft of the Hanford Barrier, is considered to be incredible.

For this event to occur, the following conditions must exist:

- Flammable gases must be generated from the waste;
- The concentration of the flammable gas must exceed the lower flammability limit;
- There must be an ignition source; and
- The deflagration would have to generate enough energy to breach the tank and crack the asphalt liner.

Generation of Flammable Gas

All 177 waste tanks produce flammable gases at the molecular level such as hydrogen, ammonia, and methane due to radiolysis, organic degradation, and corrosion.

Gas Concentration

Gases generated from the residual tank waste would diffuse and accumulate in the voids within the gravel and the tank headspace created by the waste settling under the pressure of the fill. If the hydrogen is not allowed to escape from the tank through leaks or cracks in the tank, the hydrogen concentration will continue to increase as long as the potential for radiolysis, organic degradation, or corrosion exists.

It has been shown in tank waste that hydrogen generation rates may drop by approximately one-half every 15 years. Therefore, the gas concentration potential could be reduced by allowing the tanks to vent for 100 years (during institutional controls) through vent pipes passing up through the Hanford Barrier. The vents could then be sealed off. Allowing the tanks to vent for 100 years would reduce the probability of hydrogen reaching the LFL in the tank. Hydrogen gas concentration could be retarded by placing catalytic recombiners in the tank that would recombine hydrogen and oxygen.

Ignition of Gas

If the gas concentrations in the tank manage to exceed the LFL, the ignition sources are limited. Possible ignition sources would include a lightning strike, an earthquake, or heat produced by reactions taking place in the materials remaining in the tank. If the gas was ignited, the propagation of the burn through the gravel is dependent upon the size of the voids in the gravel matrix. Flames will not propagate in a porous material if the pore size is less than a critical value.

Consequences

The probable sequence of events is that the tank would breach and possibly the asphalt layer in the Hanford Barrier would crack allowing an increased movement of the residual tank waste into the groundwater.

E.9.4.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault that would increase exposure to the waste after remediation is considered to be incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.10.0 PHASED IMPLEMENTATION ALTERNATIVE

The Phased Implementation alternative includes remediating the tank waste in a two-phase process. The first phase would be a commercial demonstration of the separations and immobilization processes for selected tank waste. The second step would involve scaling-up the demonstration processes to treat the remaining tank waste and construction of larger treatment facilities. The phased implementation approach could be applied to any of the tank waste alternatives involving ex situ waste treatment, however, for the purposes of analysis the Ex Situ Intermediate Separations alternative, with some

additional separations, was selected as the representative alternative. The Phased Implementation alternative is presented in two parts, Phase 1 first, then Phase 2.

E.10.1 PHASE 1

Phase 1 would consist of one LAW treatment facility and one LAW and HLW facility using vitrification to produce a stabilized waste form to specification. This alternative would involve constructing and operating vitrification and support facilities, and transfer lines from the tank farms and T Plant to the vitrification facilities. This alternative would also involve vehicle traffic of the personnel required to support the alternative. This section analyzes the construction, operation, and transportation risks associated with this alternative.

E.10.1.1 Construction Accidents

The potential exists for accidents resulting from construction activities. The construction activities are outlined in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated as follows.

The number of construction personnel was estimated at an average 1.07E+04 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities during construction were calculated using the incidence rates from Table E.1.2.1 as follows:

Total Recordable Cases = (1.07E+04 person-years) · (9.75E+00 incidences/100 person-years) = 1.04E+03
Lost Workday Cases = (1.07E+04 person-years) · (2.45E+00 incidences/100 person-years) = 2.62E+02
Fatalities = (1.07E+04 person-years) · (3.2E-03 fatalities/100 person-years) = 3.42E-01

E.10.1.2 Transportation Accidents

Transportation activities associated with this alternative are:

- Transporting construction material to the Hanford Site;
- Transporting earthen material from onsite borrow sites;
- Transporting process material from offsite to the vitrification facilities;
- Transporting vitrified and unvitrified LAW and HLW to the canister storage building (CSB);
- Transporting contaminated waste from decommissioned facilities to low-level waste burial ground;
- Transporting noncontaminated waste from decommissioned facilities to regulated landfill; and
- Employees commuting to work each day.

9613409.1462

E.10.1.2.1 Radiological Cancer Risk from Transportation

Canisters of Cs and technetium would be transported to the CSB by truck. The radiological cancer risk from this activity was compared to a similar activity in Section E.14.2.1. Section E.14.2.1 evaluated the radiological cancer risk from transporting Cs and Sr capsules from WESF to an onsite vitrification facility. The radiological cancer risk from transporting 1.93E+03 of Cs and Sr capsules to the vitrification facility was analyzed (Green 1995) and summarized in Section E.14.2.1 of this appendix. The estimated number of LCFs in an integrated population, resulting from an accident, was 1.2E-05. Approximately half as many Cs and technetium canisters would be transported to the CSB in the Phase 1, therefore 1.2E-05 LCFs would be reduced by a factor of two resulting in approximately 6.0E-06 LCFs for the Phased Implementation alternative.

E.10.1.2.2 Chemical Exposure from Transportation Accidents

The chemical exposure from transportation accidents would be bound by the analysis preformed in Section 6.2.2. The chemical exposure and frequency of the integrated accident was reproduced in Table E.10.1.1. The comparison of exposure concentration from postulated chemical released to exposure limits was reproduced in Table E.10.1.2.

For the MEI general public the ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.24 E+01, which exceed the acceptable criterion of 1.0 and is indicative of potential lethal effects. This acute hazard index is primarily attributable to anhydrous ammonia (over 99.9 percent of the total hazard).

E.10.1.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation

Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the Site for this alternative were estimated (WHC 1995j) and are summarized in Table E.10.1.3.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.10.1.4 by the appropriate unit risk factors shown in Table E.1.3.1. The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3. The expected injuries and fatalities resulting from transportation accidents associated with Phase 1 are summarized in Table E.10.1.5.

Employee Traffic

In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, Site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 1.77E+04.

Table E.10.1.1 Chemical Releases from Postulated Accidents for Phase 1

Chemical	Concentration	Frequency
Nitric Acid	0.28 mg/m^3	5.0E-08/yr
Sodium Hydroxide	4.9 mg/m^3	2.0E-07/yr
Anhydrous Ammonia	8,770 mg/m^3	2.0E-07/yr
Dicyclopentadiene	1.02 mg/m^3	1.0E-8/yr

Table E.10.1.2 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for Phase 1

Analyte (Threshold values are presented in mg/m^3)		Exposure (mg/m^3)	ERPG-1 (mg/m^3)	ERPG-2 (mg/m^3)	ERPG-3 (mg/m^3)
Anhydrous Ammonia [1]	Threshold Value		1.77E+01	1.42E+02	7.10E+02
			Ratio of Exposure to ERPG		
	MEI General Public	8.77E+03	4.95E+02	6.18E+01	1.24E+01
Dicyclopentadiene [2]	Threshold Value		2.20E+01	1.10E+02	1.10E+04
			Ratio of Exposure to ERPG		
	MEI General Public	1.02E+00	4.64E-02	9.27E-03	9.27E-05
Nitric Acid [3]	Threshold Value		5.20E+00	6.55E+01	1.31E+02
			Ratio of Exposure ERPG		
	MEI General Public	2.80E-01	5.38E-02	4.27E-03	2.14E-03
Sodium Hydroxide [4]	Threshold Value		2.00E+00	4.00E+01	1.00E+02
			Ratio of Exposure to ERPG		
	MEI General Public	4.90E+00	2.45E+00	1.23E-01	4.90E-02

Notes:
[1] AIHA ERPGs were used for anhydrous ammonia.
[2] The OSHA permissible exposure limit-time weighted average (PEL-TWA) concentration for dicyclopentadiene (27 mg/m^3) was similar to the PEL-TWA for 1,3-butadiene (22 mg/m^3). Therefore, the ERPGs for 1,3-butadiene were conservatively used as surrogate values.
[3] AIHA ERPGs were used for nitric acid.
[4] AIHA ERPGs were used for sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

Table E.10.1.3 Summary of Transportation Activities for Phase 1

Activity	Cargo	Trips	Distance (km) (round-trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Waste Transfer System Upgrade (W-314)							
Truck - onsite	Borrow	1.38E+03	1.00E+01[1]	1.38E+04	N/A	N/A	N/A
Truck-offsite	Steel	5.30E+01	8.00E+02[2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02[3]	N/A	N/A	1.40E+04	N/A
Vitrification							
Construction Truck - onsite	Borrow	1.96E+03	1.00E+01[1]	1.96E+04	N/A	N/A	N/A
Truck - offsite	Concrete	1.20E+03	1.40E+02[3]	N/A	N/A	1.68E+05	N/A
	Steel	7.32E+03	8.00E+02[2]	N/A	N/A	5.86E+06	N/A
	Miscellaneous	3.18E+03	1.40E+02[3]	N/A	N/A	4.45E+05	N/A
Processing Truck - offsite	Process material	3.50E+03	8.00E+02[2]	N/A	N/A	2.80E+06	N/A
	Process material	3.57E+03	1.40E+02[3]	N/A	N/A	5.00E+05	N/A
	Miscellaneous	5.20E+04	1.40E+02[3]	N/A	N/A	7.28E+06	N/A
Rail - offsite	Process material	2.18E+02	8.00E+02[2]	N/A	N/A	N/A	1.74E+05
Site Restoration							
Truck - onsite	Contaminated Waste	1.50E+03	1.61E+01[4]	2.41E+04	N/A	N/A	N/A
	Noncontaminated Waste	6.23E+04	1.61E+01[5]	1.00E+06	N/A	N/A	N/A
			Total	1.05E+06	N/A	1.71E+07	1.74E+05

Notes:
[1] Round-trip distance from Borrow site.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from Tri-Cities area.
[4] Round-trip distance to low-level waste burial ground.
[5] Round-trip distance to regulated landfill.
N/A= Not Applicable

Table E.10.1.4 Distance Traveled in Population Zones for Phase 1

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	8.55E+05	1.90E+06	1.54E+07
Rail	8.72E+03	8.72E+03	1.57E+05

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.10.1.3.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.10.1.3.
[3] Rural represents 90 percent of total offsite distance from Table E.10.1.3.

Table E.10.1.5 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for Phase 1

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	6.41E-03	2.47E-02	8.16E-01	8.47E-01	N/A
	Injury	3.16E-01	7.23E-01	1.24E+01	N/A	1.33E+01
Rail	Fatality	1.48E-04	1.48E-04	2.67E-03	2.97E-03	N/A
	Injury	2.88E-04	2.88E-04	5.18E-03	N/A	5.76E-03
				Total	8.58E-01	1.34E+01

Notes:
N/A= Not Applicable

Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:

$$(1.77E+04 \text{ person-years}) \cdot (260 \text{ days/year}) \cdot (140 \text{ km/day}) \cdot (1/1.35 \text{ passengers per vehicle}) = 4.76E+08 \text{ km } (2.96E+08 \text{ mi})$$

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

$$\text{Injuries} = (4.76E+08 \text{ km}) \cdot (7.1E-07 \text{ injuries/km}) = 3.40E+02$$
$$\text{Fatalities} = (4.76E+08 \text{ km}) \cdot (8.98E-09 \text{ fatalities/km}) = 4.27E+00$$

Cumulative Transportation Injuries and Fatalities

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.10.1.6.

E.10.1.3 Operation Accidents

Operations are discussed in Appendix B. The radiological and chemical operation accidents, consequences, and risk for Phase 1 are summarized in the following text.

Table E.10.1.6 Cumulative Injuries and Fatalities from Traffic Impacts for Phase 1

Mode	Fatalities	Injuries
Truck and rail transport	8.50E-01	1.34E+01
Employee vehicle	4.27E+00	3.40E+02
Total	5.12E+00	3.53E+02

E.10.1.3.1 Continued Operation Accidents

The dominant continued operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The probability of the No Action alternative was based upon 10 years of waste transfers. Phase 1 is based on 10 years of operations, therefore, the probability would be the same 1.1E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.10.1.7.

Table E.10.1.7 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for Phase 1 and are reproduced in Table E.10.1.8. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Table E.10.1.8 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	1.1E-01	1.2E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	1.1E-01	1.2E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	1.1E-01	1.1E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	1.1E-01	5.9E-03
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	1.1E-01	3.4E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	1.1E-01	1.6E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences

Potential acute hazards associated with a mispositioned jumper are summarized in Tables E.2.2.4 and E.2.2.5 for toxic and corrosive/irritant effects, respectively.

Toxic Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 and is indicative of potential reversible effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC is assumed to be tributylphosphate which provides a conservative estimate of the potential acute hazards. The acute hazard indices for the MEI noninvolved worker and general public ration was less than 1.0 for ERPG-1 comparisons.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, exceeds 1.0, and is indicative of potential reversible effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.1E+00 and is indicative of mild, transient effects. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard). The acute hazard index for the MEI general public ratio was less than 1.0 for ERPG-1 comparisons.

E.10.1.3.2 Pretreatment Accidents

The dominant pretreatment operations accident is the seismic induced line break in vault accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.3 and is summarized as follows:

Source Term - The source term resulting from the airborne release in Section E.6.3.3.1 was calculated to be 7.3E-02 L (7.7E-02 qt).

Probability - The frequency of the accident in Section E.6.3.3.2 was 6.0E-05 per year. Phase 1 was based on 10 years of operations, therefore, the probability was calculated to be 6.0E-04.

Radiological Consequences - The radiological consequences presented in Section 6.3.3.3 are reproduced in Table E.10.1.9.

Table E.10.1.9 Dose Consequence from Seismic Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.4E+01
MEI worker	3.4E+00
Noninvolved workers (5,500) [1]	7.1E+00
MEI noninvolved worker	2.9E-01
General public (114,734) [1]	2.7E+00
MEI general public	4.5E-04

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.10.1.10. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.10.1.10 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.4E+01	4.0E-04	1.4E-02	6.0E-04	8.2E-06
MEI worker	3.4E+00	4.0E-04	1.4E-03	6.0E-04	8.2E-07
Noninvolved workers (5,500) [2]	7.1E+00	4.0E-04	2.8E-03	6.0E-04	1.7E-06
MEI noninvolved worker	2.9E-01	4.0E-04	1.2E-04	6.0E-04	7.0E-08
General public (114,734) [2]	2.7E+00	5.0E-04	1.4E-03	6.0E-04	8.1E-07
MEI general public	4.5E-04	5.0E-04	2.3E-07	6.0E-04	1.4E-10

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Consequences - For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.12E+00, which exceeds 1.0. This acute hazard index is primarily attributable to thallium (approximately over 99 percent of the total hazard). The general public was less than 1.0, and because the accident takes place within a vault the emissions are from a stack and the worker does not receive a dose. For all receptors, the cumulative ratio of exposure to ERPG values for corrosive/irritant chemicals was less than 1.0.

E.10.1.3.3 Treatment Accidents

The dominant treatment operations accident is a crushed Cs canister. It was postulated that the Cs canister is breached when a heavy object falls on the canister. The source term, probability, and dose consequences were taken from (WHC 1995k) and summarized in the following text.

Scenario and Source Term Development

It was assumed that the initial shock of the drop of a heavy object on the canister would spill the entire canister contents and loft a fraction of 1.0E-03 of the activity by free-fall. This would be resuspended for 8 hours at 4.0E-06 per hour and released from the facility through two stage HEPA filters that would provide a LPF of 2.0E-06. The source term would be 8.0E-05 Ci.

Probability

The scenario was considered to be unlikely with a frequency range of 1.0E-02 per year to 1.0E-04 per year. For conservatism, a frequency of 1.0E-02 per year was used for calculating risk. Based on a separations operation of 10 years, the probability was calculated to be 1.0E-01.

Radiological Consequences

The radiological dose to the receptors from the accident scenario was calculated using the methodology previously discussed in Section 1.1.6. The results are summarized in Table E.10.1.11. Dose consequences for the worker was not evaluated since the accident was assumed to take place in a vault and would result in a filtered stack release.

Table E.10.1.11 Dose Consequence from Crushed Cesium Canister

Receptor	Dose CEDE (person-rem)
Non involved workers (5,500) [1]	2.3E-04
MEI non involved worker	2.7E-05
General public (114,734) [1]	5.8E-05
MEI general public	1.8E-08

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk

Based on a dose-to-risk conversion factor of 4.0E-04 LCF per person-rem for the workers and non involved workers and 5.0E-04 LCF per person-rem for the general public, the LCFs and the LCF point estimate risk were calculated for the receptors and presented in Table E.10.1.12. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.10.1.12 Latent Cancer Fatality Risk from Crushed Cesium Canister

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF[1]	Probability	LCF Risk (point estimate)
Noninvolved workers (5,500) [2]	2.3E-04	4.0E-04	9.2E-08	1.0E-01	9.2E-09
MEI noninvolved worker	2.7E-05	4.0E-04	1.1E-08	1.0E-01	1.1E-09
General public (114,734) [2]	5.8E-05	5.0E-04	2.9E-08	1.0E-01	2.9E-09
MEI general public	1.8E-08	5.0E-04	9.0E-12	1.0E-01	9.0E-13

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

Chemical Exposure

Chemical exposure was not evaluated since there would essentially be no other chemical in the canister other than Cs which was evaluated under Radiological consequences.

E.10.1.3.4 Disposal/Storage Accidents

No DBA accidents resulting in a radiological or chemical consequences to the receptors were identified. This is largely due to the vitrified waste form of the material and the engineered structural packaging of the vitrified LAW and vitrified HLW in shipping containers.

E.10.1.3.5 Beyond Design Basis Accident

The dominant BDBA accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows.

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.4E-01 L (2.6E-01 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 10 years of operation was therefore estimated to be 2.25E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.10.1.13.

Table E.10.1.13 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are reproduced in Table E.10.1.14.

Table E.10.1.14 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	2.3E-04	2.3E-04[2]
MEI worker	2.2E+04	N/A	N/A	2.3E-04	2.3E-04[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	2.3E-04	2.2E-03
MEI noninvolved worker	1.7E+03	N/A	N/A	2.3E-04	2.3E-04
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	2.3E-04	4.2E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	2.3E-04	4.8E-07

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not applied

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences

Potential acute hazards associated with a hydrogen burn in a waste storage tank are summarized in Table E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiological dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.10.1.3.6 Occupational Injuries and Fatalities

The number of operation personnel to support Phase 1 was estimated at 6.93E+03 (Jacobs 1996). The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (6.93E+03 person-years) · (2.2E+00 incidences/100 person-years) = 1.52E+02
Lost Workday Cases = (6.93E+03 person-years) · (1.1E+00 incidences/100 person-years) = 7.62E+01
Fatalities = (6.93E+03 person-years) · (3.2E-03 fatalities/100 person-years) = 2.22E-01

E.10.2 TOTAL ALTERNATIVE

The Total alternative for tank waste would involve constructing and operating vitrification and support facilities, low-activity vitrified waste burial vaults, and transfer lines from the tank farms and T Plant to the vitrification facilities. This alternative would also involve transporting retrieved tank waste and high-level vitrified waste to an offsite potential geologic repository, and vehicle traffic of the personnel required to support the alternative. This section analyzes the construction, operation, and transportation risks associated with this alternative.

E.10.2.1 Construction Accidents

The potential exists for accidents resulting from construction activities. The construction activities are outlined in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated as follows.

The number of construction personnel was estimated at an average 3.14E+04 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities during construction were calculated using the incidence rates from Table E.1.2.1 as follows:

Total Recordable Cases = (3.14E+04 person-years) · (9.75E+00 incidences/100 person-years) = 3.06E+03
Lost Workday Cases = (3.14E+04 person-years) · (2.45E+00 incidences/100 person-years) = 7.69E+02
Fatalities = (3.14E+04 person-years) · (3.2E-03 fatalities/100 person-years) = 1.00E+00

E.10.2.2 Transportation Accidents

Under the Total alternative, Hanford Site tank waste would be stabilized by vitrification. The vitrified HLW would be shipped to an offsite potential geologic repository and the LAW would be buried in vaults on the Hanford Site. These waste streams would be transported by pipeline, truck, and rail. In addition to transporting the waste, construction materials and process chemicals would be transported to the Hanford Site by truck and rail. This alternative would also be supported by a work force of employees that would commute to work each day.

E.10.2.2.1 Radiological Cancer Risk

The radiological cancer risk would be the same as that previously discussed in Section E.6.2.1. for truck transport of retrieved tank waste to the vitrification facility and rail transport of vitrified HLW to an offsite potential geologic repository.

Truck Transport of Retrieved Tank Waste - The receptor dose, LCFs, and LCF risk resulting from a truck transport accident during retrieval of MUST waste and SST residuals for the integrated population and for the MEI worker and MEI general public was evaluated in Section E.6.2.1.1. These are reproduced in Tables E.10.2.1 and E.10.2.2.

Table E.10.2.1 Integrated Radiological Impact from Retrieval Transport Accidents

Transport Activity	Population Dose (person-rem)	LCF/rem	LCF Risk
MUSTs	3.43E-03	4.0E-04	1.37E-06
SSTs	1.58E-02	4.0E-04	6.32E-06

Notes:
LCF = Latent cancer fatalities
MUST = Miscellaneous underground storage tank
SST = Single-shell tank

Table E.10.2.2 Maximally Exposed Individual Radiological Impact from Retrieval Transport Accidents

Receptor	Dose (rem)	LCF/rem	LCF Risk
MUSTs			
Worker MEI	3.5E-01	4.0E-04	1.4E-04
General public MEI	1.5E-03	5.0E-04	7.5E-07
SSTs			
Worker MEI	1.8E+00	4.0E-04	7.2E-04
General public MEI	7.6E-03	5.0E-04	3.8E-06

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual
MUST = Miscellaneous underground storage tank
SST = Single-shell tank

There would be no LCFs resulting from an accident while transporting retrieved waste on site.

Rail Transport of Vitrified High-Level Waste - The receptor dose and LCF risk resulting from a rail accident while transporting vitrified HLW to an offsite potential geologic repository for the integrated population, urban population, MEI worker, and MEI general public was evaluated in Section E.6.2.1.2 and reproduced in Table E.10.2.3. The calculations show there would be no LCFs.

Table E.10.2.3 Radiological Impact from Transport Accidents while Transporting Vitrified HLW to a Potential Geologic Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated population	9.27E-02	5.0E-04	4.6E-05
Urban population	2.5E-02	5.0E-04	1.3E-05
MEI worker	6.9E+00	4.0E-04	2.8E-03
MEI general public	3.0E-02	5.0E-04	1.5E-05

Notes:
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

E.10.2.2.2 Chemical Exposure

Chemicals transported to the Hanford Site to support the pretreatment and vitrification processes would have the greatest chemical impact. The impacts were previously analyzed in Section E.6.2.2. The evaluation showed the general public exposure to anhydrous ammonia would exceed the ratio of exposure to ERPG-3 by 1.24E+01 and sodium hydroxide would exceed the ratio of exposure to ERPG-1 by 2.45E+00 for corrosive/irritant chemicals. The magnitude of the anhydrous ammonia exceedance indicates potential lethal effects for the MEI general public.

E.10.2.2.3 Occupational Injuries and Fatalities

Truck and Rail Transportation - Injuries and fatalities resulting from direct impact of transportation accidents are analyzed in this subsection. Rail and truck transportation activities to transport materials and supplies to the Site for this alternative were estimated (WHC 1995j) and are summarized in Table E.10.2.4.

The number of injuries and fatalities were calculated by multiplying the total distance traveled in each zone shown in Table E.10.2.5 by the appropriate unit risk factors shown in Table E.1.3.1.

The distance traveled in the population zones were calculated using the methodology previously discussed in Section E.1.3. The expected injuries and fatalities resulting from transportation accidents associated with the Total alternative are summarized in Table E.10.2.6.

Employee Traffic - In addition to transporting materials and supplies to and from the Hanford Site by truck and rail, Site workers and other personnel required to perform the various activities would be driving to the site in their vehicles. The total person-years to perform the activities was estimated at 8.73E+04.

Each person was assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area was estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total employee vehicle distance was therefore calculated as follows:
(8.73E+04 person-years) · (260 days/year) · (140 km/day) · (1/1.35) = 2.35E+09 km (1.46E+09 mi)

Table E.10.2.4 Summary of Transportation Activities for the Total Alternative

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Retrieval							
Construction Truck - offsite	Concrete	4.80E+02/year (20 year)	1.40E+02 [1]	N/A	N/A	1.34E+06	N/A
	Raw material	4.50E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	7.20E+05	N/A
	Equipment	2.50E+01/year (20 year)	1.00E+04 [3]	N/A	N/A	5.00E+06	N/A
	Miscellaneous	5.20E+03/year (20 year)	1.40E+02 [1]	N/A	N/A	1.46E+07	N/A
Rail - offsite	Raw material	1.00E+01/year (20 year)	8.00E+02 [2]	N/A	N/A	N/A	1.60E+05
Waste Transport Truck - onsite	Inactive miscellaneous underground storage tank waste	6.25E+02	2.0E+01	1.25E+04	N/A	N/A	N/A
Waste Transfer System Upgrade (W-314)							
Truck - onsite	Borrow	1.38E+03	1.00E+01 [4]	1.38E+04	N/A	N/A	N/A
Truck - offsite	Steel	5.3E+01	8.00E+02 [2]	N/A	N/A	4.24E+04	N/A
	Cement	1.00E+02	1.40E+02 [1]	N/A	N/A	1.40E+04	N/A
Vitrification							
Construction Truck - onsite	Borrow	1.44E+05	1.00E+01 [4]	1.44E+06	N/A	N/A	N/A
Truck - offsite	Concrete	2.61E+04	1.40E+02 [1]	N/A	N /A	3.65E+06	N/A
	Steel	9.70E+03	8.00E+02 [2]	N/A	N/A	7.76E+06	N/A
	Miscellaneous	3.11E+04	1.40E+02 [1]	N/A	N/A	4.35E+06	N/A
Processing Truck - offsite	Process material	1.65E+04	8.00E+02 [2]	N/A	N/A	1.32E+07	N/A
	Process material	3.00E+04	1.40E+02 [1]	N/A	N/A	4.20E+06	N/A
	Miscellaneous	1.03E+05	1.40E+02 [1]	N/A	N/A	1.44E+07	N/A

Table E.10.2.4 Summary of Transportation Activities for the Total Alternative (cont'd)

Activity	Cargo	Trips	Distance (km) (round trip)	Total distance (km)			
				Onsite		Offsite	
				Truck	Rail	Truck	Rail
Rail - offsite	Process material	3.00E+03	8.00E+02 [2]	N/A	N/A	N/A	2.40E+06
Vitrified High-Level Waste Transport							
Rail - offsite	Vitrified glass	8.35E+02	4.28E+03 [5]	N/A	N/A	N/A	3.57E+06
Grout Fill MUSTs							
Truck - onsite	Sand/Gravel	2.20+03	1.00E+01 [4]	2.20E+04	N/A	N/A	N/A
Truck - offsite	Cement	4.63E+02	1.40E+02 [1]	N/A	N/A	6.48E+04	N/A
Closure							
Truck - onsite	Silt [8]	8.53E+04	3.00E+01 [6]	2.56E+06	N/A	N/A	N/A
	Riprap [8]	1.22E+05	3.20E+01 [7]	3.90E+06	N/A	N/A	N/A
	Sand [8]	1.00E+05	1.00E+01 [4]	1.00E+06	N/A	N/A	N/A
	Fill [9]	9.86E+04	1.00E+01 [4]	9.86E+05	N/A	N/A	N/A
			Total	9.92E+06	N/A	6.93E+07	6.19E+06

Notes:
[1] Round-trip distance from Tri-Cities area.
[2] Round-trip distance from Portland/Seattle area.
[3] Round-trip distance from East Coast.
[4] Round-trip distance from Pit 30 borrow site.
[5] Round-trip distance to Yucca Mountain.
[6] Round-trip distance from McGee Ranch borrow site.
[7] Round-trip distance from Vernita Quarry borrow site.
[8] For Hanford Barrier.
[9] For tank fill.
N/A= Not Applicable

Table E.10.2.5 Distance Traveled in Population Zones for the Total Alternative

Mode	Urban	Suburban	Rural
Truck	3.46E+06	1.34E+07	6.24E+07
Rail	3.10E+05	3.10E+05	5.57E+06

Table E.10.2.6 Injuries and Fatalities Resulting from Truck and Rail Transportation Accidents for the Total Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatalities	Total Injuries
Truck	Fatality	2.60E-02	1.74E-01	3.31E+00	3.51E+00	N/A
	Injury	1.28E+00	5.09E+00	4.99E+01	N/A	5.63E+01
Rail	Fatality	5.26E-03	5.26E-03	9.47E-02	1.05E-01	N/A
	Injury	1.02E-02	1.02E-02	1.84E-01	N/A	2.04E-01
				Total	3.61E+00	5.65E+01

Notes:
N/A = Not Applicable

To calculate the expected number of injuries and fatalities resulting from vehicle accidents, the injury/fatality rates discussed in Section E.1.3 were used. The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (2.35E+09 km) · (7.1E-07 injuries/km) = 1.68E+03
Fatalities = (2.35E+09 km) · (8.98E-09 fatalities/km) = 2.11E+01

Cumulative Transportation Injuries and Fatalities - The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are the sum of the truck and rail transport and employee vehicle accidents. The results are summarized in Table E.10.2.7.

Table E.10.2.7 Cumulative Injuries and Fatalities from Traffic Impacts for the Total Alternative

Mode	Fatalities	Injuries
Truck and rail transport	3.61E+00	5.65E+01
Employee vehicle	2.11E+01	1.68E+03
Total	2.47E+01	1.74E+03

E.10.2.3 Operation Accidents

Operation accidents would be the same as those analyzed in Section E.6.3.

E.10.2.3.1 Routine Operation Accidents

The dominant routine operations accident is the mispositioned jumper accident previously discussed in the No Action alternative in Section E.2.2.1 and summarized as follows:

Source Term - The source term resulting from a spray release in Section E.2.2.1.1 was calculated to be 52 L (55 qt).

Probability - The frequency of a mispositioned jumper in Section E.2.2.1.2 was 1.1E-02 per year. The Ex Situ Intermediate Separations alternative was based on 22 years of operations, therefore, the probability was calculated to be 2.4E-01.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.10.2.8.

Table E.10.2.8 Dose Consequence from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	1.4E+03
MEI worker	1.4E+02
Noninvolved workers (1,835) [1]	2.5E+03
MEI noninvolved worker	6.7E+01
General public (114,734) [1]	6.2E+02
MEI general public	2.9E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.1.4 are the same for the Total alternative. However, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.10.2.9. The calculations show there would be one fatal cancer attributable to this exposure to the workers and one to the noninvolved workers if the accident occurred. The calculations show there would be no expected cancer fatalities to the general public.

Table E.10.2.9 Latent Cancer Fatality Risk from Mispositioned Jumper

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	1.4E+03	8.0E-04	1.1E+00	2.4E-01	2.7E-01
MEI worker	1.4E+02	8.0E-04	1.1E-01	2.4E-01	2.7E-02
Noninvolved workers (1,835) [2]	2.5E+03	4.0E-04	1.0E+00	2.4E-01	2.4E-01
MEI noninvolved worker	6.7E+01	8.0E-04	5.4E-02	2.4E-01	1.3E-02
General public (114,734) [2]	6.2E+02	5.0E-04	3.1E-01	2.4E-01	7.5E-02
MEI general public	2.9E-01	5.0E-04	1.5E-04	2.4E-01	3.5E-05

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally exposed individual

Chemical Consequences - Potential acute hazards associated with a mispositioned jumper accident evaluated in Section E.2.2.1.4 for toxic and corrosive/irritant exposures are summarized as follows:

Toxic Impact from Chemical Exposure - For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 1.62E+00, which exceeds 1.0 and would be indicative of reversible acute effects. This acute hazard index is primarily attributable to TOC (approximately 64 percent of the total hazard). The TOC was assumed to be tributylphosphate which provides a conservative estimate of the potential acute hazard. The acute hazard indices for the MEI noninvolved worker and general public were less than 1.0 for ERPG-1 comparisons and would not be indicative of any acute effects.

Corrosive/Irritant Impact from Chemical Exposure - For the MEI worker, the cumulative ratio of exposure to ERPG-2 values for corrosive/irritant chemicals was 1.93E+00, which exceeds the ratio of 1.0 and indicates reversible, acute health effects. The MEI noninvolved worker cumulative ratio of exposure to ERPG-1 values was 3.1E+00. This acute hazard index is primarily attributable to sodium hydroxide (approximately 90 percent of the total hazard) and would be indicative of transient effects. The acute hazard index for the MEI general public was less than 1.0 for ERPG-1 comparisons and would not be indicative of any acute effects.

E.10.2.3.2 Retrieval Accidents

The dominant routine operations accident is the loss of filtration accident previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.2 and summarized as follows:

Source Term - The source term resulting from a loss of filtration in Section E.6.3.2.1 was calculated to be 2.5E-01L (2.6E-09 qt).

Probability - The frequency of a loss of filtration in Section E.6.3.2.2 was 8.8E-06 per year. The Total alternative retrieval activity was based on 22 years of operation, therefore the probability was calculated to be 1.94E-04.

Radiological Consequence - The radiological consequences presented in Table E.6.3.4 are reproduced in Table E.10.2.10.

Radiological Cancer Risk - The LCFs calculated in Section E.6.3.2.4 are reproduced in Table E.10.2.11. Aside from all 10 workers and the MEI noninvolved worker dying from a lethal dose, the calculations show there would be 9 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Chemical Consequences - Potential acute hazards associated with loss of filtration are summarized in Tables E.6.3.6 and E.6.3.7 for toxic corrosive/irritant effects.

Table E.10.2.10 Dose Consequence for Loss of Filtration

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.7E+04
MEI worker	3.7E+03
Noninvolved workers (1,835) [1]	1.0E+03
MEI noninvolved worker	2.4E+01
General public (114,734) [1]	1.6E+02
MEI general public	1.0E-01

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally exposed individual

Table E.10.2.11 Latent Cancer Fatality Risk from Loss of Filtration

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.7E+04	N/A	N/A	1.9E-04	1.9E-04[3]
MEI worker	3.7E+03	N/A	N/A	1.9E-04	1.9E-04[3]
Noninvolved workers (1,835) [2]	1.0E+03	4.0E-04	4.2E-01	1.9E-04	8.1E-05
MEI noninvolved worker	2.4E+01	8.0E-04	1.9E-02	1.9E-04	3.8E-06
General public (114,734) [2]	1.6E+02	5.0E-04	7.8E-02	1.9E-04	1.5E-05
MEI general public	1.0E-01	5.0E-04	5.2E-05	1.9E-04	1.0E-08

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
[3] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
LCF = Latent cancer fatality
MEI = Maximally exposed individual
N/A = Receptor receives lethal dose, therefore LCFs are not included.

Chemical impacts were not evaluated for the MEI worker because all workers would receive a lethal radiological dose as discussed preciously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 6.60E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Uranium (approximately 52 percent of the total hazard);
- Oxalate (approximately 26 percent of the total hazard);
- Selenium (approximately 7 percent of the total hazard);
- TOC as tributyl phosphate (approximately 6 percent of the total hazard); and
- Mercury (approximately 5 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-2 values for toxic chemicals was 2.36E+00, which exceeds the ratio of 1.0 and indicates reversible, acute health effects. The next nearest noninvolved worker population consists of 1,500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 8.60E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 1.2E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 47 percent of the total hazard);
- Calcium (approximately 36 percent of the total hazard); and
- Chromium (approximately 11 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 2.24E+00, which exceeds the ratio of 1.0 and would indicate only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 3.01E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 7.03E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.10.2.3.3 Pretreatment

The dominant pretreatment operations accident was the line break within a vault due to an earthquake previously discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.3 and summarized as follows:

Source Term - The source term resulting from a line break in a vault in Section E.6.3.3.1 was calculated to be 7.3E-02 L (7.7E-02 qt).

Probability - The probability of a seismic induced line break in Section E.6.3.3.2 was calculated to be 1.6E-03.

Radiological Consequences - The radiological consequences presented in Table E.6.3.8 are reproduced in Table E.10.2.12.

Table E.10.2.12 Dose Consequence for Seismic Reduced Line Break in Vault

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	3.4E+01
MEI worker	3.4E+00
Noninvolved workers (5,500) [1]	7.1E+00
MEI noninvolved worker	2.9E-01
General public (114,734) [1]	2.7E+00
MEI general public	4.5E-04

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI= Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.6.3.3.4 are reproduced in Table E.10.2.13. The calculations show there would be no LCFs attributable to this exposure if the accident occurs.

Table E.10.2.13 Latent Cancer Fatality Risk from Seismic Induced Line Break in Vault

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	3.4E+01	4.0E-04	1.4E-02	1.6E-03	2.1E-05
MEI worker	3.4E+00	4.0E-04	1.4E-03	1.6E-03	2.1E-06
Noninvolved workers (5,500) [2]	7.1E+00	4.0E-04	2.8E-03	1.6E-03	4.4E-06
MEI noninvolved worker	2.9E-01	4.0E-04	1.2E-04	1.6E-03	1.8E-07
General public (114,734) [2]	2.7E+00	5.0E-04	1.4E-03	1.6E-03	2.1E-06
MEI general public	4.5E-04	5.0E-04	2.3E-07	1.6E-03	3.5E-10

Notes:
[1] Total number of fatal cancer in the population if the accident occurs.
[2] Number of people in exposed population.
LCF = Latent cancer fatalities
MEI = Maximally-exposed individual

Chemical Consequences - The chemical exposure evaluated in Section E.6.3.3.5 for toxic and corrosive/irritant effects are summarized as follows:

Toxic Impact from Chemical Exposure - For the MEI noninvolved worker, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 2.12E+00, which exceeds 1.0 and would be indicative of minor transient effects. This acute hazard index is primarily attributable to thallium (approximately over 99 percent of the total hazard). The acute hazard index for the general public was less than 1.0, and because the accident takes place within a vault, the emissions are from a stack and the worker does not receive an exposure.

Corrosive/Irritant Impact from Chemical Exposure - For all receptors, the cumulative ratio of exposure to ERPG values for corrosive/irritant chemicals was less than 1.0 and not indicative of any acute effects.

E.10.2.3.4 Treatment Accidents

The dominant routine operations accident is an inadvertent HLW canister drop discussed in the Ex Situ Intermediate Separations alternative in Section E.6.3.4 and summarized as follows:

Source Term from Breached Canister - The source term in Section E.6.3.4.1 was 2.5E-06 grams (8.8E-08 ounces).

Probability - The probability of dropping a canister in Section E.6.3.4.3 was calculated to be 1.0E+00.

Radiological Consequences - The radiological consequences presented in Table E.6.3.12 are reproduced in Table E.10.2.14

Table E.10.2.14 Dose Consequence for Breached Canister

Receptor	Dose CEDE (person-rem)
Worker (10) [1]	1.5E-04
MEI worker	1.5E-05
Noninvolved workers (5,500) [1]	5.8E-08
MEI noninvolved worker.	4.0E-09
General public (114,734) [1]	1.5E-08
MEI general public	2.4E-12

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section 6.3.4.4 are reproduced in Table E.10.2.15. The calculations show there would be no LCFs attributable to this exposure.

Chemical Consequences - No chemical consequences were evaluated in (Shire et al. 1995) since the release would first pass through two-stage HEPA filters that would reduce the source term to a very small amount, well below the cumulative ratio of exposure to ERPG-1 values for toxic or corrosive/irritant chemicals.

Table E.10.2.15 Latent Cancer Fatality Risk from Breached Canister

Receptor	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Worker (10) [2]	1.5E-04	4.0E-04	5.8E-08	1.0E+00	5.8E-08
MEI worker	1.5E-05	4.0E-04	5.8E-09	1.0E+00	5.8E-09
Noninvolved worker (5,500) [2]	5.8E-08	4.0E-04	2.3E-11	1.0E+00	2.3E-11
MEI noninvolved worker	4.0E-09	4.0E-04	1.6E-12	1.0E+00	1.6E-12
General public (114,734) [2]	1.5E-08	5.0E-04	7.5E-12	1.0E+00	7.5E-12
MEI general public	2.4E-12	5.0E-04	1.2E-15	1.0E+00	1.2E-15

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
LCF = Latent cancer fatality
MEI = Maximally exposed individual

E.10.2.3.5 Disposal/Storage Accidents

No DBA accidents resulting in radiological or chemical consequences to the receptors were identified. This is largely due to the vitrified waste form of the material and the engineered structural packaging of the vitrified LAW in burial vaults and vitrified HLW in shipping containers.

E.10.2.3.6 Beyond Design Basis Accident

The dominant beyond design basis accident is a hydrogen burn in a waste storage tank previously discussed in the No Action alternative in Section E.2.2.2.1 and is summarized as follows.

Source Term - The source term resulting from the fire in Section E.2.2.2.1 was calculated to be 2.5E-01L (2.6E-01 qt).

Probability - The frequency of the hydrogen burn in a waste storage tank in Section E.2.2.2.2 was estimated to be 9.0E-07 per year. The probability of the scenario based on 25 flammable gas Watchlist tanks and 22 years of operation was therefore estimated to be 4.95E-04.

Radiological Consequences - The radiological consequences presented in Table E.2.1.2 are reproduced in Table E.10.2.16.

Radiological Cancer Risk - The LCFs calculated in Section E.2.2.2.4 are the same for the Total alternative. However, the LCF risk (point estimate) is not the same due to the difference in probabilities. The LCR and the LCF risk are calculated in Table E.10.2.17.

In addition to all 10 workers and the MEI noninvolved worker dying directly following the exposure, the calculations show there would be 10 LCFs attributed to the exposure to the noninvolved workers and 2 LCFs to the general public if the accident occurred.

Table E.10.2.16 Dose Consequence from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)
Workers (10) [1]	2.2E+05
MEI worker	2.2E+04
Noninvolved workers (1,835) [1]	2.5E+04
MEI noninvolved worker	1.7E+03
General public (114,734) [1]	3.7E+03
MEI general public	4.2E+00

Notes:
[1] Number of people in exposed population.
CEDE = Committed effective dose equivalent
MEI = Maximally exposed individual

Table E.10.2.17 Latent Cancer Fatality Risk from Hydrogen Burn in Waste Storage Tank

Receptor	Dose CEDE (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	2.2E+05	N/A	N/A	5.0E-04	5.0E-04[2]
MEI worker	2.2E+04	N/A	N/A	5.0E-04	5.0E-04[2]
Noninvolved workers (1,835) [3]	2.5E+04	4.0E-04	9.8E+00	5.0E-04	4.9E-03
MEI noninvolved worker	1.7E-+03	N/A	N/A	5.0E-04	5.0E-04[2]
General public (114,734) [3]	3.7E+03	5.0E-04	1.9E+00	5.0E-04	9.2E-04
MEI general public	4.2E+00	5.0E-04	2.1E-03	5.0E-04	1.1E-06

Notes:
[1] Total number of fatal cancers if the accident occurs
[2] The risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally exposed individual
N/A = Receptor receives lethal dose therefore LCFs are not applied

Chemical Consequences - Potential acute hazards associated with a postulated hydrogen burn in a waste storage tank are summarized in Tables E.2.2.8 and E.2.2.9 for toxic and corrosive/irritant effects, respectively.

Chemical impacts were not evaluated for the MEI worker since all workers would receive a lethal radiation dose as discussed previously.

Toxic Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for toxic chemicals was 4.11E+01 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Oxalate (approximately 41 percent of the total hazard);
- Cadmium (approximately 16 percent of the total hazard);
- Uranium (approximately 13 percent of the total hazard);
- TOC as tributyl phosphate (approximately 9 percent of the total hazard);
- Beryllium (approximately 8 percent of the total hazard);
- Tellurium (approximately 4 percent of the total hazard);
- Thallium (approximately 4 percent of the total hazard); and
- Arsenic (approximately 3 percent of the total hazard).

The nearest noninvolved worker population consists of 335 people and is located 290 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 3.70E+00, which exceeds the ratio of 1.0 and indicates only minor, transient effects. The next nearest noninvolved worker population consists of 1500 people and is located 1,780 m from the accident. The cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.97E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for toxic chemicals was 4.06E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

Corrosive/Irritant Impact from Chemical Exposure

For the MEI noninvolved worker located 100 m from the accident, the cumulative ratio of exposure to ERPG-3 values for corrosive/irritant chemicals was 9.08E+00 and exceeds 1.0, which indicates potential irreversible health effects or death. This acute hazard index is primarily attributable to:

- Sodium hydroxide (approximately 62 percent of the total hazard);
- Chromium (approximately 14 percent of the total hazard); and
- Calcium (approximately 13 percent of the total hazard).

For the noninvolved worker population located 290 m from the accident, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.66E+00, which exceeds the ratio of 1.0 and would be indicative of only minor, transient effects. For the noninvolved worker population located 1,780 m from the accident, the cumulative ratio of exposure to ERPG-1 values was 2.23E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

For the MEI general public, the cumulative ratio of exposure to ERPG-1 values for corrosive/irritant chemicals was 1.82E-02, which does not exceed the ratio of 1.0 and indicates no acute effects.

E.10.2.3.7 Occupational Injuries and Fatalities

The number of operation person-years to support the Ex Situ Intermediate Separations alternative was estimated to be 5.59E+04 (Jacobs 1996). The total recordable injuries and illnesses, lost workday cases, and fatalities were calculated as follows:

Total Recordable Cases = (5.59E+04 person-years) · (2.2E+00 incidences/100 person-years) = 1.23E+03

Lost Workday Cases = (5.59E+04 person-years) · (1.1E+00 incidences/100 person-years) = 6.15E+02

Fatalities = (5.59E+04 person-years) · 3.2E-03 fatalities/100 person-years) = 1.79E+00

E.10.3 POST-REMEDIATION ACCIDENT

E.10.3.1 Deflagration in Storage Tank

After 99 percent of the tank waste has been removed from each tank, the probability of a tank generating enough hydrogen to exceed the LFL is considered to be incredible.

E.10.3.2 Seismic Induced Rupture of Stabilized Tanks

As discussed in Section E.4.4.2, displacement on a fault that would increase exposure to the waste after remediation is considered incredible. The tanks would most likely crack, allowing increased infiltration to the groundwater.

E.11.0 NO ACTION ALTERNATIVE (CAPSULES)

The No Action alternative for Cs and Sr capsules would involve the continued operation of Waste Encapsulation and Storage Facility (WESF) for 10 years. This section analyzes potential operation and transportation risks resulting from accidents associated with this alternative. Because there would be no construction, accidents associated with construction were not analyzed.

E.11.1 TRANSPORTATION ACCIDENTS

Employee Vehicles

Personnel required to support the various activities would drive to the site in their vehicles. The total person-years to support the alternative for 10 years was calculated to be 1.00E+03 (Jacobs 1996). Each person is assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area is estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total personnel vehicle distance was therefore calculated as follows:

(1.00E+03 person-years) · (260 days/year) · (140 km/day) · (1/1.35 person) = 2.70E+07 km (1.68E+07 mi)

The expected numbers of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (2.70E+07 km) · (7.14E-07 injuries/km) = 1.93E+01

Fatalities = (2.70E+07 km) · (8.98E-09 fatalities/km) = 2.42E-01

E.11.2 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities, which are discussed in Appendix B. The potential accidents were identified in the document entitled Potential Accidents for Storage and Disposition of Cesium and Strontium Capsules for the Tank Waste Remediation System-EIS (WHC 1995k). The data package provided a range of potential accidents, probability of the accidents, and the consequences of the accidents. These accidents are summarized in the Accident Screening Table (Table E.11.2.1). The dominant accident scenario analyzed in the following subsection was selected from the table.

E.11.2.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility

Types of potential accidents associated with pool cell storage at WESF are leaks, direct exposure, fires, mechanical impacts, and explosions. From Table E.11.2.1, the DBA accident identified as having the highest risk would be an earthquake that would result in the combination of Accident 3.1.2 "loss of shielding in a single pool cell," and Accident 3.1.1, "strontium capsule leak."

E.11.2.1.1 Scenario and Source Term Development for Pool Cell Storage Accident

It was postulated that the earthquake results in the roof of the building collapsing breaching 40 Sr capsules. The pool cell is also breached and all the water drained from the cell. The source term resulting from the breached canisters for the noninvolved worker receptor as calculated in the capsule data package (WHC 1995k) would be 1.2E-01 Ci based on 8 hours exposure. The general public was calculated to be 3.5E-01 Ci based on 24 hours exposure. In addition to the source term, the loss of the water shielding the capsules would result in high direct radiation doses to the receptors. It was assumed that all workers would die in the building from the collapsed roof.

E.11.2.1.2 Probability of Pool Cell Storage Accident

The initiating event is a beyond design basis earthquake with a frequency of 2.5E-04 per year. Based on an operation duration of 10 years, the probability of the event would be 2.5E-03.

E.11.2.1.3 Radiological Consequence of Pool Cell Storage Accident

The radiological dose to the receptors from the previous source term was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section E.1.1.6.

The direct radiation dose to the receptors from the accident scenario was calculated using the Monte Carlo Neutron Photon (MCNP) computer code. Because the pools are belowground, the primary source of dose rates to people outside the facility would be due to radiation scattering (often referred to as shine) from the air. The results, which are taken from the potential accident data package for the capsules (WHC 1995k), are summarized in Table E.11.2.2.

Table E.11.2.1 Accident Screening Table for the No Action Alternative (Capsules)

Mode	Hazard	Cause		Severity	Annual Frequency	Risk
Pool Cell Storage	Leak	3.1.1	Cs capsule leak	No	EU	2
	Leak	**3.1.1**	**Sr capsule leak**	**No**	**EU**	**2**
	Direct exposure	**3.1.2**	**Loss of shielding in single pool cell**	**High**	**U**	**12**
	Hydrogen explosion	3.1.3	Hydrogen explosion in capsule	Low	BDBA	2
	Resuspension	3.1.4.1	Cs release from K-3 ventilation system ductwork due to vibration	Low	U	6
	Resuspension	3.1.4.1	Sr release from K-3 ventilation system ductwork due to vibration	Low	U	6
	K-3 duct flood	3.1.4.2	Cs release from K-3 ventilation system ductwork due to flooding	Low	U	6
	K-3 duct flood	3.1.4.2	Sr release from K-3 ventilation system ductwork due to flooding	Low	U	6
	Mechanical impact	3.1.5	Transportation accident	Low	EU	4
	Fire	3.1.6	Cs release from fire in solid waste in truck port	No	U	3
	Fire	3.1.6	Sr release from fire in solid waste in truck port	Low	U	6
	Fire	3.1.7	Fire in solid wast in process cell	Low	U	6

Notes:
BDBA = Beyond design basis accident
Cs = cesium
EU = Extremely unlikely
Sr = Strontium
U = Unlikely

Table E.11.2.2 Dose Consequence for Pool Cell Storage Accident

Receptor	Dose CEDE (person-rem)		
	Direct Exposure	Inhalation	Combined
Workers (10) [a]	N/A	N/A	N/A
MEI worker	N/A	N/A	N/A
Noninvolved workers (1,876) [a]	1.6E+03 [b]	2.9E+02	1.9E+03
MEI noninvolved worker	3.2E+01	2.7E-01	3.2E+01
General public (114,734) [a]	N/E	7.7E-03	7.7E-03
MEI general public	N/E	5.9E-04	5.9E-04

Notes:
[a] Number of people in exposed population.
[b] Based on a population of 250 people at 200 m.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual
N/A = Workers are assumed to have died inside WESF from the collapsed roof
N/E = Exposure would be extremely small due to the distance

E.11.2.1.4 Radiological Cancer Risk for Pool Cell Accident

To calculate the LCFs and the LCF risk (point estimate) for the receptors, a dose-to-risk conversion factor of 4.0E-04 LCF per person-rem for the noninvolved worker and MEI noninvolved worker and 5.0E-04 for the general public and MEI general public was used. The results are presented in Table E.11.2.3. Aside from the 10 workers dying from the collapsed roof, the calculations show there would be no fatal cancer.

Table E.11.2.3 Latent Cancer Fatality Risk from Pool Cell Accident

Receptor	Dose CEDE (person-rem)	LCF/rem	LCFs [1]	Probability	LCF risk (point estimate)
Workers (10) [3]	N/A	N/A	N/A	2.5E-03	2.5E-03 [2]
MEI worker	N/A	N/A	N/A	2.5E-03	2.5E-03 [2]
Noninvolved workers (1,876) [3]	1.6E+03	4.0E-04	6.4E-01	2.5E-03	1.6E-03
MEI noninvolved worker	3.2E+01	4.0E-04	1.3E-02	2.5E-03	3.2E-05
General public (114,736) [3]	7.7E-03	5.0E-04	3.9E-06	2.5E-03	9.6E-09
MEI General public	5.9E-04	5.0E-04	3.0E-07	2.5E-03	7.4E-10

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Risk of dying from the accident. Workers would potentially die from collapsed building, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF= Latent cancer fatality
MEI= Maximally-exposed individual
N/A = Workers die from the collapsed roof

E.11.2.1.5 Chemical Consequences for Pool Cell Accident

Chemical consequences were not evaluated in (WHC 1995k) since the small quantity of nonradiological constituents in the capsules would result in an exposure to all receptors well below the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.11.2.2 Occupational Fatalities and Injuries

The number of operation personnel was estimated at approximately 1.00E+03 person-years (Jacobs 1996). The number of injuries, illnesses, and fatalities for the 10 years of operation are calculated as follows:

Total Recordable Cases = (1.00E+03 person-years) · (2.2E+00 incidences/100 person-years) = 2.2E+01

Lost Workday Cases = (1.00E+03 person-years) · (1.1E+00 incidences/100 person-years) = 1.1E+01

Fatalities = (1.00E+03 person-years) · (3.2E-03 fatalities/100 person-years) = 3.2E-02

E.12.0 ONSITE DISPOSAL ALTERNATIVE

The Onsite Disposal alternative for Cs and Sr capsules would involve the continued operation of WESF until the disposal facility was completed. The capsules would then be removed from the basin, placed in overpack canisters, and transferred to storage for disposal where they would remain. This section analyzes potential construction, operation, and transportation risks resulting from accidents associated with this alternative.

E.12.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Onsite Disposal alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from construction accidents are calculated in the following text.

The number of construction personnel was estimated at 2.10E+02 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities for the 8 years of construction are calculated using the incidents rates from Table E.1.2.1 as follows:

Total Recordable Cases = (2.10E+02 person-years) · (9.75E+00 incidences/100 person-years) = 2.05E+01

Lost Workday Cases = (2.10E+02 person-years) · (2.45E+00 incidences/100 person-years) = 5.15E+00

Fatalities = (2.10E+02 person-years) · (3.2E-03 fatalities/100 person-years) = 6.72E-03

E.12.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative include:

- Transporting construction material from offsite by truck to support WESF modifications;
- Transporting fill material from an onsite borrow site to support dry-well construction;
- Transporting the overpacked capsules from WESF to dry-well disposal; and
- Employees commuting to work each day.

E.12.2.1 Radiological Cancer Risk

Radiological exposures resulting from accidents during transport of the capsules to the Dry-Well Disposal Facility were analyzed (Green 1995), and the methodology of this analysis is discussed in Section E.1.1.6. The results of the analysis are summarized in Tables E.12.2.1 and E.12.2.2. The calculations show there would be no fatal cancers attributable to this exposure.

Table E.12.2.1 Integrated Radiological Impact from Accidents for the Onsite Dry Storage Alternative

Transport Activity	Population Dose (person-rem)	LCF Risk
Capsule transport	1.33E-05	5.33E-09

Notes:
LCF = Latent cancer fatalities

Table E.12.2.2 Maximum Individual Radiological Impact from Accidents for the Onsite Dry Storage Alternative

Transport Activity	MEI Dose (rem)		LCF Risk	
	Worker	Public	Worker	Public
Capsule transport	9.02E-01	4.10E-03	3.61E-04	2.05E-06

Notes:
MEI = Maximally-exposed individual

E.12.2.2 Chemical Exposure

Because chemicals other than small amounts of common chemicals (e.g., lubricants) are required to implement in this alternative, essentially no chemical exposure would occur.

E.12.2.3 Occupational Fatalities and Injuries

Truck Transport

WESF would be modified to support overpacking operations. Construction material would be transported by truck from the Tri-Cities area 70 km (43 mi) away. This would require an estimated 200 trips.

The area of land that would be graded is 1.8E+03 m^2 (2.2E+03 yd^2). Dry-wells (672) would be bored with a dry-well encasement placed on center in the dry-well. The encasement would be backfilled with sand and covered with a sandplug after placement of the capsule in the encasement. One hundred loads of sand would be trucked from a borrow site 5 km (3 mi) away. The 672 encasement pipes would be

transported by truck from the Portland or Seattle area 400 km (249 mi) away. The encasement pipe would require an estimated 14 trips.

The 1,929 capsules would be transported by truck to dry-well disposal. Capsule transport would require 184 trips. Table E.12.2.3 provides a summary of the expected distance to be traveled by truck in support of the construction and capsule transport activities. The number of injuries and fatalities are calculated by multiplying the total distance traveled in each zone, shown in Table E.12.2.4, by the appropriate unit risk factors shown in Table E.1.3.1. The expected injuries and fatalities resulting from transportation accidents associated with the alternative are summarized in Table E.12.2.5.

Table E.12.2.3 Summary of Transportation Activities for the Onsite Disposal Alternative

Truck Transport Activity	Onsite	Offsite
Construction	1.00E+03 km	3.92E+04 km
Capsule transport	5.89E+03 km	N/A
Total	6.89E+03 km	3.92E+04 km

Notes:
N/A= Not Applicable

Table E.12.2.4 Distance Traveled in Population Zones for the Onsite Disposal Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	1.96E+03 km	8.85E+03 km	3.53E+04 km

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.12.2.3.
[2] Suburban represents 5 percent of total offsite distance and 100 percent total onsite distance from Table E.12.2.3.
[3] Rural represents 90 percent of total offsite distance from Table E.12.2.3.

Table E.12.2.5 Injuries/Fatalities Resulting from Truck Accidents for the Onsite Disposal Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatality	Total Injury
Truck	Fatality	1.47E-05	1.15E-04	1.87E-03	2.00E-03	N/A
	Injury	7.25E-04	3.36E-03	2.82E-02	N/A	3.23E-02

Notes:
N/A= Not Applicable

Employee Vehicles

In addition to transporting materials and supplies to and from the Hanford Site by truck, site workers and other personnel required to support the various activities will be driving to the site in their vehicles.

The total person-years to support the alternative for an estimated 88 years was calculated to be 1,294 (Jacobs 1996). Each person is assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area is estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a). The total personnel vehicle distance was therefore

calculated as follows:

$$(1.29E+03 \text{ person-years}) \cdot (260 \text{ days/year}) \cdot (140 \text{ km/day}) \cdot (1/1.35 \text{ person}) = 3.49E+07 \text{ km } (2.2E+07 \text{ mi})$$

The expected numbers of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (3.49E+07 km) · (7.14E-07 injuries/km) = 2.49E+01
Fatalities = (3.49E+07 km) · (8.98E-09 fatalities/km) = 3.13E-01

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are summarized in Table E.12.2.6. It is most likely there would be 25 injuries and no fatalities resulting from traffic accidents.

Table E.12.2.6 Cumulative Injuries and Fatalities from Traffic Impacts for the Onsite Disposal Alternative

Mode	Fatalities	Injuries
Truck transport	2.00E-03	3.23E-02
Employee vehicle	3.13E-01	2.49E+01
Total	3.15E-01	2.50E+01

E.12.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities. The operations are discussed in Appendix B. This analysis separates and analyzes the operations according to the following modes of operation:

- Pool cell storage at WESF - Cs and Sr capsules would remain stored in water-filled basins until they are transported to dry-well disposal.
- Capsule overpacking at WESF - Cs and Sr capsules would be removed from the basin and sealed in overpack canisters.
- Transport of overpacked capsules to dry-well disposal - The transport of overpacked capsules to dry-well disposal was previously discussed in Section E.7.2.
- Storage of capsules in dry-wells - Cs and Sr capsules are stored in dry-wells for an indefinite length of time.

The potential accidents were identified in the document entitled Potential Accidents for Storage and Disposition of Cesium and Strontium Capsules for the Tank Waste Remediation System (WHC 1995k). The data package provided a range of potential accidents, probability of the accidents, and the consequences of the accidents. These accidents are summarized in the Accident Screening Table (Table E.12.3.1). The dominant accident scenarios analyzed in the following subsections were selected from the table, whose methodology was previously discussed in Section E.1.1.2.

E.12.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility

The dominant pool cell storage accident at WESF is the earthquake previously discussed in the No Action alternative in Section E.11.2.1 and is summarized in the following.

Source Term - The source term presented in Section E.11.1.1 resulting from the breached canisters for the noninvolved worker receptor was 1.2E-01 Ci based on 8 hours exposure. The general public was calculated to be 3.5E-01 Ci based on 24 hours exposure. In addition to the source term, the loss of the water shielding the capsules would result in high direct radiation doses to the receptors. It was assumed that all the workers would die in the building from the collapsed roof.

Probability - The frequency of the earthquake in Section E.11.2.1.2 was 2.5E-04 per year. The Onsite Disposal alternative was based on 19 years of operations, therefore, the probability was calculated to be 4.8E-03.

Radiological Consequences - The radiological consequences presented in Table E.11.2.2 are reproduced in Table E.12.3.2.

Radiological Cancer Risk - The LCFs calculated in Section E.11.2.1.4 are the same for the Onsite Disposal alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.12.3.3. Aside from the 10 workers dying from the collapsed roof, the calculations show there would be no fatal cancers.

Radiological Cancer Risk - The LCFs calculated in Section E.11.2.1.4 are the same for the Onsite Disposal alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.12.3.3. Aside from the 10 workers dying from the collapsed roof, the calculations show there would be no fatal cancers.

Chemical Consequences - Chemical consequences presented in Section E.11.2.1.5 concluded there would be no exposure that would exceed the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.12.3.2 Overpacking and Dry-Well Disposal Accident

Types of potential accidents associated with overpacking and dry-well disposal are leaks and mechanical impacts. From Table E.12.3.1, the DBA accident identified as having the highest risk is Accident 3.2.1, "Sr Capsule Crushed in Overpacking or Dry Storage". It was postulated that during overpacking a Sr capsule was breached when a heavy object falls on the canister.

Table E.12.3.1 Accident Screening Table for the Onsite Disposal Alternative

Mode	Hazard	Cause		Severity	Annual Frequency	Risk
Pool Cell Storage	Leak	3.1.1	Cs capsule leak	No	EU	2
	Leak	3.1.1	Sr capsule leak	No	EU	2
	Direct exposure	**3.1.2**	**Loss of shielding in single pool cell**	**High**	**U**	**12**
	Hydrogen explosion	3.1.3	Hydrogen explosion in capsule	Low	BDBA	2
	Resuspension	3.1.4.1	Cs release from K-3 ventilation system ductwork due to vibration	Low	U	6
	Resuspension	3.1.4.1	Sr release from K-3 ventilation system ductwork due to vibration	Low	U	6
	K-3 duct flood	3.1.4.2	Cs release from K-3 ventilation system ductwork due to flooding	Low	U	6
	K-3 duct flood	3.1.4.2	Sr release from K-3 ventilation system ductwork due to flooding	Low	U	6
	Mechanical impact	3.1.5	Transportation accident	Low	EU	4
	Fire	3.1.6	Cs release from fire in solid waste in truck port	No	U	3
	Fire	3.1.6	Sr release from fire in solid waste in truck port	Low	U	6
	Fire	3.1.7	Fire in solid wast in process cell	Low	U	6
Capsule Overpacking or Dry Storage	Leak	3.2.1	Cs capsule leak in dry storage	Low	U	6
	Leak	3.2.1	Sr capsule leak in dry storage	Low	U	6
	Mechanical impact	3.2.1	Cs capsule crushed in overpacking or dry storage	Low	U	6
	Mechanical impact	**3.2.1**	**Sr capsule crushed in overpacking or dry storage**	**Low**	**U**	**6**

Notes:
BDBA = Beyond design basis accident
Cs = Cesium
EU = Extremely unlikely
Sr = Strontium
U = Unlikely

Table E.12.3.2 Dose Consequence for Pool Cell Storage Accident

Receptor	Dose CEDE (person-rem)		
	Direct Exposure	Inhalation	Combined
Workers (10) [1]	N/A	N/A	N/A
MEI worker	N/A	N/A	N/A
Noninvolved workers (1,876) [1]	1.6E+03 [2]	2.9E+02	1.9E+03
MEI noninvolved worker	3.2E+01	2.7E-01	3.2E+01
General public (114,734) [1]	N/E	7.7E-03	7.7E-03
MEI general public	N/E	5.9E-04	5.9E-04

Notes:
[1] Number of people in exposed population
[2] Based on a population of 250 people at 200 m.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual
N/A = Workers are assumed to have died inside WESF from the collapsed roof
N/E = Exposure would be extremely small due to the distance

Table E.12.3.3 Latent Cancer Fatality Risk from Pool Cell Accident

Receptor	Dose CEDE (person-rem)	LCF/rem	LCFs [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
MEI worker	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
Noninvolved workers (1,876) [3]	1.6E+03	4.0E-04	6.4E-01	4.8E-03	3.1E-03
MEI noninvolved worker	3.2E+01	4.0E-04	1.3E-02	4.8E-03	6.1E-05
General public (114,736) [3]	7.7E-03	5.0E-04	3.9E-06	4.8E-03	1.8E-08
MEI General public	5.9E-04	5.0E-04	3.0E-07	4.8E-03	1.4E-09

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Risk of dying from the accident. Workers would potentially die from collapsed building, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF= Latent cancer fatality
MEI= Maximally-exposed individual
N/A = Workers die from the collapsed roof

E.12.3.2.1 Scenario and Source Term Development for Crushed Strontium Capsule

It was assumed that the initial shock of the drop of a heavy object on the capsule would spill the entire capsule contents and loft a fraction of 1.0E-03 of the activity by free-fall. This would be resuspended for 8 hours at 4.0E-06 per hour. The source term would be 38.5 Ci.

E.12.3.2.2 Probability of Crushed Strontium Capsule

This scenario was considered to be unlikely with a frequency range of 1.0 E-02 per year to 1.0 E-04 per year. For conservatism, a frequency of 1.0 E-02 per year is used for calculating risk. Based on a packaging operation of 19 years, the probability was calculated to be 1.9E-01.

E.12.3.2.3 Radiological Consequence from Crushed Strontium Capsule

The radiological dose to the receptors from the accident scenario was calculated by the GENII computer code (Napier et al. 1988) using the methodology previously discussed in Section 1.1.6. The results, taken from the potential accident data package for the capsules (WHC 1995k), are summarized in Table E.12.3.4.

Table E.12.3.4 Dose Consequence from Crushed Strontium Capsule

Receptor	Dose (person-rem)	
	Bounding	Beyond design basis
Workers	3.6E-03	1.1E+05
MEI worker	3.6E-04	1.1E+04
Noninvolved workers	1.2E-03	1.2E+03
MEI noninvolved worker	3.5E-05	9.3E+01
General public	2.2E-04	2.0E+02
MEI general public	4.1E-08	6.2E-02

Notes:
MEI = Maximally-exposed individual

E.12.3.2.4 Radiological Cancer Risk from Crushed Strontium Capsule

Based on a dose-to-risk conversion factor of 4.0 E-04 LCF per person-rem for the worker/noninvolved worker and 5.0 E-04 LCF per person-rem for the general public, the LCF risk is calculated for the receptors in Table E.12.3.5.

For the bounding scenario the calculations show there would be no fatal cancers attributable to this exposure.

The BDBA represents an unmitigated release (the HEPA filters fail). For the BDBA the calculations show all 10 workers would receive a lethal dose, there would be 1.2E+03 LCF in the noninvolved worker population, and 6.20E+02 LCFs in the general public.

E.12.3.2.5 Chemical Consequences from Crushed Strontium Capsule

Chemical consequences were not evaluated in (WHC 1995k) since the small quantity of nonradiological constituents in a capsule would result in an exposure to all receptors well below the cumulative ratio of 1.0 to ERPG-1 values for toxic corrosive/irritant chemicals.

Table E.12.3.5 Latent Cancer Fatality Risk from Crushed Strontium Capsule

Receptor	Case	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	Bounding	1.7E+00	4.0E-04	6.8E-04	1.9E-01	1.3E-04
	BDBA	1.1E+05	N/A	N/A	<1.0E-06	1.0E-06 [3]
MEI worker	Bounding	1.7E-01	4.0E-04	6.8E-05	1.9E-01	1.3E-05
	BDBA	1.1E+04	N/A	N/A	<1.0E-06	1.0E-06 [3]
Noninvolved workers (1,876) [2]	Bounding	1.2E-03	4.0E-04	4.8E-07	1.9E-01	9.1E-08
	BDBA	1.2E+03	4.0E-04	4.8E-01	<1.0E-06	4.8E-07
MEI noninvolved worker	Bounding	3.5E-05	4.0E-04	1.4E-08	1.9E-01	2.7E-09
	BDBA	9.3E+01	4.0E-04	3.7E-02	<1.0E-06	3.7E-08
General public (114,734) [3]	Bounding	2.2E-04	5.0 E-04	1.1E-07	1.9E-01	2.1E-08
	BDBA	2.0E+02	5.0E-04	1.0E-01	<1.0E-06	1.0E-07
MEI general public	Bounding	4.1E-08	5.0E-04	2.1E-11	1.9E-01	3.9E-12
	BDBA	6.2E-02	5.0E-04	3.1E-05	<1.0E-06	3.1E-11

Notes:
[1] Total number of fatal cancers in the population if the accident occurs.
[2] Number of people in exposed population.
[3] Risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
BDBA = Beyond design basis accident, the unmitigated case (WHC 1995k)
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Receptor receives a lethal dose

E.12.3.3 Occupational Fatalities and Injuries

The number of operation personnel was estimated at approximately 1.08E+03 person-years (Jacobs 1996). The number of injuries, illnesses, and fatalities for the 88 years of operation are calculated as follows:

Total Recordable Cases = (1.08E+03 person-years) · (2.2E+00 incidences/100 person-years) = 2.38E+01

Lost Workday Cases = (1.08E+03 person-years) · (1.1E+00 incidences/100 person-years) = 1.19E+01

Fatalities = (1.08E+03 person-years) · (3.2E-03 fatalities/100 person-years) = 3.47E-02

E.13.0 OVERPACK AND SHIP ALTERNATIVE

The Overpack and Ship alternative for Cs and Sr capsules would involve the continued storage of the capsules in the WESF water basin with final disposal in the potential geologic repository. The capsules would not be removed from the WESF pools until a repository became available. The capsules would be removed from the pools and placed in overpacks prior to shipment. The capsules would be transported by rail to the potential geologic repository.

E.13.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Overpack and Ship alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from construction accidents are calculated in the following text.

The number of construction personnel was estimated at 1.0E+02 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities for the 8 years of construction are calculated using the incidence rates from Table E.1.2.1 of this appendix as follows:

Total Recordable Cases = (1.00E+02 person-years) · (9.75E+00 incidences/100 person-years) = 9.75E+00
Lost Workday Cases = (1.00E+02 person-years) · (2.45E+00 incidences/100 person-years) = 2.45E+00
Fatalities = (1.00E+02 person-years) · (3.2E-03 fatalities/100 person-years) = 3.20E-03

There would be an estimated ten total recordable cases, two to three lost workday case, and no fatalities resulting from construction.

E.13.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are:

- Transporting construction material from offsite by truck to support WESF modification;
- Transporting overpacked capsules by rail from WESF the potential geologic repository; and
- Employees commuting to work each day.

E.13.2.1 Radiological Cancer Risk

Radiological exposures resulting from accidents while transporting the capsules to an offsite potential geologic repository were analyzed (Green 1995). The methodology of the analysis was previously discussed in Section E.1.1.6. The results of the analysis are summarized in Tables E.13.2.1 and E.13.2.2. The calculations show there would be no fatal cancers attributed to this exposure.

Table E.13.2.1 Integrated Radiological Impact from Accidents for the Overpack and Ship Alternative

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Integrated Population	3.4E-05	5.0E-04	1.7E-08
Urban Population	1.8E-07	5.0E-04	9.0E-11

Notes:
LCF = Latent cancer fatalities

Table E.13.2.2 Maximum Individual Radiological Impact from Accidents for the Overpack and Ship Alternative

Transport Activity	MEI Dose (rem)		LCF Risk	
	Worker	Public	Worker	Public
Capsule transport	1.30E+00	5.60E-03	5.20E-04	2.80E-06

Notes:
MEI = Maximally-exposed individual

E.13.2.2 Chemical Exposure

Only small amounts of chemicals (e.g., lubricants) would be required under this alternative so only very minor chemical exposure would be expected to occur.

E.13.2.3 Occupational Fatalities and Injuries

Table E.13.2.3 provides a summary of the expected distances to be traveled by truck and rail to support construction and capsule transport activities.

Table E.13.2.3 Summary of Transportation Activities for the Overpack and Ship Alternative

Transport Activity	Onsite	Offsite
Construction transport - Truck	N/A	2.80E+04 km
Capsule transport - Rail	N/A	1.47E+04 km

Notes:
N/A = Not Applicable

Construction Transport

There would be modifications to WESF to support overpacking operations. Construction material would be transported by truck from the Tri-Cities area 70 km (43 mi) away. This would require an estimated 200 trips.

Capsule Transport

It would require 5 rail shipments to transport the capsules to an offsite potential geologic repository 1,465 km (910 mi) away (Green 1995).

The number of injuries and fatalities are calculated by multiplying the total distance traveled in each zone, shown in Table E.13.2.4, by the appropriate unit risk factors shown in Table E.1.3.1.

In addition to transporting materials and supplies to and from the Hanford Site, site workers and other personnel required to support the various activities would be driving to the site in their vehicles. The total person-years to support the alternative for an estimated 39 years was calculated to be 241 (Jacobs 1996). Each person is assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area is estimated at 140 km (87 mi), with an estimated 1.35 passengers per vehicle (DOE 1994a). The total personnel vehicle distance was therefore calculated as follows:

(241 person-years) · (260 days/year) · (140 km/day) · (1/1.35 person) = 6.50E+06 km (4.0E+06 mi)

Table E.13.2.4 Distance Traveled in Population Zones for the Overpack and Ship Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	1.40E+03 km	1.4E+03	2.52E+04 km
Rail	7.33E+02 km	7.33E+02 km	1.32E+04 km

Notes:
[1] Urban represent 5 percent of total offsite distance from Table E.13.2.3
[2] Suburban represent 5 percent of total offsite and 100 percent of total onsite distance from Table E.13.2.3
[3] Rural represent 90 percent of total offsite distance from Table E.13.2.3.

The expected injuries and fatalities resulting from transportation accidents associated with the Overpack and Ship alternative are summarized in Table E.13.2.5.

Table E.13.2.5 Injuries/Fatalities Resulting from Transportation Accidents for the Overpack and Ship Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatality	Total Injury
Rail	Fatality	1.05E-05	1.82E-05	1.34E-03	1.37E-03	N/A
	Injury	5.18E-04	5.32E-04	2.02E-02	N/A	0.0213
Truck	Fatality	1.25E-05	1.25E-05	2.24E-04	2.37E-04	N/A
	Injury	2.42E-05	2.42E-05	4.35E-04	N/A	4.83E-04
				Total	1.61E-03	2.17E-02

Notes:
N/A = Not Applicable

The expected number of injuries and fatalities resulting from employee vehicle accidents were calculated as follows:

Injuries = (6.50E+06 km) · (7.14E-07 injuries/km) = 4.64E+00
Fatalities = (6.50E+06 km) · (8.98E-09 fatalities/km) = 5.84E-02

The cumulative nonradiological and nontoxicological injuries and fatalities incurred as a direct result of traffic accident impacts are summarized in Table E.13.2.6. It is mostly likely there would be 4 injuries and no fatalities resulting from traffic accidents.

Table E.13.2.6 Cumulative Injuries and Fatalities from Traffic Impacts for the Overpack and Ship Alternative

Mode	Fatalities	Injuries
Truck and rail transport	1.61E-03	2.17E-02
Employee vehicle	5.84E-02	4.64E+00
Total	6.00E-02	4.66E+00

E.13.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities. These operations are discussed in Appendix B. The operations are separated and analyzed according to the following modes of operation:

- Pool cell storage at WESF - Cs and Sr capsules would remain stored in water-filled basins until they are transported to dry-well disposal.
- Capsule overpacking at WESF - Cs and Sr capsules would be removed from the basin and sealed in overpack canisters, and stored for shipment to a potential geologic repository.

E.13.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility

The dominant pool cell storage accident at WESF is the earthquake, which was previously discussed in the No Action alternative in Section E.11.2.1 and is summarized in the following.

Source Term - The source term presented in Section E.11.2.1.1 resulting from the breached canisters for the noninvolved worker receptor was 1.2E-01 Ci, based on 8 hours exposure. The general public was calculated to be 3.5E-01 Ci, based on 24 hours exposure. In addition to the source term, the loss of water shielding the capsules would result in high direct radiation doses to the receptors. It was assumed that all of the workers would die in the building from the collapsed roof.

Probability - The frequency of the earthquake (Section E.11.2.1.2) was 2.5E-04 per year. The Overpack and Ship alternative was based on 19 years of operations, therefore, the probability was calculated to be 4.8E-03.

Radiological Consequences - The radiological consequences presented in Table E.11.2.2 are reproduced in Table E.13.3.1.

Radiological Cancer Risk - The LCFs calculated in Section E.11.2.1.4 are the same for the Onsite Disposal alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.13.3.2. Except for the 10 workers dying from the collapsed roof, the calculations show there would be no fatal cancers.

Chemical Consequences - Chemical consequences presented in Section E.11.2.1.5 concluded there would be no exposure that would exceed the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.13.3.2 Overpacking Accident

The dominant overpacking accident at WESF was the crushed Sr capsule previously discussed in the Onsite Disposal alternative in Section E.12.3.2 and is summarized as follows:

Source Term - The source term presented in Section E.12.3.2.1 resulting from the breached canisters was 38.5 Ci.

Table E.13.3.1 Dose Consequence for Pool Cell Storage Accident

Receptor	Dose CEDE (Person-rem)		
	Direct Exposure	Inhalation	Combined
Workers (10) [1]	N/A	N/A	N/A
MEI worker	N/A	N/A	N/A
Noninvolved workers (1,876) [1]	1.6E+03 [2]	2.9E+02	1.9E+03
MEI noninvolved worker	3.2E+01	2.7E-01	3.2E+01
General public (114,734) [1]	N/E	7.7E-03	7.7E-03
MEI general public	N/E	5.9E-04	5.9E-04

Notes:
[1] Number of people in exposed population.
[2] Based on a population of 250 people at 200 m.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual
N/A = Workers are assumed to have died inside WESF from the collapsed roof
N/E = Exposure would be extremely small due to the distance

Table E.13.3.2 Latent Cancer Fatality Risk from Pool Cell Accident

Receptor	Dose CEDE (person-rem)	LCF/rem	LCFs [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
MEI worker	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
Noninvolved workers (1,876) [3]	1.6E+03	4.0E-04	6.4E-01	4.8E-03	3.1E-03
MEI noninvolved worker	3.2E+01	4.0E-04	1.3E-02	4.8E-03	6.1E-05
General public (114,736) [3]	7.7E-03	5.0E-04	3.9E-06	4.8E-03	1.8E-08
MEI General public	5.9E-04	5.0E-04	3.0E-07	4.8E-03	1.4E-09

Notes:
[1] Total number of fatal cancers in the population if the accident occurs.
[2] Risk of dying from the accident. Receptor would potentially die from collapsed building, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF = Latent cancer fatality
MEI = Maximally-exposed individual
N/A = Workers die from the collapsed roof

Probability - The frequency of the accident in Section E.12.3.2.2 was 1.0E-02 per year. The Overpack and Ship alternative was based on 19 years of operations, therefore, the probability was calculated to be 1.9E-01.

Radiological Consequences - The radiological consequences presented in Section E.12.3.2.3 are reproduced in Table E.13.3.3.

Table E.13.3.3 Dose Consequence from Crushed Strontium Capsule

Receptor	Dose (person-rem)	
	Bounding	Beyond Design Basis
Workers	3.6E-03	1.1E+05
MEI worker	3.6E-04	1.1E+04
Noninvolved workers	1.2E-03	1.2E+03
MEI noninvolved worker	3.5E-05	9.3E+01
General public	2.2E-04	2.0E+02
MEI general public	4.1E-08	6.2E-02

Notes:
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.12.3.2.4 are the same for the Overpack and Ship alternative and are reproduced in Table E.13.3.4.

Table E.13.3.4 Latent Cancer Fatality Risk from Crushed Strontium Capsule

Receptor	Case	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	Bounding	1.7E+00	4.0E-04	6.8E-04	1.9E-01	1.3E-04 [3]
	BDBA	1.1E+05	N/A	N/A	<1.0E-06	1.0E-06
MEI worker	Bounding	1.7E-01	4.0E-04	6.8E-05	1.9E-01	1.3E-05
	BDBA [1]	1.1E+04	4.0E-04	N/A	<1.0E.-06	1.0E-06 [3]
Noninvolved workers (1,876) [2]	Bounding	1.2E-03	4.0E-04	4.8E-07	1.9E-01	9.1E-08
	BDBA	1.2E+03	4.0E-04	4.8E-01	<1.0E-06	4.8E-07
MEI noninvolved worker	Bounding	3.5E-05	4.0E-04	1.4E-08	1.9E-01	2.7E-09
	BDBA	9.3E+01	4.0E-04	3.7E-02	<1.0E-06	3.7E-08
General public (114,734) [2]	Bounding	2.2E-04	5.0 E-04	1.1E-07	1.9E-01	2.1E-08
	BDBA	2.0E+02	5.0E-04	1.0E-01	<1.0E-06	1.0E-07
MEI general public	Bounding	4.1E-08	5.0E-04	2.1E-11	1.9E-01	3.9E-12
	BDBA	6.2E-02	5.0E-04	3.1E-05	<1.0E-06	3.1E-11

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in the exposed population.
[3] Risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
BDBA = Beyond Design Basis Accident is the unmitigated case in WHC 1995k)
LCF = Latent cancer fatality
MEI= Maximally-exposed individual
N/A = Receptor receives a lethal dose

Chemical Consequences - Chemical consequences presented in Section E.12.3.2.5 concluded there would be no exposure that would exceed the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.13.3.3 Occupational Injuries and Fatalities

The number of operation personnel was estimated at approximately 1.41E+02 person-years (Jacobs 1996). The number total recordable injuries and illnesses, lost workday cases, and fatalities are calculated as follows:

Total Recordable Cases = (1.41E+02 person-years) · (2.2E+00 incidences/100 person-years) = 3.10E+00
Lost Workday Cases = (1.41E+02 person-years) · (1.1E+00 incidences/100 person-years) = 1.55E+00
Fatalities = (1.41E+02 person-years) · (3.2E-03 fatalities/100 person-years) = 4.51E-03

E.14.0 VITRIFY WITH TANK WASTE ALTERNATIVE

The Vitrify With Tank Waste alternative for Cs and Sr capsules would involve the continued operation of WESF until a HLW vitrification facility was completed. The capsules would then be removed from the basin, placed in overpacks, and transferred by truck to the HLW vitrification facility where they would be cut up and blended with the HLW from the tank farms. This section analyzes potential construction, operation, and transportation risks resulting from accidents associated with this alternative.

E.14.1 CONSTRUCTION ACCIDENTS

The construction activities associated with the Vitrify with Tank Waste alternative are discussed in Appendix B of the EIS. It should be noted there are no radiological or chemical consequences associated with construction accidents. Occupational injuries, illnesses, and fatalities resulting from potential construction accidents are calculated in the following text.

The number of construction personnel was estimated at 1.00E+02 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities for the 8 years of construction are calculated using the incidence rates from Table E.1.2.1 of this Appendix as follows:

Total Recordable Cases = (1.00E+02 persón-years) · (9.75E+00 incidences/100 person-years) = 9.75E+00
Lost Workday Cases = (1.00E+02 person-years) · (2.45E+00 incidences/100 person-years) = 2.45E+00
Fatalities = (1.00E+02 person-years) · (3.2E-03 fatalities/100 person-years) = 3.20E-03

E.14.2 TRANSPORTATION ACCIDENTS

Transportation activities associated with this alternative are:

- Transporting construction material from offsite to modify WESF;
- Transporting the overpacked capsules from WESF to the HLW vitrification facility;
- Transporting vitrified HLW to a national HLW repository; and
- Employees commuting to work each day.

E.14.2.1 Radiological Cancer Risk

Radiological exposures resulting from accidents during transport of the capsules to the HLW vitrification facility were analyzed (Green 1995), the methodology of the analysis is discussed in Section E.6.2.1. The results of the analysis are summarized in Tables E.14.2.1 and E.14.2.2.

Table E.14.2.1 Integrated Radiological Impact from Accidents for the Vitrify with Tank Waste Alternative

Transport Activity	Population Dose (person-rem)	LCF Risk
Capsule transport	1.33E-05	5.33E-09

Notes:
LCF = Latent cancer fatalities

Table E.14.2.2 Maximum Individual Radiological Impact from Accidents for Vitrify with Tank Waste Alternative

Transport Activity	MEI Dose (rem)		LCF Risk	
	Worker	Public	Worker	Public
Capsule transport	9.2E-01	4.1E-03	3.7E-04	2.1E-06

Notes:
MEI = Maximally-exposed individual

It is most likely there would be no fatal cancers attributable to this exposure.

The receptor dose and LCF risk resulting from the accident analysis for transporting vitrified HLW to an offsite geologic repository is presented tn Table E.14.2.3 for the integrated population and urban population. Since the capsules could be mixed and vitrified with any of the ex situ tank remediation alternatives, Table E.14.2.3 presents the LCF Risk for each of the alternatives.

E.14.2.2 Chemical Exposure

Chemicals would be transported to the Hanford Site in support of vitrifying the Cs and Sr capsules with the tank waste. An analysis was performed to identify the hazardous chemicals that could result in the largest toxicological impacts and evaluate the toxicological impacts of the bounding scenario accidents involving the highest hazard chemicals (Green 1995). A preliminary screening analysis was performed to identify the chemicals representing the highest potential toxicological hazard. The highest hazard chemicals in terms of toxicity were determined to be nitric acid and sulfuric acid. The chemical concentrations resulting from the bounding-case scenario accident at 100 m (3.28E+02 ft) and the frequency of the accidents as postulated (Green 1995) are summarized in Table E.14.2.4.

Table E.14.2.3 Radiological Impact from Transport Accident While Transporting Vitrified HLW to a National HLW Repository

Receptor	Dose (person-rem)	LCF/rem	LCF Risk
Ex Situ Intermediate Separations Alternative			
Integrated population	2.1E-01	5.0E-04	1.1E-04
Urban population	5.6E-02	5.0E-04	2.8E-05
Ex Situ No Separations Alternative			
Integrated population	2.9E-01	5.0E-04	1.5E-04
Urban population	7.6E-02	5.0E-04	3.8E-05
Ex Situ Extensive Separations Alternative			
Integrated population	1.3E-01	5.0E-04	6.5E-05
Urban population	4.8E-03	5.0E-04	2.4E-06
Ex Situ/In Situ Combination Alternative			
Integrated population	1.9E-01	5.0E-04	9.5E-05
Urban population	5.1E-02	5.0E-04	2.6E-05
Phased Implementation			
Integrated population	2.1E-01	5.0E-04	1.1E-04
Urban population	5.6E-02	5.0E-04	2.8E-05

Notes:
LCF = Latent cancer fatalities

Table E.14.2.4 Comparison of Chemical Concentrations to Corrosive/Irritant Concentration Limits for the Capsules Alternative

Analyte (Threshold Values are presented in mg/m³)		Exposure (mg/m³)	ERPG-1 (mg/m³)	ERPG-2 (mg/m³)	ERPG-3 (mg/m³)
Nitric Acid [1]	Threshold Value		5.20E+00	6.55E+01	1.31E+02
			Ratio of Exposure to ERPG		
	MEI General Public	1.32E-01	2.54E-02	2.02E-03	1.01E-03
Sulfuric Acid [2]	Threshold Value		2.00E+00	1.00E+01	3.00E+01
			Ratio of Exposure to ERPG		
	MEI General Public	1.37E+00	6.85E-01	1.37E-01	4.57E-02

Notes:
[1] AIHA ERPGs were used for nitric acid.
[2] AIHA ERPGs were used for sodium hydroxide.
ERPG = Emergency response planning guideline values.
ERPG-1 = These are maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
MEI = Maximally-exposed individual

Table E.14.2.5 compares the respirable concentration of the postulated chemical releases to acute exposure criteria (ERPGs) discussed in Section E.1.1.7. For the MEI general public, no ERPGs would be exceeded.

Table E.14.2.5 Comparison of Exposed Chemical Concentrations to Concentration Limits for the Vitrify with Tank Waste Alternative

Chemical	Concentration mg/m³	ERPG-1 mg/m³	ERPG-2 mg/m³	ERPG-3 mg/m³
Nitric Acid	0.28	5.2	65.5	131.0
Sulfuric Acid	1.03	2.0	40.0	100.0

Notes:
OSHA permissible exposure limit-time weighted average concentration.
ERPG = Emergency response planning guide values.
ERPG-1 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
ERPG-2 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG-3 = These are the maximum airborne concentrations below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

E.14.2.3 Occupational Fatalities and Injuries

Table E.14.2.6 provides a summary of the expected distance to be traveled by truck to support the construction and capsule transport activities.

Table E.14.2.6 Summary of Transportation Activities for the Vitrify with Tank Waste Alternative

Transport Activity	Onsite	Offsite
Construction - truck	N/A	2.80E+04 km
Capsule transport - truck	5.89E+03 km	N/A

Notes:
N/A = Not Applicable

Construction Material Transport

There would be modifications to WESF to support overpacking operations. Construction materials would be transported by truck from the Tri Cities 70 km (43 mi) and would require an estimated 200 trips.

Capsule Transport

The 1,929 capsules would be transported by truck to the HLW vitrification facility. Capsule transport would require 184 trips. The number of injuries and fatalities are calculated by multiplying the total distance traveled in each zone, shown in Table E.14.2.7, by the appropriate unit risk factors shown in Table E.1.3.1.

Table E.14.2.7 Distance Traveled in Population Zones for the Vitrify with Tank Waste Alternative

Mode	Urban [1]	Suburban [2]	Rural [3]
Truck	1.40E+03 km	1.40E+03 km	2.52E+04 km

Notes:
[1] Urban represents 5 percent of total offsite distance from Table E.14.2.5.
[2] Suburban represents 5 percent of total offsite and 100 percent total onsite distance from Table E.14.2.5.
[3] Rural represent 90 percent of total offsite distance from Table E.14.2.5.

The expected injuries and fatalities resulting from transportation accidents associated with the Vitrify With Tank Waste alternative are summarized in Table E.14.2.8.

Table E.14.2.8 Injuries and Fatalities Resulting from Truck Accidents for the Vitrify with Tank Waste Alternative

Mode	Impact	Urban	Suburban	Rural	Total Fatality	Total Injury
Truck	Fatality	1.05E-05	1.82E-05	1.34E-03	1.36E-03	N/A
	Injury	5.18E-04	5.32E-04	2.02E-2	N/A	2.12E-02

Notes:
N/A = Not Applicable

In addition to transporting materials and supplies to and from the Hanford Site by truck, site workers and other personnel required to support the various activities will be driving to the site in their vehicles. The total person-years to support the alternative was calculated to be 241 (Jacobs 1996). Each person is assumed to work 260 days of the year. The round-trip distance traveled to work from the Tri-Cities area is estimated at 140 km (87 mi) with an estimated 1.35 passengers per vehicle (DOE 1994a).

The total personnel vehicle distance was therefore calculated as follows:

$$(241 \text{ person-years}) \cdot (260 \text{ days/year}) \cdot (140 \text{ km/day}) \cdot (1/1.35 \text{ person}) = 6.50\text{E}+06 \text{ km}$$
$$(4.0\text{E}+06 \text{ mi})$$

The expected number of injuries and fatalities resulting from employee vehicle accidents was calculated as follows:

Injuries = (6.50E+06 km) · (7.14E-07 injuries/km) = 4.66E+00
Fatalities = (6.50E+06 km) · (8.98E-09 fatalities/km) = 5.97E-02

The cumulative noncancer injuries and fatalities incurred as a direct result of traffic accident impacts are summarized in Table E.14.2.9. It is most likely there would be four injuries and no fatalities resulting from traffic accidents.

Table E.14.2.9 Cumulative Injuries and Fatalities from Traffic Impacts for the Vitrify with Tank Waste Alternative

Mode	Fatalities	Injuries
Truck transport	1.36E-03	2.12E-02
Employee vehicle	5.97E-02	4.66E+00
Total	5.97E-02	4.66E+00

E.14.3 OPERATION ACCIDENTS

The potential exists for accidents resulting from operation activities. These operations are discussed in Appendix B. The operations are separated and analyzed according to the following modes of operation:

- Pool cell storage at WESF - Cs and Sr capsules would remain stored in water-filled basins until they are transported to HLW vitrification facility.
- Capsule overpacking at WESF - Cs and Sr capsules would be removed from the basin and placed in overpacks.
- Vitrification preparation - Cs and Sr capsules would be cut up and blended into the HLW from tank farms.

E.14.3.1 Pool Cell Storage Accident at the Waste Encapsulation and Storage Facility

The dominant pool cell storage accident at WESF is the earthquake previously discussed in the No Action alternative in Section E.11.2.1 and is summarized as follows:

Source Term - The source term presented in Section E.11.2.1.1 resulting from the breached canisters for the non-involved worker receptor was 1.2E-01 Ci based on 8 hours exposure. The general public was calculated to be 3.5E-01 Ci based on 24 hours exposure. In addition to the source term the loss of the water shielding the capsules would result in high direct radiation doses to the receptors. It was assumed that all the workers would die in the building from the collapsed roof.

Probability - The frequency of the earthquake in Section E.11.2.1.2 was 2.5E-04 per year. The Vitrify with Tank Waste alternative was based on 19 years of operations, therefore, the probability was calculated to be 4.8E-03.

Radiological Consequences - The radiological consequences presented in Table E.11.2.2 are reproduced in Table E.14.3.1.

Table E.14.3.1 Dose Consequence for Pool Cell Storage Accident

Receptor	Dose CEDE (person-rem)		
	Direct Exposure	Inhalation	Combined
Workers (10) [1]	N/A	N/A	N/A
MEI worker	N/A	N/A	N/A
Noninvolved workers (1,876) [1]	1.6E+03 [2]	2.9E+02	1.9E+03
MEI noninvolved worker	3.2E+01	2.7E-01	3.2E+01
General public (114,734) [1]	N/E	7.7E-03	7.7E-03
MEI general public	N/E	5.9E-04	5.9E-04

Notes:
[1] Number of people in exposed population.
[2] Based on a population of 250 people at 200 m.
CEDE = Committed effective dose equivalent
MEI = Maximally-exposed individual
N/A = Workers are assumed to have died inside WESF from the collapsed roof
N/E = Exposure would be extremely small due to the distance

Radiological Cancer Risk - The LCFs calculated in Section E.11.2.1.4 are the same for the Vitrify with Tank Waste alternative, however, the LCF point estimate risk is not the same due to the difference in probabilities. The LCFs and the LCF risk are calculated in Table E.14.3.2. Aside from the 10 workers dying from the collapsed roof, the calculations show there would be no fatal cancers.

Chemical Consequences - Chemical consequences presented in Section E.11.2.1.5 concluded there would be no exposure that would exceed the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.14.3.2 Overpacking Accident

The dominant overpacking accident at WESF is the crushed Sr capsule previously discussed in the Onsite Disposal alternative in Section E.12.3.2 and is summarized as follows:

Table E.14.3.2 Latent Cancer Fatality Risk from Pool Cell Accident

Receptor	Dose CEDE (person-rem)	LCF/rem	LCFs [1]	Probability	LCF Risk (point estimate)
Workers (10) [3]	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
MEI worker	N/A	N/A	N/A	4.8E-03	4.8E-03 [2]
Noninvolved workers (1,876) [3]	1.6E+03	4.0E-04	6.4E-01	4.8E-03	3.1E-03
MEI noninvolved worker	3.2E+01	4.0E-04	1.3E-02	4.8E-03	6.1E-05
General public (114,736) [3]	7.7E-03	5.0E-04	3.9E-06	4.8E-03	1.8E-08
MEI General public	5.9E-04	5.0E-04	3.0E-07	4.8E-03	1.4E-09

Notes:
[1] Total number of fatal cancers in the population if the accident occurs.
[2] Risk of dying from the accident. Workers would potentially die from collapsed building, not from latent cancer.
[3] Number of people in exposed population.
CEDE = Committed effective dose equivalent
LCF= Latent cancer fatality
MEI= Maximally-exposed individual
N/A = Workers die from the collapsed roof

Source Term - The source term presented in Section E.12.3.2.1 resulting from the breached canisters was 38.5 Ci.

Probability - The frequency of the accident in Section E.12.3.2.2 was 1.0E-02 per year. The Vitrify with Tank Waste alternative was based on 19 years of operations, therefore, the probability was calculated to be 1.9E-01.

Radiological Consequences - The radiological consequences presented in Section E.12.3.2.3 are reproduced in Table E.14.3.3.

Table E.14.3.3 Dose Consequence from Crushed Strontium Capsule

Receptor	Dose (Person-rem)	
	Bounding	Beyond Design Basis
Workers	3.6E-03	1.1E+05
MEI worker	3.6E-04	1.1E+04
Noninvolved workers	1.2E-03	1.2E+03
MEI noninvolved worker	3.5E-05	9.3E+01
General public	2.2E-04	2.0E+02
MEI general public	4.1E-08	6.2E-02

Notes:
MEI = Maximally-exposed individual

Radiological Cancer Risk - The LCFs calculated in Section E.12.3.2.4 are the same for the Vitrify with Tank Waste alternative and are reproduced in Table E.14.3.4.

Table E.14.3.4 Latent Cancer Fatality Risk from Crushed Strontium Capsule

Receptor	Case	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Workers (10) [2]	Bounding	1.7E+00	4.0E-04	6.8E-04	1.9E-01	1.3E-04 [3]
	BDBA	1.1E+05	N/A	N/A	<1.0E-06	1.0E-06
MEI worker	Bounding	1.7E-01	4.0E-04	6.8E-05	1.9E-01	1.3E-05
	BDBA [1]	1.1E+04	4.0E-04	N/A	<1.0E.-06	1.0E-06 [3]
Noninvolved workers (1,876) [2]	Bounding	1.2E-03	4.0E-04	4.8E-07	1.9E-01	9.1E-08
	BDBA	1.2E+03	4.0E-04	4.8E-01	<1.0E-06	4.8E-07
MEI noninvolved worker	Bounding	3.5E-05	4.0E-04	1.4E-08	1.9E-01	2.7E-09
	BDBA	9.3E+01	4.0E-04	3.7E-02	<1.0E-06	3.7E-08
General public (114,734) [2]	Bounding	2.2E-04	5.0 E-04	1.1E-07	1.9E-01	2.1E-08
	BDBA	2.0E+02	5.0E-04	1.0E-01	<1.0E-06	1.0E-07
MEI general public	Bounding	4.1E-08	5.0E-04	2.1E-11	1.9E-01	3.9E-12
	BDBA	6.2E-02	5.0E-04	3.1E-05	<1.0E-06	3.1E-11

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in the exposed population.
[3] Risk of receiving a lethal dose. Receptor would potentially die from lethal dose, not from latent cancer.
BDBA = Beyond design basis accident is the unmitigated case in WHC 1995k
LCF = Latent cancer fatality
MEI= Maximally-exposed individual
N/A = Receptor receives a lethal dose

Chemical Consequences - Chemical consequences presented in Section E.12.3.2.5 concluded there would be no exposure that would exceed the cumulative ratio of 1.0 to ERPG-1 values for toxic or corrosive/irritant chemicals.

E.14.3.3 Vitrification Preparation Accident

Types of potential accidents associated with vitrification preparation include sprays, spills, leaks, and explosions. The DBA accident identified in Table E.14.3.5 as having the highest risk is Accident 3.3.3.1 "Cs ion exchange column explosion". It was postulated that a fully loaded ion exchange column over pressurizes and explodes.

E.14.3.3.1 Scenario and Source Term Development for Cesium Ion Exchange Column Explosion

It was postulated that after the column was loaded with Cs, undiluted nitric acid was inadvertently used to dilute the Cs from the column instead of diluted nitric acid. The nitric acid reacts with the resin giving off gas and heat. The gas over pressurizes the column and explodes. A 10 percent airborne

9613409.1489

Table E.14.3.5 Accident Screening Table for the Vitrify with Tank Waste Alternative

Mode	Hazard	Cause		Severity	Annual Frequency	Risk
Vitrification Preparation	Powder spill	3.3.1	Cs chloride powder release during capsule dismantling	No	A	4
	Spill	3.3.2	Cs solution spill during dissolution	No	U	3
	Fire/explosion	**3.3.3.1**	**Cs ion exchange column fire/explosion**	**Low**	**U**	**6**
	Spray	3.3.3.3	Cs nitrate spray	Low	U	6
	Spray	3.3.3.4	Cs chloride spray	Low	U	6
	Powder spill	3.5.1	Sr fluoride release during capsule dismantling	No	A	4
	Powder spill	3.5.2	Sr powder spill	No	U	3
	Spray	3.6.1	Sr slurry spray	Low	U	6
	Spill	3.7	Sr sulfate spill	No	U	3
	Spill	3.7.2	Sr sulfate spill	No	EU	2

Notes:
A =
Cs = Cesium
EU = Extremely likely
Sr = Strontium
U = Unlikely

release fraction was assumed. It is also assumed that the facility in which the ion exchange would be performed would be equipped with two stages of high-efficiency particulate filters with a LPF of 2.0E-06. The source term was calculated to be 1.27E+06 Ci.

E.14.3.3.2 Probability of Cesium Ion Exchange Column Explosion

This was considered to be an unlikely event with a frequency range of 1.0E-02 per year to 1.0E-04 per year. For conservatism the frequency of 1.0E-02 was assumed for calculating risk. Based on 19 years of operation the probability was calculated to be 1.9E-01.

E.14.3.3.3 Radiological Consequence from Cesium Ion Exchange Column Explosion

The radiological dose to the receptors from the previous source term was calculated by the GENII computer program using the methodology previously discussed in Section E.1.1.6. The results are summarized in Table E.14.3.6 (WHC 1995k).

Table E.14.3.6 Dose Consequence from Cesium Ion Exchange Column Explosion

Receptor	Dose (person-rem)
Noninvolved work	1.1E+01
MEI noninvolved worker	8.7E-01
General public	1.8E+00
MEI general public	5.8E-04

Notes:
MEI = Maximally-exposed individual

E.14.3.3.4 Radiological Cancer Risk from Cesium Ion Exchange Column Explosion

Based on a dose-to-risk conversion factor of 4.0E-04 LCF per person-rem for the worker and noninvolved worker and 5.0E-04 LCF per person-rem for the general public, the LCF risk is calculated for the receptors in Tables E.14.3.7.

Table E.14.3.7 Latent Cancer Fatality Risk from Cesium Ion Exchange Column Explosion

Receptor	Case	Dose (person-rem)	LCF/rem	LCF [1]	Probability	LCF Risk (point estimate)
Noninvolved worker (5,500) [2]	Bounding-case scenario	1.1E+01	4.0E-04	4.4E-03	1.9E-01	8.36E-04
MEI noninvolved worker	Bounding-case scenario	8.7E-01	4.0E-04	3.5E-04	1.9E-01	6.6E-05
General public (114,734) [2]	Bounding-case scenario	1.8E+00	5.0 E-04	5.0E-04	1.9E-01	9.5E-05
MEI general public	Bounding-case scenario	5.8E-04	5.0E-04	2.9E-07	1.9E-01	5.5E-08

Notes:
[1] Total number of fatal cancers if the accident occurs.
[2] Number of people in exposed population.
LCF = Latent cancer fatality
MEI = Maximally-exposed individual

The calculations show there would be no fatal cancers attributable to this exposure. Because the accident would occur in a canyon and the release would be from the stack, the workers would not receive a dose.

E.14.3.3.5 Chemical Consequences from Cesium Ion Exchange Column Explosion

Chemical exposures resulting from accidents at the vitrification facility are addressed in the Ex Situ Intermediate Separations alternative in Section E.6.

E.14.3.4 Occupational Fatalities and Injuries

The number of operation personnel was estimated at approximately 1.41E+02 person-years (Jacobs 1996). The number of total recordable injuries and illnesses, lost workday cases, and fatalities are calculated as follows:

Total Recordable Cases = (1.41E+02 person-years) · (2.2E+00 incidences/100 person-years) = 3.10E+00

Lost Workday Cases = (1.41E+02 person-years) · (1.1E+00 incidences/per 100 person-years) = 1.55E+00

Fatalities = (1.41E+02 person-years) · (3.2E-03 fatalities/100 person-years) = 4.51E-03

E.15.0 UNCERTAINTY

The uncertainties in calculating the radiological doses and the toxicological exposures resulting from operation accidents include the tank inventory concentration and the atmospheric dispersion once the source term is in the air. To demonstrate these uncertainties, a sample accident scenario is presented in Table E.15.0.1. The demonstration shows the difference between the bounding and nominal parameters; the concentration of the inventory is a factor of 30; and the atmospheric dispersion coefficient is a factor of 12 for the MEI noninvolved worker, a factor of 30 for the noninvolved worker population, a factor of 22 for the MEI general public, and a factor of 15 for the general public population. For the noninvolved worker population, a dose of 2.52E+03 person-rem was calculated based on bounding parameters, which is 3 orders of magnitude higher than the nominal dose calculated at 2.89E+00 person-rem.

The main uncertainty associated with calculating the radiological doses resulting from transportation accidents while transporting vitrified HLW to a potential geologic repository was the percent of the waste by weight that could be mixed with the glass matrix. To demonstrate these uncertainties, a sample accident scenario is presented in Table E.15.0.2. The baseline analysis used in the EIS assumed a 20 weight percent waste loading. A range from the base line from as little as 15 weight percent to as much as 40 weight percent are used in the uncertainty evaluation in Table E.15.0.2. The population dose was calculated by RADTRAN 4 (Neuhauser-Kanipe 1992) and was based on the worst credible accident parameters in the urban population zone.

Table E.15.0.1 Uncertainty Evaluation for Mispositioned Jumper - Common to All Tank Alternatives

Parameters	Bounding	Nominal
Inventory (activity concentration of inventory)	1.20E+06 rem/L (activity concentration bounding 100 percent of the sampled inventory by volume)	4.20E+04 rem/L (activity concentration bounding 50 percent of the sampled inventory by volume)
Source Term (respirable amount of waste the receptors are exposed to)	26 L onsite (8-hr exposure) 52 L offsite (16-hr exposure)	26 L onsite (8-hr exposure) 52 L offsite (16-hr exposure)
Atmospheric dispersion coefficients (X/Q) - (determines the down wind concentrations)	99.5 percent maximum sector meteorology MEI nonworker = 6.51E-03 s/m^3 Nonworkers = 2.45E-01 s/m^3 MEI general public = 1.43E-05 s/m^3 General population = 3.00E-02 s/m^3	Annual average meteorology MEI nonworker = 5.49E-04 s/m^3 Nonworkers = 8.01E-03 s/m^3 MEI general public = 6.54E-07 s/m^3 General population = 2.03E-03 s/m^3
Breathing rate (typical acute breathing rate during light activity)	3.3E-4 m^3/s	3.3E-4 m^3/s
Dose - Is the product of the inventory · tank head space · head space concentration · LPF X/Q · breathing rate	MEI nonworker = 6.70E+01 rem Nonworkers = 2.52E+03 person-rem MEI general public = 2.94E-01 rem General population = 6.18E+02 person-rem	MEI nonworker = 1.98E-01 rem Nonworkers = 2.89E+00 person rem MEI general public = 4.71E-04 rem General population = 1.46E+00 person-rem

Notes:
Bounding:
[1] MEI nonworker = (1.20E+06 rem/L) · (2.60E+01 L) · (6.51E-03 s/m^3) · (3.3E-04 m^3/s) = 6.70E+01 rem.
[2] Nonworkers = (1.20E+06 rem/L) · (2.60E+01 L) · (2.45E-01 s/m^3) · (3.3E-04 m^3/s) = 2.52E+03 rem.
[3] MEI general public = (1.20E+06 rem/L) · (5.20E+01 L) · (1.43E-05 s/m^3) · (3.3E-04 m^3/s) = 2.94E-01 rem.
[4] General public = (1.20E+06 rem/L) · (5.20E+01 L) · (3.00E-02 s/m^3) · (3.3E-04 m^3/s) =6.18E+02 rem.
Nominal:
[5] MEI nonworker = (4.20E+04 rem/L) · (2.60E+01 L) · (5.49E-04 s/m^3) · (3.3E-04 m^3/s) = 1.98E-01 rem.
[6] Nonworkers = (4.20E+04 rem/L) · (2.60E+01 L) · (8.01E-03 s/m^3) · (3.3E-04 m^3/s) = 2.89E+00 rem.
[7] MEI general public = (4.20E+04 rem/L) ·(5.20E+01 L) · (6.54E-07 s/m^3) · (3.3E-04 m^3/s) = 4.71E-04 rem.
[8] General public = (4.20E+04 rem/L) · (5.20E+01 L) · (2.03E-03 s/m^3) · (3.3E-04 m^3/s) = 1.46E+00 rem.

Table E.15.0.2 Uncertainty Evaluation for HLW Glass Transport Accident - Ex Situ Intermediate Separations Alternative

Inventory	Population Dose (person-rem)
HLW glass with 20 weight percent waste oxide loading (base case)	4.2E+03
HLW glass with 15 weight percent waste oxide loading	3.3E+03
HLW glass with 40 weight percent waste oxide loading	7.9E+03

The nonradiological injuries and fatalities resulting from construction and operation accidents were based on incidence rates taken from the occupational injuries summary report (DOE 1994j).
The transportation injuries and fatalities from trucks and train were based on incidence rates taken from statistics compiled by the U.S. Department of Transportation (Rao et al. 1982). Injuries and fatalities resulting from employee vehicle accidents were based on incidence rates taken from the Washington State Highway Accident Report (WSDT 1993). Because these are widely accepted incidence rates, there was no attempt to evaluate the uncertainties.

9613409.1491

APPENDIX E
REFERENCES

56 FR 23363. Preamble to Standard for Protection Against Radiation. Federal Register. U.S. Nuclear Regulatory Commission. Washington D.C. May 21, 1991.

Dentler 1995. Dentler, M.E. Toxicological Evaluation of Tank Waste Chemicals. Hanford Environmental Health Foundation Industrial Hygiene Assessments. Richland, Washington. January 13, 1995.

DOE 1994a. Draft Environmental Impact Statement Safe Interim Storage of Hanford Tank Wastes. DOE/EIS-0212. U.S. Department of Energy. Richland, Washington. July 1994.

DOE 1994j. Occupational Injury and Property Damage Summary, January - December 1993. DOE/EH/01570-H5. U.S. Department of Energy. Washington, D.C. 1994.

Fox-Stepnewski 1994. Fox, G.L., Jr., and D.D. Stepnewski. Hazard Assessments of Double-Shell Flammable Gas Tanks. WHC-SD-WM-SAR-064. Westinghouse Hanford Company. Richland, Washington. 1994.

Golberg 1994. Golberg, C.E. Final Environmental Impact Statement and 1994 Integrated Database Tank Inventory Tables. 71220-94-041. Internal Memorandum to G.K. Allen et al. Westinghouse Hanford Company. Richland, Washington. December 13, 1994.

Green 1995. Green, J.R. Transportation Impact Analysis for the Tank Waste Remediation System Environmental Impact Statement Proposed Alternatives. WHC-SD-RPT-016, Rev. B. Westinghouse Hanford Company. Richland, Washington. January 1995.

ICRP 1975. Report of the Task Group on Reference Man, Report No. 23. International Commission on Radiological Protection. 1975.

ICRP 1991. 1990 Recommendations of the International Commission on Radiological Protection. Pergamon Press. 1991.

Jacobs 1996. Engineering Calculations for the Tank Waste Remediation System Environmental Impact Statement. Jacobs Engineering Group Inc. Kennwwick, Washington. August 1996.

Julyk 1994. Julyk, L.J. Static Internal Pressure Capacity of Hanford Single-Shell Waste Tanks. WHC-SD-WM-TI-623, Rev. 0. Westinghouse Hanford Company. Richland, Washington. 1994

LANL 1995. A Safety Assessment for Proposed Pump Mixing to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington. LA-UR-92-3196, Rev. 14. Los Alamos National Laboratory. Los Alamos, New Mexico. 1995.

Lipke et al. 1995. Lipke, E.J., H. Babad, G.R. Franz, J.E. Meacham, L.D. Muhlestein. TWRS Safety Basis. Westinghouse Hanford Company. Richland, Washington. June 1995.

Napier et al. 1988. Napier, B.A., R.E. Peloquin, D.L. Strenge, and J.V. Ramsdall. GENII - The Hanford Environmental Radiation Dosimetry Software System. PNL-6584. Pacific Northwest National Laboratory. Richland, Washington. 1988.

Neuhauser-Kanipe 1992. Neuhauser, K.S. and F. L. Kanipe. RADTRAN 4: Volume 3 - User Guide SAND89-2370. Sandia National Laboratories. Albuquerque, New Mexico. 1992.

NRC 1982. Atmospheric Dispersion Models for Potential Accident Consequences Assessment at Nuclear Power Plants. NUREG-1.145. U.S. Nuclear Regulatory Commission. Washington D.C. November 1982.

NRC 1977. Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes. NUREG-0170. Nuclear Regulatory Commission. Washington, D.C. 1977.

Rao et al. 1982. Rao, R. K., et al. Non-Radiological Impacts of Transporting Radioactive Material. SAND81-1703. Sandia National Laboratories. Albuquerque, New Mexico. 1982.

Rockwell 1983. Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site. Rockwell International. Richland, Washington. March 1993.

Schreckhise 1993. Schreckhise, R.G. Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters. PNL-3777, Rev. 2. Pacific Northwest National Laboratory. Richland, Washington. April 1993.

Shire et al. 1995. Shire, P.R., W.L. Cowely, B.H. Gilbert, D.A. Smith, and G.L. Smith. Potential Accidents with Radiological and Toxicological Source Terms for Hanford Tank Waste Remediation System Environmental Impact Statement. WHC-SD-WM-ANAL-041, Rev. 0. Westinghouse Hanford Company. Richland, Washington. May 1995.

Sutton 1996. Sutton, L. Westinghouse Hanford Company. Personal Communication. Richland, Washington. February 12, 1996.

WHC 1996a. Emergency Management Procedures. WHC-CM-4-43. Westinghouse Hanford Company. Richland, Washington. 1996.

9613409.1492

WHC 1996b. Probabalistic Hazard Analysis, DOE Hanford Site, Washington. WHC-SD-W236A-TI-002, Rev. 1. Westinghouse Hanford Company. Richland, Washington. 1996.

WHC 1995c. No Separations Data Package for the Tank Waste Remediation System Environmental Impact Statement. WHC-SD-WM-EV-103, Rev. 0. Westinghouse Hanford Company. Richland, Washington. July 1995.

WHC 1995e. Extensive Separations Pretreatment Alternative Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement. WHC-SD-EV-100, Rev. 0. Westinghouse Hanford Company. Richland, Washington. September 1995.

WHC 1995f. In Situ Treatment and Disposal of Radioactive Waste in Hanford Site Underground Storage Tanks Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement. WHC-SD-WM-EV-101, Rev. 0. Westinghouse Hanford Company. Richland, Washington. July 1995.

WHC 1995g. No Disposal Action Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement. WHC-SD-WM-EV-099, Rev. 0. Westinghouse Hanford Company. Richland, Washington. July 1995.

WHC 1995j. Tri-Party Agreement Alternative Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement WHC-SD-WM-EV-104, Rev. 0. Westinghouse Hanford Company. Richland, Washington. July 1995.

WHC 1995k. Potential Accidents for Storage and Disposition of Cesium and Strontium Capsules for the Tank Waste Remediation System. Westinghouse Hanford Company. Richland, Washington. 1995.

WSDT 1993. Washington State Highway Accident Report 1993. Washington State Department of Transportation. Planning and Programming, Service Center Transportation Data Office. Olympia, Washington. 1993.

This page intentionally left blank.

9613409.1493

APPENDIX F
GROUNDWATER MODELING

This page intentionally left blank.

9613409.1494

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS xi

NAMES AND SYMBOLS FOR UNITS OF MEASURE AND RADIOACTIVITY xi

F.1.0 INTRODUCTION F-1

F.2.0 METHODOLOGY AND APPROACH F-3
F.2.1 SCREENING ALTERNATIVES F-3
F.2.1.1 No Action Alternative (Tank Waste) F-6
F.2.1.2 Long-Term Management Alternative F-6
F.2.1.3 In Situ Fill and Cap Alternative F-6
F.2.1.4 In Situ Vitrification Alternative F-6
F.2.1.5 Ex Situ Intermediate Separations Alternative F-7
F.2.1.6 Ex Situ No Separations Alternative F-7
F.2.1.7 Ex Situ Extensive Separations Alternative F-7
F.2.1.8 Ex Situ/In Situ Combination Alternative F-7
F.2.1.9 Phased Implementation Alternative F-8
F.2.1.10 Effluent Treatment Facility F-8
F.2.1.11 No Action Alternative (Capsules) F-8
F.2.1.12 Onsite Disposal Alternative F-8
F.2.1.13 Overpack and Ship Alternative F-10
F.2.1.14 Vitrify with Tank Waste Alternative F-10
F.2.2 SOURCE CHARACTERIZATION F-10
F.2.2.1 Aggregate Source Areas F-11
F.2.2.2 Contaminant Groups F-11
F.2.2.2.1 No Action Alternative (Tank Waste) F-13
F.2.2.2.2 Long-Term Management Alternative F-13
F.2.2.2.3 In Situ Fill and Cap Alternative F-13
F.2.2.2.4 In Situ Vitrification Alternative F-19
F.2.2.2.5 Ex Situ Intermediate Separations Alternative F-19
F.2.2.2.6 Ex Situ No Separations Alternative F-24
F.2.2.2.7 Ex Situ Extensive Separations Alternative F-24
F.2.2.2.8 Ex Situ/In Situ Combination Alternative F-25
F.2.2.2.9 Phased Implementation F-26
F.2.2.3 Source Terms F-32
F.2.2.3.1 No Action Alternative (Tank Waste) F-33
F.2.2.3.2 Long-Term Management Alternative F-35
F.2.2.3.3 In Situ Fill and Cap Alternative F-35
F.2.2.3.4 In Situ Vitrification Alternative F-38
F.2.2.3.5 Ex Situ Intermediate Separations Alternative F-41

TABLE OF CONTENTS (cont'd)

F.2.2.3.6 Ex Situ No Separations Alternative F-44
F.2.2.3.7 Ex Situ Extensive Separations Alternative F-45
F.2.2.3.8 Ex Situ/In Situ Combination Alternative F-46
F.2.2.3.9 Phased Implementation Alternative F-52
F.2.3 VADOSE ZONE MODELING F-52
F.2.3.1 Vadose Zone Conceptual Models F-53
F.2.3.1.1 Hydrostratigraphy and Soil Properties F-53
F.2.3.1.2 Flow Properties F-54
F.2.3.1.3 Contaminant Transport Properties F-60
F.2.3.2 Post-Processing for Groundwater Model Input F-63
F.2.4 GROUNDWATER MODELING F-64
F.2.4.1 Groundwater Conceptual Model F-66
F.2.4.1.1 Geology F-67
F.2.4.1.2 Hydrology F-67
F.2.4.1.3 Flow Properties F-69
F.2.4.1.4 Saturated Zone Contaminant Transport Properties F-72
F.2.4.2 Post-Processing Groundwater Results for Risk Assessment F-78
F.2.4.2.1 Reducing Data Results to 1-km (0.62-mi) Grid F-78
F.2.4.2.2 Adjusting Raw Data to Constituent Concentrations F-79

F.3.0 PREDICTED CONTAMINANT CONCENTRATIONS F-81
F.3.1 NO ACTION ALTERNATIVE (TANK WASTE) F-82
F.3.1.1 Vadose Zone F-82
F.3.1.2 Groundwater F-83
F.3.2 LONG-TERM MANAGEMENT ALTERNATIVE F-83
F.3.2.1 Vadose Zone F-84
F.3.2.2 Groundwater F-85
F.3.3 IN SITU FILL AND CAP ALTERNATIVE F-86
F.3.3.1 Vadose Zone F-86
F.3.3.2 Groundwater F-87
F.3.4 IN SITU VITRIFICATION ALTERNATIVE F-88
F.3.4.1 Vadose Zone F-88
F.3.4.2 Groundwater F-88
F.3.5 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE F-89
F.3.5.1 Vadose Zone F-89
F.3.5.2 Groundwater F-90
F.3.6 EX SITU NO SEPARATIONS ALTERNATIVE F-91
F.3.7 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE F-92
F.3.8 EX SITU/IN SITU COMBINATION ALTERNATIVE F-92

9613409.1495

TABLE OF CONTENTS (cont'd)

F.3.8.1 Vadose Zone F-92
F.3.8.2 Groundwater F-93
F.3.9 PHASED IMPLEMENTATION ALTERNATIVE F-93
F.3.10 EFFLUENT TREATMENT FACILITY F-94
F.3.11 SUMMARY OF RESULTS F-94
F.3.11.1 Observed Contamination Concentrations F-94
F.3.11.2 Calculated Contaminant Concentrations F-94

F.4.0 FLOW AND TRANSPORT MODEL F-95
F.4.1 FEATURES OF THE VAM2D FLOW AND TRANSPORT CODE F-96
F.4.2 LIMITATIONS OF THE TRANSPORT MODEL F-96
F.4.3 RELIABILITY TESTING OF CALCULATED RESULTS F-97
F.4.3.1 Verification F-97
F.4.3.2 Benchmarking F-98
F.4.3.3 Calibration F-98
F.4.3.4 Validation F-99
F.4.3.5 Parameter Sensitivity F-99
F.4.4 MODELING ASSUMPTIONS AND UNCERTAINTIES F-102
F.4.5 CONCEPTUAL GROUNDWATER CUMULATIVE IMPACTS F-111
F.4.5.1 Past Practice Liquid Waste Disposal F-112
F.4.5.2 Past Practice Solid Waste Disposal F-113
F.4.5.3 Solid Low-Level Radioactive Waste Disposal in the Environmental Restoration Disposal Facility F-114
F.4.5.4 Solid Low-Level Radioactive Waste Disposal in the 200 West Burial Grounds F-115
F.4.5.5 Solid Low-Level Radioactive Waste Disposal in the US Ecology Burial Grounds F-115

FIGURES:

F.1.0.1 Location of Tank Waste Source Areas, Proposed LAW Vaults and Proposed Capsule Dry-Well Disposal F-2
F.1.0.2 Area of Potential Groundwater Impact F-4
F.2.0.1 Groundwater Impacts Assessment Approach F-5
F.2.2.1 Water Flux Versus Time for Tank Source 1WSS, No Action Alternative (Tank Waste) F-34
F.2.2.2 Water Flux Versus Time for All Tank Sources, In Situ Vitrification Alternative F-40
F.2.3.1 Conceptual Profiles of the Vadose Zone for Source Areas in the 200 West Area F-55

TABLE OF CONTENTS (cont'd)

F.2.3.2 Conceptual Profiles of the Vadose Zone for Source Areas in the 200 East Area F-56
F.2.3.3 Example of Groundwater Model Input Development from Vadose Model Results F-65
F.2.4.1 Stratigraphic Column for the Hanford Site Showing Nomenclature From Previous Investigations F-68
F.2.4.2 Results of CFEST Steady-State Simulations for December 1979 . . . . . F-70
F.2.4.3 Longitudinal Dispersivity Values Observed in the Field F-75
F.2.4.4 Hanford Environmental Settings Areas F-76
F.3.1.1 Calculated Contaminant Concentration for the No Action Alternative (K_d=0) at the Vadose Zone/Groundwater Interface F-116
F.3.1.2 Calculated Contaminant Concentration for the No Action Alternative (K_d=1) at the Vadose Zone/Groundwater Interface F-117
F.3.1.3 Calculated Nitrate Concentrations in Groundwater at 300 Years for the No Action Alternative F-118
F.3.1.4 Calculated Concentration of Nitrate in Groundwater at Selected Locations for the No Action Alternative (K_d=0) F-119
F.3.1.5 Calculated Bismuth Concentrations in Groundwater at 5,000 Years for the No Action Alternative F-120
F.3.1.6 Calculated Concentration of Bismuth in Groundwater at Selected Locations for the No Action Alternative (K_d=1) F-121
F.3.1.7 Calculated Technetium-99 Concentrations in Groundwater at 300 Years for the No Action Alternative F-122
F.3.1.8 Calculated Iodine-129 Concentrations in Groundwater at 300 Years for the No Action Alternative F-123
F.3.1.9 Calculated Carbon-14 Concentrations in Groundwater at 300 Years for the No Action Alternative F-124
F.3.1.10 Calculated Uranium-238 Concentrations in Groundwater at 300 Years for the No Action Alternative F-125
F.3.1.11 Calculated Technetium-99 Concentrations in Groundwater at 500 Years for the No Action Alternative F-126
F.3.1.12 Calculated Iodine-129 Concentrations in Groundwater at 500 Years for the No Action Alternative F-127
F.3.1.13 Calculated Carbon-14 Concentrations in Groundwater at 500 Years for the No Action Alternative F-128
F.3.1.14 Calculated Uranium-238 Concentrations in Groundwater at 500 Years for the No ActionAlternative F-129
F.3.1.15 Calculated Nitrate Concentrations in Groundwater at 500 Years for the No ActionAlternative F-130

TABLE OF CONTENTS (cont'd)

F.3.1.16 Calculated Technetium-99 Concentrations in Groundwater at 2,500 Years for the No Action Alternative F-131
F.3.1.17 Calculated Iodine-129 Concentrations in Groundwater at 2,500 Years for the No Action Alternative F-132
F.3.1.18 Calculated Carbon-14 Concentrations in Groundwater at 2,500 Years for the No Action Alternative F-133
F.3.1.19 Calculated Uranium-238 Concentrations in Groundwater at 2,500 Years for the No Action Alternative F-134
F.3.1.20 Calculated Nitrate Concentrations in Groundwater at 2,500 Years for the No Action Alternative F-135
F.3.2.1 Calculated Contaminant Concentration for the Long-Term Management Alternative (K_d=0) at the Vadose Zone/Groundwater Interface F-136
F.3.2.2 Calculated Contaminant Concentration for the Long-Term Management Alternative (K_d=1) at the Vadose Zone/Groundwater Interface F-137
F.3.2.3 Calculated Nitrate Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative F-138
F.3.2.4 Calculated Concentration of Nitrate in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d=0) F-139
F.3.2.5 Calculated Bismuth Concentrations in Groundwater at 5,000 Years for the Long-Term Management Alternative F-140
F.3.2.6 Calculated Concentration of Bismuth in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d=1) F-141
F.3.2.7 Calculated Technetium-99 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative F-142
F.3.2.8 Calculated Iodine-129 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative F-143
F.3.2.9 Calculated Carbon-14 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative F-144
F.3.2.10 Calculated Uranium-238 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative F-145
F.3.2.11 Calculated Technetium-99 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative F-146
F.3.2.12 Calculated Iodine-129 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative F-147
F.3.2.13 Calculated Carbon-14 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative F-148
F.3.2.14 Calculated Uranium-238 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative F-149

TABLE OF CONTENTS (cont'd)

F.3.2.15 Calculated Nitrate Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative F-150
F.3.2.16 Calculated Technetium-99 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative F-151
F.3.2.17 Calculated Iodine-129 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative F-152
F.3.2.18 Calculated Carbon-14 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative F-153
F.3.2.19 Calculated Uranium-238 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative F-154
F.3.2.20 Calculated Nitrate Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative F-155
F.3.3.1 Calculated Concentration for the In Situ Fill and Cap Alternative at the Vadose Zone/Groundwater Interface F-156
F.3.3.2 Calculated Nitrate Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative F-157
F.3.3.3 Calculated Concentration of Nitrate in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (K_d=0) F-158
F.3.3.4 Calculated Technetium-99 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative F-159
F.3.3.5 Calculated Iodine-129 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative F-160
F.3.3.6 Calculated Carbon-14 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative F-161
F.3.3.7 Calculated Uranium-238 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative F-162
F.3.3.8 Calculated Nitrate Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative F-163
F.3.3.9 Calculated Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative F-164
F.3.3.10 Calculated Iodine-129 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative F-165
F.3.3.11 Calculated Carbon-14 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative F-166
F.3.3.12 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative F-167
F.3.3.13 Calculated Technetium-99 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative F-168

TABLE OF CONTENTS (cont'd)

F.3.3.14 Calculated Iodine-129 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative F-169
F.3.3.15 Calculated Carbon-14 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative F-170
F.3.3.16 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative F-171
F.3.3.17 Calculated Nitrate Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative F-172
F.3.4.1 Calculated Contaminant Concentration for the In Situ Vitrification Alternative at the Vadose Zone/Groundwater Interface F-173
F.3.4.2 Calculated Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative F-174
F.3.4.3 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative F-175
F.3.4.4 Calculated Concentration of Uranium-238 in Groundwater at Selected Locations for the In Situ Vitrification Alternative (K_d=0) F-176
F.3.4.5 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative F-177
F.3.5.1 Calculated Contaminant Concentration for the Ex Situ Intermediate Separations Alternative at the Vadose Zone/Groundwater Interface (K_d=0) F-178
F.3.5.2 Calculated Nitrate Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank Sources Only) F-179
F.3.5.3 Calculated Concentration of Nitrate in Groundwater at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only) F-180
F.3.5.4 Calculated Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only) F-181
F.3.5.5 Calculated Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (LAW Vault Sources Only) F-182
F.3.5.6 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank and LAW Vault Sources Combined) F-183
F.3.6.1 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ No Separations Alternative (Tank Sources Only) F-184
F.3.7.1 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Extensive Separations Alternative (Tank and LAW Vault Sources Combined) F-185
F.3.8.1 Calculated Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) . . F-186

TABLE OF CONTENTS (cont'd)

F.3.8.2 Calculated Iodine-129 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) F-187
F.3.8.3 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) F-188
F.3.8.4 Calculated Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only) F-189
F.3.8.5 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only) F-190
F.3.8.6 Calculated Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) F-191
F.3.8.7 Calculated Iodine-129 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) F-192
F.3.8.8 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only) F-193
F.3.8.9 Calculated Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only) F-194
F.3.8.10 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only) F-195
F.4.3.1 Comparison of Groundwater Elevations Calculated by VAM2D and CFEST . . F-196
F.4.3.2 Tritium Distribution in Unconfined Groundwater Based on 1977 Water Monitoring F-197
F.4.3.3 Calculated Tritium Concentrations in Groundwater At 10, 20, and 30 Years from a B-Pond Source F-198
F.4.3.4 Calculated Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative (High Glass Corrosion Concentration) F-199
F.4.3.5 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative (High Glass Corrosion Concentration) . F-200
F.4.3.6 Calculated Nitrate Concentration in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (500-Year Cap) F-201
F.4.3.7 Calculated Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative (500-Year Cap) F-202
F.4.3.8 Hindcast of Water Levels in the Unconfined Aquifer F-203

TABLES:

F.2.2.1 Tank Waste Source Area Designations and Descriptions F-12
F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste) F-14
F.2.2.3 Radionuclides Excluded from Vadose Zone and Groundwater Modeling F-19
F.2.2.4 Inventory of Contaminants for the In Situ Vitrification Alternative F-20

TABLE OF CONTENTS (cont'd)

F.2.2.5 Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative F-21
F.2.2.6 Inventory of Contaminants for the Low-Activity Waste Vaults - Ex Situ Intermediate Separations Alternative F-24
F.2.2.7 Inventory of Contaminants for the LAW Vaults - Ex Situ Extensive Separations Alternative F-25
F.2.2.8 Inventory of Contaminants Released During Retrieval - Ex Situ/In Situ Combination Alternative F-27
F.2.2.9 Inventory of Contaminants in Tanks Remediated In Situ - Ex Situ/In Situ Combination Alternative F-30
F.2.2.10 Contaminant Releases Modeled for the No Action Alternative (Tank Waste) . . F-35
F.2.2.11 Concentration of Contaminants Released for the No Action Alternative (Tank Waste) F-36
F.2.2.12 Contaminant Releases Modeled for the Long-Term Management Alternative . . F-37
F.2.2.13 Contaminant Releases Modeled for the In Situ Fill and Cap Alternative F-39
F.2.2.14 Contaminant Releases Modeled for the In Situ Vitrification Alternative F-41
F.2.2.15 Concentrations of Contaminants for the In Situ Vitrification Alternative in K_d Group One (K_d=0) F-41
F.2.2.16 Contaminant Releases Modeled for the Ex Situ Intermediate Separations Alternative F-43
F.2.2.17 Concentrations of Contaminants for the LAW Vault Source for K_d Group One (K_d=0) Ex Situ Intermediate Separations Alternative F-45
F.2.2.18 Concentration of Contaminants in K_d Group One (K_d=0) For the Ex Situ Extensive Separations Alternative (LAW Vaults) F-46
F.2.2.19 Concentration of Contaminants in K_d Group 1 (K_d=0) Associated with Waste Retrieval- Ex Situ/In Situ Combination Alternative F-48
F.2.2.20 Contaminant Releases Modeled for the Ex Situ/In Situ Combination Alternative F-49
F.2.2.21 Concentration of Contaminants in K_d Group One (K_d=0) Associated with Waste Tanks Remediated In Situ for the Ex Situ/In Situ Combination Alternative . . . F-50
F.2.3.1 Tank Depths and Material Property Intervals Within the Vadose Zone at 200 East Source Areas F-54
F.2.3.2 Tank Depths and Material Property Intervals Within the Vadose Zone at 200 West Source Areas F-54
F.2.3.3 Porous Medium Properties for Each Material Type in the 200 East Area F-58
F.2.3.4 Porous Medium Properties for Each Material Type in the 200 West Area F-58
F.2.3.5 Van Genuchten Parameters for Each Material Type in the 200 East Area F-59
F.2.3.6 Van Genuchten Parameters for Each Material Type in the 200 West Area F-59
F.2.3.7 Longitudinal Dispersivity Values for the 200 East and 200 West Areas F-61

TABLE OF CONTENTS (cont'd)

F.2.3.8 Effective Porosity Values for the 200 East Area F-62
F.2.3.9 Effective Porosity Values for the 200 West Area F-62
F.2.3.10 Bulk Density Values for the 200 East and 200 West Areas F-62
F.2.4.1 Summary of Fixed Flux Boundaries from CFEST Model F-72
F.2.4.2 Source Area Fixed Flux Boundaries F-72
F.2.4.3 Effective Porosity Values Recommended for the Hanford Site F-77
F.2.4.4 Bulk Density Values Recommended for the Hanford Site F-77
F.3.1.1 Maximum Concentrations Calculated for the No Action Alternative F-204
F.3.2.1 Maximum Concentrations Calculated for the Long-Term Management Alternative F-206
F.3.3.1 Maximum Concentrations Calculated for the In Situ Fill and Cap Alternative . F-208
F.3.4.1 Maximum Concentrations Calculated for the In Situ Vitrification Alternative . . F-210
F.3.5.1 Maximum Concentrations Calculated for the Ex Situ Intermediate Separations Alternative - Tank Sources F-211
F.3.5.2 Maximum Concentrations Calculated for the LAW Vaults - Ex Situ Intermediate Separations Alternative F-212
F.3.8.1 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (Tank Retrieval Component) F-213
F.3.8.2 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (In Situ Tank Remediation Component) F-214
F.3.8.3 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (LAW Vault Component) F-215
F.3.9.1 Maximum Concentrations Calculated in Groundwater for the Phased Implementation Total Alternative (Tank Sources) F-216
F.3.9.2 Maximum Concentration Calculated in Groundwater for the Phased Implementation Total Alternative (LAW Vaults) F-217
F.3.11.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for Each Alternative F-218
F.4.4.1 Estimated Mass of Selected Contaminants Released During Retrievaland as Residual for the E F-223
F.4.5.1 Estimated Past Practice and Projected Future Waste Disposed Quantities Compared to Tank Waste Quantity F-224
F.4.5.2 Potential Maximum Groundwater Contaminant Concentrations Associated with Solid Waste Disposal in the Central Plateau F-224

REFERENCES F-225

9613409.1499

ACRONYMS AND ABBREVIATIONS

AOI	area of interest
CFEST	Coupled Fluid, Energy, and Solute Transport
DOE	U.S. Department of Energy
DST	double-shell tanks
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
GIS	ARC/INFO Geographic Information System
HLW	high-level waste
LAW	low-activity waste
PUREX	Plutonium-Uranium Extraction Plant
PEIS	Programmatic Environmental Impact Statement
SST	single-shell tank
TEDF	Treated Effluent Disposal Facility
TWRS	Tank Waste Remediation System
2-D	two-dimensional

NAMES AND SYMBOLS FOR UNITS OF MEASURE AND RADIOACTIVITY

Length

cm	centimeter
ft	foot
in.	inch
km	kilometer
m	meter
mi	mile

Area

ha	hectare
ac	acre
km^2	square kilometer
mi^2	square mile
ft^2	square foot

Volume

cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Mass

g	gram
kg	kilogram
mg	milligram
lb	pound
mt	metric ton

Radioactivity

Ci	curie
mCi	millicurie (1.0E-03 Ci)
μCi	microcurie (1.0E-06 Ci)
nCi	nanocurie (1.0E-09 Ci)
pCi	picocurie (1.0E-12 Ci)

This page intentionally left blank.

APPENDIX F GROUNDWATER

F.1.0 INTRODUCTION

This appendix describes the approach and results of the groundwater impact analysis for the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) alternatives. The purpose of groundwater modeling is to predict concentrations of contaminants in groundwater from the various TWRS EIS alternatives. Using these calculations, potential human health risk and ecological risk can be estimated and compared between the alternatives. The potential sources of groundwater contamination are the waste tanks, the proposed low-activity waste (LAW) disposal facility, the proposed cesium-137 (Cs-137) and strontium-90 (Sr-90) capsule disposal facility, and the Effluent Treatment Facility (ETF). The groundwater exposure pathway is downward through the vadose zone underlying the potential sources; and laterally through the unconfined aquifer immediately underlying the vadose zone to the Columbia River. The tanks, LAW disposal facility, and Cs-137 and Sr-90 capsule storage areas are all located on the 200 Area Plateau (Figure F.1.0.1). The groundwater assessment has been performed using a combination of screening techniques and numerical modeling. The groundwater modeling results predict contaminant concentrations in the groundwater associated with selected alternatives from the present to 10,000 years from the present. The groundwater assessments provided in this appendix required several assumptions to address uncertainties. The major assumptions and uncertainties are related to either the natural system (i.e., an understanding and ability to assign vadose zone and aquifer parameter values) or uncertainties inherent to the assessment approach.

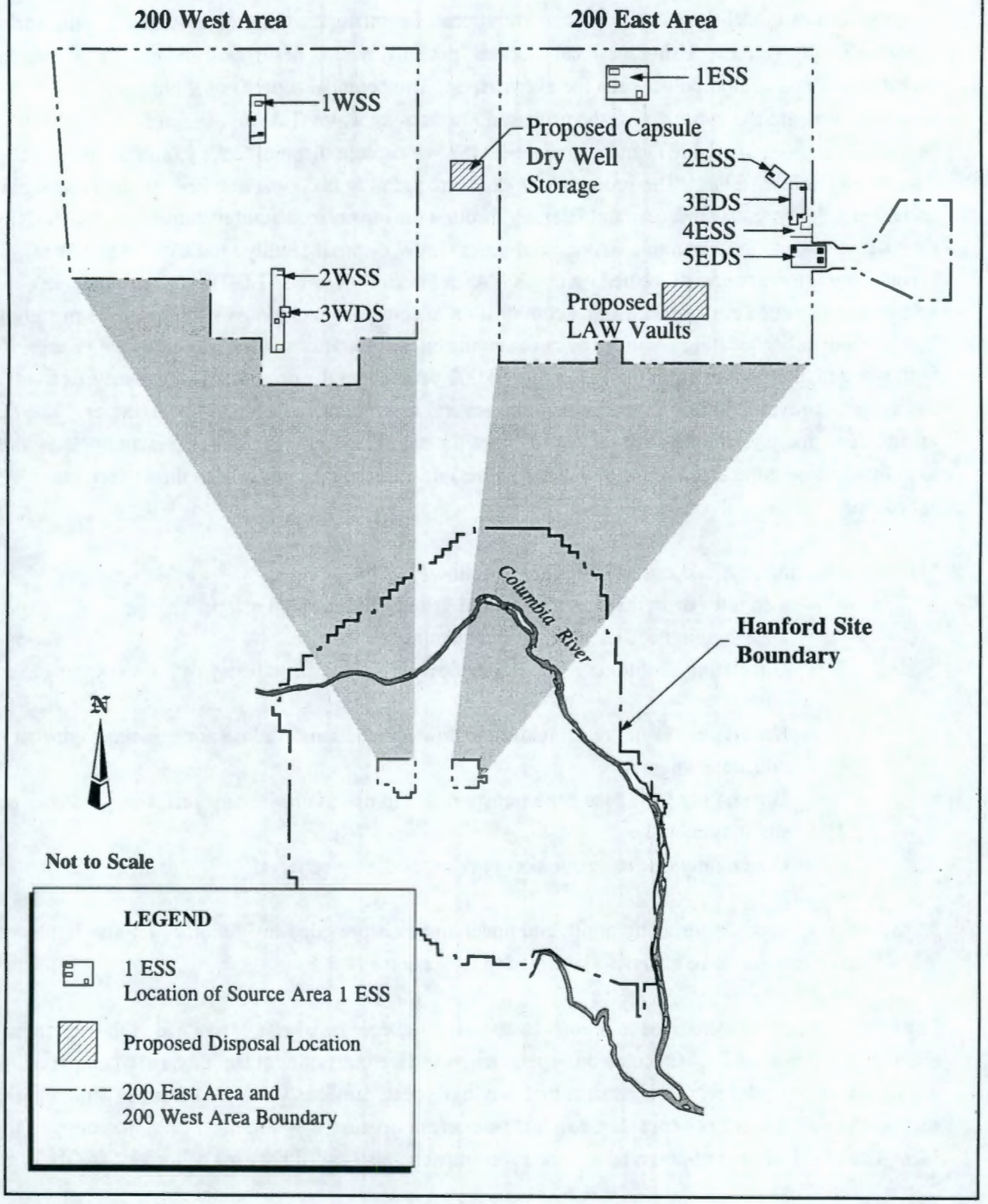
The major assumptions and uncertainties are as follows:

- The rates of infiltration into natural ground and through a cap;
- Distribution coefficient (K_d) of contaminants;
- Uncertainty in future groundwater flow direction due to decay of groundwater mounds onsite;
- Uncertainty in future groundwater flow direction and vadose zone thickness due to climate change;
- Uncertainty in vadose zone transport due to use of one-dimensional flow and transport simulation; and
- Uncertainty due to calculation of releases during retrieval.

A discussion of these major assumptions and uncertainties is provided in Section F.4.4 and results of a limited parameter sensitive analysis are provided in Section F.4.3.5.

The modeling results were used to predict human risk and ecological risk associated with each modeled alternative (Appendix D). Calculated concentrations of five indicator contaminants are compared with drinking water standards. Contaminants that may have been previously released from existing facilities, such as the tanks, were not considered in this assessment because they are not within the scope of this EIS. The physical area of potential groundwater impacts, also called the area of interest (AOI), is the

Figure F.1.0.1 Location of Tank Waste Source Areas, Proposed LAW Vaults, and Proposed Capsule Dry-Well Disposal



unconfined aquifer bounded laterally by the Rattlesnake Hills in the west and southwest, by the Columbia River in the north and east, and by the Yakima River to the south (Figure F.1.0.2).

F.2.0 METHODOLOGY AND APPROACH

The approach and steps taken to assess potential impacts to the groundwater system are provided in this section. The alternatives considered in this assessment are as follows:

- Tank Waste
  - No Action
  - Long-Term Management
  - In Situ Fill and Cap
  - In Situ Vitrification
  - Ex Situ Intermediate Separations
  - Ex Situ No Separations
  - Ex Situ Extensive Separations
  - Ex Situ/In Situ Combination
  - Phased Implementation
- Cesium and Strontium Capsules
  - No Action
  - Onsite Disposal
  - Overpack and Ship
  - Vitrify with Tank Waste

These alternatives are described in detail in Appendix B.

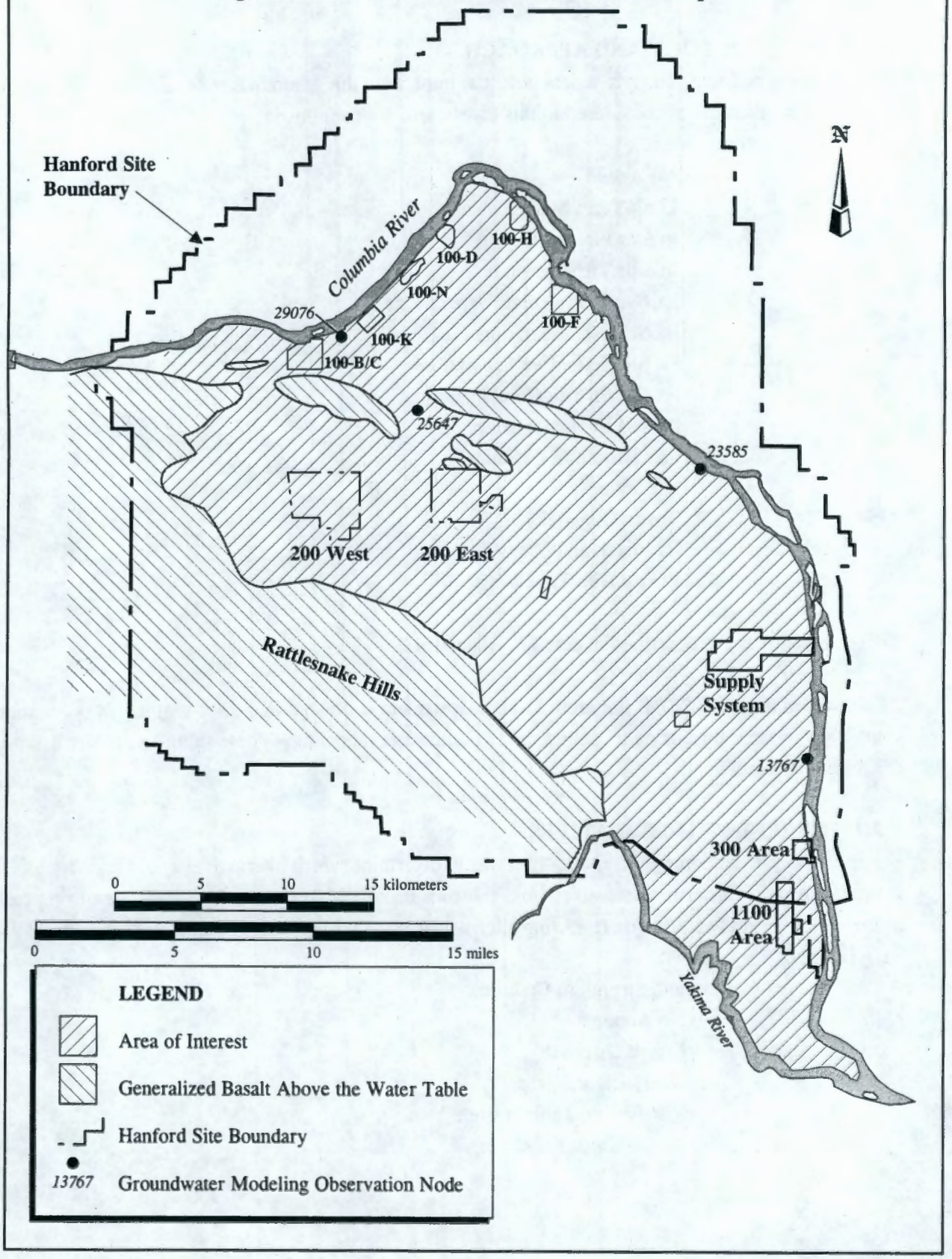
As shown on Figure F.2.0.1, the groundwater assessment is divided into three major subtasks: source characterization, vadose zone modeling, and groundwater modeling. These subtasks are discussed in the following sections.

F.2.1 SCREENING ALTERNATIVES

The initial step in screening the alternatives was to determine which alternatives could impact groundwater and eliminate alternatives from rigorous numerical modeling that have little or no potential of impacting groundwater. The following alternatives were screened from numerical modeling analysis:

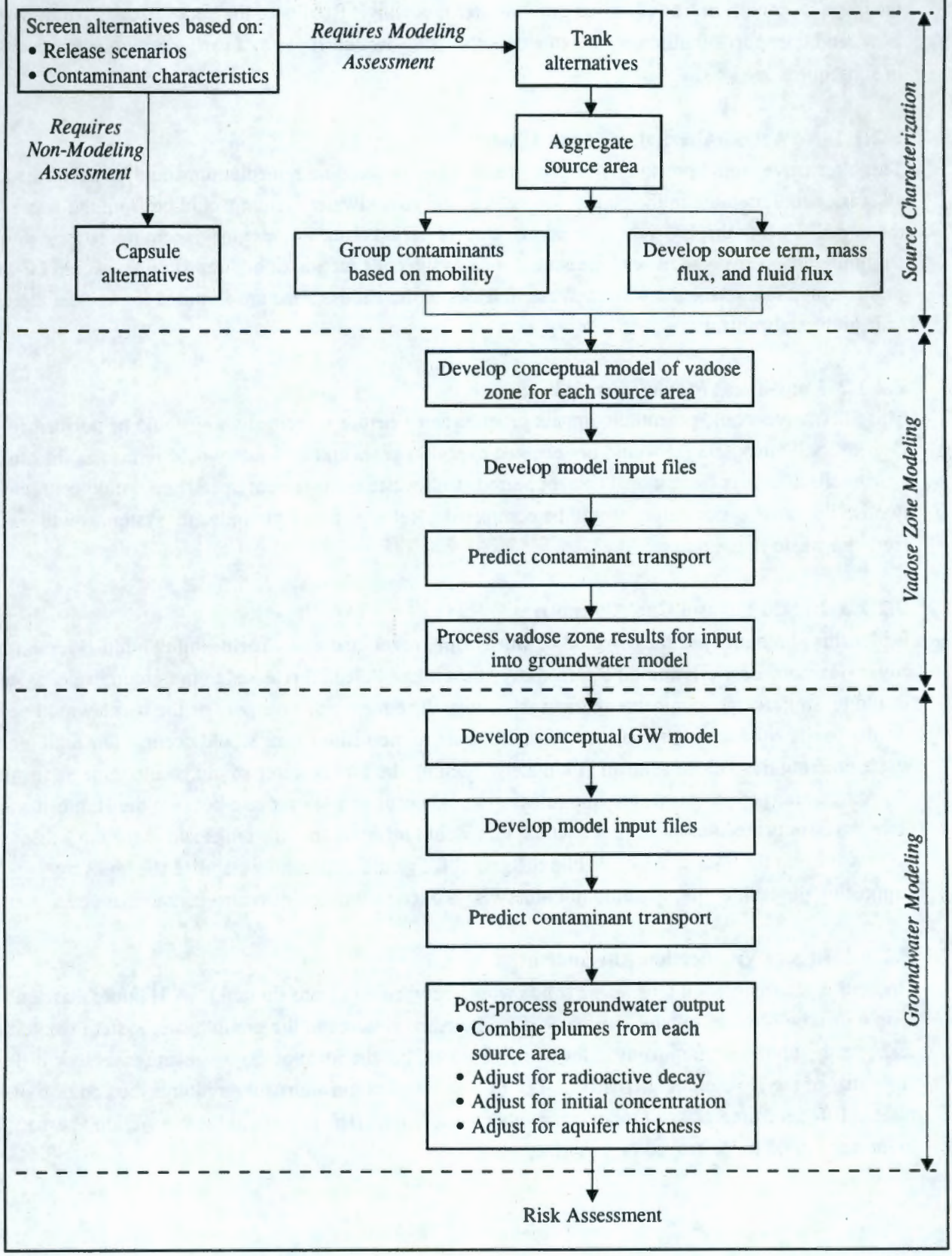
- Cesium and Strontium Capsules
  - No Action
  - Onsite Disposal
  - Overpack and Ship
  - Vitrify with Tank Waste

Figure F.1.0.2 Area of Potential Groundwater Impact



9613409.1502

Figure F.2.0.1 Groundwater Impacts Assessment Approach



The remaining alternatives considered for numerical modeling are the tank waste-related alternatives listed previously. The following sections provide the rationale for screening each alternative for inclusion or exclusion from detailed groundwater modeling. Results of the vadose zone, groundwater flow, and transport simulations used to assess the groundwater impacts of each alternative are provided in subsequent sections.

F.2.1.1 No Action Alternative (Tank Waste)

This alternative would potentially impact groundwater because no remediation would be performed and all waste would remain in the tanks. Releases to the groundwater system would be from the waste in the tanks. During the 100-year institutional control period, tank waste management operations would continue, however no additional measures, such as the construction of additional tanks, would be implemented to manage the waste. Waste releases to the vadose zone are assumed to occur at the end of institutional control.

F.2.1.2 Long-Term Management Alternative

This alternative would potentially impact groundwater because no remediation would be performed. Double-shell tanks (DSTs) would be retanked every 50 years and all waste would remain in the tanks. During the 100-year institutional control period, tank waste management operations would continue and two DST retanking campaigns would be completed. Releases to the groundwater system would be from the waste in the tanks.

F.2.1.3 In Situ Fill and Cap Alternative

Under this alternative the tanks would be filled with gravel, and a low permeability multi-layer earthen cover (Hanford Barrier) would be placed over the tanks. Potential releases to the groundwater system would be from the contaminants in the waste tanks. The form and inventory of the waste would be similar to the No Action alternative. Waste releases to the vadose zone would occur. The total mass of waste entering the vadose zone and ultimately reaching the groundwater would be the same as for the No Action alternative. However, the releases would occur at a slower rate because the Hanford Barrier restricts the amount of precipitation that would infiltrate into the tanks and carry the waste downward into the vadose zone. While the gravel fill would structurally stabilize the tanks by supporting the tank dome, it would not otherwise reduce infiltration or retard contaminant transport.

F.2.1.4 In Situ Vitrification Alternative

Under this alternative, all tank waste solids would be vitrified in situ (in tank). A Hanford Barrier would then be placed over the vitrified waste. Potential releases to the groundwater system would be associated with the contaminants in the vitrified waste, but the form of the waste and inventory differ from that of the No Action alternative. The In Situ Vitrification alternative requires the addition of materials for forming glass. Organic and other volatile materials present in the No Action alternative inventory would be destroyed or vaporized.

F.2.1.5 Ex Situ Intermediate Separations Alternative

Under this alternative, waste would be retrieved from the tanks, high-level waste (HLW) would be separated from the LAW, and both HLW and LAW would be vitrified. The HLW would then be shipped to a potential geologic repository and the LAW would be disposed of onsite in shallow subsurface burial vaults. A Hanford Barrier would be placed over the tanks and vaults. Potential releases to the groundwater system are associated with 1) releases during retrieval from the waste tanks; 2) releases from residuals; and 3) releases from the LAW disposal facility.

F.2.1.6 Ex Situ No Separations Alternative

Under this alternative, waste would be retrieved from the tanks, vitrified or calcined, and shipped to a potential geologic repository for disposal. A Hanford Barrier would be placed over the tanks. Potential releases to the groundwater system are associated with 1) releases during retrieval from the waste tanks; and 2) releases from residuals remaining in the tanks. The vitrified or calcined waste would not have a potential groundwater impact because they would be shipped to the potential geologic repository. The groundwater impacts for this alternative would be the same as the retrieval and residual releases estimated for the tank waste Ex Situ Intermediate Separations alternative.

F.2.1.7 Ex Situ Extensive Separations Alternative

This alternative is similar to the Ex Situ Intermediate Separations alternative with the major difference being that a more extensive separations process would be used. Under this alternative, waste would be retrieved from the tanks, HLW would be separated from the LAW, and both HLW and LAW would be vitrified. The extensive separations process results in less waste volume and more activity (i.e., curies) shipped offsite to a potential geologic repository and a smaller contaminant source (i.e., curies) associated with the LAW vaults as compared to the Ex Situ Intermediate Separations alternative. A Hanford Barrier would be placed over the tanks and vaults. Potential releases to the groundwater system are associated with 1) releases during retrieval from the waste tanks; 2) releases from residuals; and 3) releases from the LAW disposal facility. Groundwater impacts associated with retrieval and residual releases are the same as for the Ex Situ Intermediate Separations alternative. The groundwater impacts resulting from releases from the LAW vaults would be lower than those from the Ex Situ Intermediate Separations alternative LAW vaults because the source term is smaller.

F.2.1.8 Ex Situ/In Situ Combination Alternative

Under this alternative, approximately half of the waste would be processed as described for the Tank Waste In Situ Fill and Cap alternative. Releases associated with this group of tanks would occur as described previously. Tanks selected for fill and cap processing would contain relatively small amounts of radioisotopes technetium-99 (Tc-99), carbon-14 (C-14), iodine-129 (I-129), and the uranium series, compared to the other tanks. The waste in the remaining tanks would be retrieved and separated into LAW and HLW. The LAW would be placed into shallow subsurface LAW burial vaults in the 200 East Area and the HLW would be shipped offsite for disposal at the potential geologic repository. A Hanford Barrier would be placed over the tanks and vaults.

F.2.1.9 Phased Implementation Alternative

Phase 1

Under the first phase, waste from the DSTs would be retrieved, vitrified and stored temporarily onsite. There would not be any groundwater impacts under this phase because 1) waste loss is assumed not to occur for retrieval from DSTs which contain primarily liquid and their double containment would catch any releases; and 2) the storage of the vitrified waste is temporary and under controlled conditions.

Total Alternative

In the second phase of this alternative, the plants constructed for Phase 1 would continue to operate and in addition the remainder of the tank waste would be retrieved and treated in the same way as in the Ex Situ Intermediate Separations alternative. Potential releases to the groundwater and contamination from those releases would be the same for the second phase of the Phased Implementation alternative and the Ex Situ Intermediate Separations alternative.

F.2.1.10 Effluent Treatment Facility

This facility would potentially impact groundwater because treated effluent from the ETF will be discharged to a State-approved land disposal site (SALDS) located immediately north of the 200 West Area. All tank alternatives considered, except No Action, contribute wastewater to the ETF through either periodic operation of the 242-A Evaporator to manage waste volume, DST retanking campaigns, or liquid effluent collected from the process facility. The SALDS would consist of a piping manifold used to infiltrate treated effluent into vadose zone soil and deeper groundwater beneath the site. The primary contaminant present in the treated effluent would be tritium, with other organic, inorganic, and radiogenic contaminants having been removed during the treatment process. Waste releases to the vadose zone beneath the SALDS would be assumed to only occur during the 100-year institutional control period.

F.2.1.11 No Action Alternative (Capsules)

Under this alternative, the capsules would be stored temporarily for a period of 10 years in the Waste Encapsulation and Storage Facility (WESF) until a decision is made to store the waste elsewhere or put the waste to a beneficial use. There would be no groundwater impacts.

F.2.1.12 Onsite Disposal Alternative

Under this alternative, the capsules would be placed in 0.3 meter (m) (1.0 foot [ft]) canisters surrounded by a 0.76 m (2.5 ft) diameter sand backfill. There would be 672 drywells on 5 m (16 ft) center-to-center spacing with a 30 m (98 ft) buffer around the facility. The overall area of the facility would 195 by 195 m (639 by 639 ft) or 38,000 square meters (m^2) (410,000 square feet [ft^2]). The dry-well depth would be 4.6 m (15.0 ft) below ground surface.

It is estimated that as of December 31, 1995, the total inventory of the Onsite Disposal Facility would be as follows:

Constituent	Inventory (Curies)	Inventory (Grams)
Cs-137	5.22E+07	604,167
Sr-90	2.25E+07	161,583

Because these storage wells are belowgrade in an arid environment, they are assumed to remain intact beyond 500 years past the end of the institutional control period, after which the contents of the drywells are assumed to be released to the vadose zone at a depth of 4.6 m (15.0 ft) belowground surface.

The potential impact to the groundwater associated with this alternative is not a concern until the time of release. The half-lives of Cs-137 and Sr-90 are 30.17 years and 28.60 years, respectively. The inventory of Cs-137 and Sr-90 remaining when release would occur would be greatly reduced from the present quantities, because of these relatively short half-lives. The estimated inventory 600 years into the future (approximately 20 half-lives) is as follows:

Constituent	Inventory (Curies)	Inventory (Grams)
Cs-137	54	0.625
Sr-90	10.98	0.079

Both Cs-137 and Sr-90 are very immobile in earth systems at the Hanford Site. The distribution coefficients (K_d) for these isotopes are as follows:

Constituent	Distribution Coefficient K_d (mL/gram)
Cs-137	51
Sr-90	24

Vadose zone and groundwater flow, and transport simulations performed for the No Action alternative for tank waste (Section F.3.1) indicate that it would take a nominal period of 1,200 years for a constituent with a K_d of one to reach the groundwater. Cs-137 and Sr-90 are transported much slower because of their greater K_d. Thus, high K_d values of Cs-137 and Sr-90 coupled with their relatively short half-lives mean that no measurable amount of either Cs-137 or Sr-90 would reach the groundwater within the 10,000-year period of interest.

Cs-137 decays to barium-137 (Ba-137), a stable isotope with an estimated K_d of over 100 (Droppo et al. 1991). This constituent would not be expected to reach the groundwater within the 10,000-year period of interest. Sr-90 decays to zirconium-90 (Zr-90), also a stable isotope, with an estimated K_d of 8.2 (Droppo et al. 1991). This constituent could reach the groundwater in very low concentrations, 5,000 to 9,000 years from the present, based on simulations performed for the No Action alternative. No further groundwater assessment is provided for this alternative.

F.2.1.13 Overpack and Ship Alternative

Under this alternative, capsules would be removed from temporary storage, overpacked, and shipped offsite. Releases to the vadose zone would not occur and groundwater impacts would not be expected for this alternative. No further groundwater assessment is provided for this alternative.

F.2.1.14 Vitrify with Tank Waste Alternative

Under this alternative, capsules would be removed from temporary storage and vitrified with the tank waste. Releases to the vadose zone would not occur and groundwater impacts would not be expected for this alternative. No further groundwater assessment is provided for this alternative.

F.2.2 SOURCE CHARACTERIZATION

The remainder of this appendix explains the approach (Figure F.2.0.1) and results of assessing groundwater impact by simulating flow and transport through the vadose zone and underlying unconfined aquifer. A series of vadose zone, groundwater flow, and transport simulations for each selected alternative were performed using a combined flow and transport model, VAM2D. The items that potentially impact groundwater are associated with the following common elements.

- The contaminant sources are associated with near-surface waste forms (e.g., residuals in tanks and vitrified LAW).
- The physical AOI is the unconfined aquifer bounded laterally by the Rattlesnake Hills in the west and southwest, by the Columbia River in the north and east, and by the Yakima River to the south. The bottom of the unconfined aquifer is a confining bed in the bottom of the Ringold Formation.
- Contaminants (tank saltcake, sludge, and vitrified waste) are assumed to be released by their desorption and dissolution into pore fluids, and then moved by advection and diffusion from the waste source into the surrounding natural material (Kincaid et al. 1993). Once in the natural material, the contaminants are assumed to move downward by advection with infiltration from precipitation and liquid leakage from tanks.
  The flow of water and transport of contaminants in the vadose zone is principally in the vertical direction because of the hydraulic gradient, and the geologic structure or layering in the vadose zone is assumed insufficient to result in extensive lateral spreading.
- The 40 inactive miscellaneous underground storage tanks associated with the tank farms contain less than one-half of 1 percent of the tank waste and are located in close proximity to the farms. Therefore, the inactive miscellaneous underground storage tank inventory is assumed to be contained within the tank vaults, and potential releases to the groundwater were not modeled separately.

This section addressed source characterization, which involves the following:

- Aggregating the many potential sources into common source areas;
- Grouping contaminants into categories based on their mobility; and
- Developing the source term (i.e., mass flux and fluid flux release as a function of time) for each source area.

The contaminant source for each alternative selected for detailed groundwater analysis is then characterized, based on contaminant inventory data (i.e., mass or activity of each constituent) (Pelton-Davis 1995).

F.2.2.1 Aggregate Source Areas

The 178 potential sources (i.e., each of the 177 tanks and the proposed LAW disposal facility) have been aggregated into 9 discrete source areas based on waste inventory and proximity (Figure F.1.0.1). The criteria used for these groupings are as follows:

- The LAW disposal facility would be located in the 200 East Area and would be considered one source area consisting of many vaults. Vault spacing would be approximately 30 m (100 ft). Four alternatives have vaults as a component. The alternative and the continuous area required for the vaults are: Ex Situ Intermediate Separations, Ex Situ Extensive Separations, and Phased Implementation (17 hectares [42 acres] each), and Ex Situ/In Situ Combination (9 hectares [22 acres]). The vaults would be covered with one continuous Hanford Barrier, and the contents of each vault would be assumed to have the same composition.
- The 177 tanks are divided into eight source areas based on tank contents (inventory), tank proximity, and groundwater flow direction. Two types of tanks, SSTs and DSTs have been constructed to hold high-level radioactive waste at the Hanford Site. The 149 SSTs and 28 DSTs are all located in the 200 Areas. Within each type of tank, inventories are assumed to be similar (i.e., contaminants and relative concentrations are similar for all SSTs). It was necessary to first group tanks by type. Tanks were constructed in tank farms ranging from two to 12 tanks in a single tank farm. The tank farms were typically located near waste-generating facilities such as the Plutonium-Uranium Extraction (PUREX) Plant, and thus the tank farms themselves are generally grouped together. The next level of grouping is by tank farm, combining nearby tank farms of same-type tanks into a single source area. Finally, a check was made to determine that source areas did not cross major hydrogeologic features such as groundwater divides.

Table F.2.2.1 provides the tank waste source area designations, a brief description of each source area, and the equivalent area of each source area.

F.2.2.2 Contaminant Groups

The tanks contain more than 100 radioactive and nonradioactive contaminants that could potentially impact groundwater. The approach used for this assessment was to group the contaminants based on their mobility in the vadose zone and underlying unconfined aquifer. The contaminant groups are used rather than the individual mobility of each contaminant primarily because of the uncertainty involved in determining the mobility of individual contaminants. The groups were selected based on relatively narrow ranges of mobility and, where there was uncertainty, contaminants were placed in the more mobile group.

Table F.2.2.1 Tank Waste Source Area Designations and Descriptions

Source Area Designation	Location and Description	Equivalent Area (m^2)
1WSS	40 SSTs at 200 West	14,892
2WSS	43 SSTs at 200 West	16,123
3WDS	3 DSTs at 200 West	1,231
1ESS	40 SSTs at 200 East	14,892
2ESS	16 SSTs at 200 East	5,042
3EDS	11 DSTs at 200 East	4,515
4ESS	10 SSTs at 200 East	4,104
5EDS	14 DSTs at 200 East	5,746

Notes:
DST = Double-shell tank
SST = Single-shell tank

Some of the contaminants such as I and Tc move at the rate of water whether they are in the vadose zone or in the underlying groundwater. The movement of others in water, such as americium (Am) and Cs, are slowed or retarded because they are absorbed onto and with particles within the ground. The VAM2D flow and transport model was able to account for the retardation of contaminant movement with the parameter referred to as K_d, which is the distribution coefficient (milliliters/gram [mL/g]). This parameter is a measure of sorption and is the ratio of the quantity of the adsorbate adsorbed per gram of solid to the amount of the adsorbate remaining in solution (Kaplan et al. 1994). Values of K_d for the contaminants range from 0 (in which the contaminant's movement in water is not retarded) to more than 100 (in which the contaminant moves much slower than water).

The waste inventory was grouped and modeled according to each contaminant's reported or assumed K_d. These groups are defined as follows:

- Group 1 - Contaminants are modeled as nonsorbing (i.e., $K_d = 0$). Contaminant movement is unretarded in water. Contaminant K_d values in this group ranged from 0 to 0.99 mL/g.
- Group 2 - Contaminants are modeled as slightly sorbing (i.e., $K_d = 1$). Contaminant K_d values in this group ranged from 1 to 9.9 mL/g.
- Group 3 - Contaminants are modeled as moderately sorbing (i.e., $K_d = 10$). Contaminant K_d values in this group ranged from 10 to 49.9 mL/g.
- Group 4 - Contaminants are modeled as strongly sorbing (i.e., $K_d = 50$). Contaminant K_d values in this group are 50 mL/g or greater.

The contaminants and associated groupings (based on K_d values) for each alternative are provided in the following sections.

F.2.2.2.1 No Action Alternative (Tank Waste)

Under this alternative, no remediation would be performed, and all waste would remain in the tanks. Potential releases to the groundwater system are all associated with the waste in the tanks. The waste inventory, which is a list of the radioactive and nonradioactive contaminants and their mass or activity for the waste tanks, is provided in Appendix A. For the radioactive contaminants, the mass was estimated for each isotope based on the decay of that isotope as of December 31, 1995. Provided in Table F.2.2.2 is a listing of the contaminants modeled, their estimated half-life (if radioactive) and their K_d group. Several radionuclides in the tank inventory are of little concern and are not considered further in the groundwater assessment. Table F.2.2.3 provides a list of these contaminants and the rationale for eliminating them from further analysis.

F.2.2.2.2 Long-Term Management Alternative

Under this alternative, minimal remediation would be performed, and all waste would remain in the tanks. The two retanking campaigns for the DSTs would delay the release of contaminants from the DSTs for approximately 100 years. Potential releases to the groundwater system are all associated with the waste in the tanks.

The waste inventory, which lists the radioactive and nonradioactive contaminants and their mass or activity for each of the eight tank source areas, is presented in Appendix A. For the radioactive contaminants, the mass estimated for each isotope is based on calculating the decay of that isotope to December 31, 1995.

The contaminants associated with this alternative are the same as those for the No Action alternative (Table F.2.2.2). The locations of the new DSTs are assumed to be within the same source area, adjacent to the old DSTs. Because the entire waste inventory is eventually released for this alternative, the portion left as residual in the old DSTs does not affect the model results.

F.2.2.2.3 In Situ Fill and Cap Alternative

Under this alternative, the tanks would be filled with gravel, and a Hanford Barrier would be placed over the tanks. Potential releases to the groundwater system are associated with the contaminants in the waste tanks. The form of the waste and inventory are similar to the No Action alternative. The gravel fill would structurally stabilized the tanks by supporting the dome to prevent collapse. The gravel fill would not otherwise serve to reduce infiltration or retard contaminant transport. The contaminants associated with this alternative are the same as for the No Action alternative. The contaminant inventory is provided in Appendix A. The contaminants, their half life, and mobility are provided in Table F.2.2.2.

Table F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste)

Constituent	Inventory (grams) [2]								Half-Life (years)[1]
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS	
K_d Group 1 (K_d = 0.0 mL/g)									
Ag^+	4.11E-02	6.46E-02	5.80E+04	2.00E-01	8.91E-03	2.10E+05	2.68E-03	1.44E+06	
As^{+5}	0.00	0.00	2.01E+05	0.00	0.00	2.60E+04	0.00	1.04E+06	
B^{+3}	0.00	0.00	4.29E+05	0.00	0.00	6.64E+04	0.00	1.02E+06	
Be^{+2}	0.00	0.00	0.00	0.00	0.00	2.23E+04	0.00	6.72E+04	
C-14	6.38E+01	1.10E+02	1.81E-01	4.11E+02	4.83E+01	5.22E+02	4.08E+01	1.18E+00	5.73E+03
Cl^-	2.19E+07	5.41E+06	0.00	1.26E+07	4.01E+04	0.00	6.03E+04	0.00	
CO_3^{-2}	7.06E+08	1.60E+08	8.75E+07	6.40E+08	6.19E+07	8.46E+08	3.80E+07	9.93E+08	
CrO_4^{-2}	3.12E+05	2.10E+07	0.00	1.80E+05	4.10E+04	0.00	2.04E+05	0.00	
F^-	1.40E+08	3.00E+07	0.00	2.30E+08	4.00E+08	0.00	3.08E+05	0.00	
$Fe(CN)_6^{-4}$	2.19E+06	1.37E+06	0.00	2.51E+08	7.00E+07	0.00	5.30E+04	0.00	
Hg^+	0.00	0.00	0.00	0.00	0.00	9.43E+02	0.00	5.75E+04	
I-129	9.66E+03	2.49E+04	0.00	5.19E+04	3.39E+03	0.00	9.71E+02	0.00	1.57E+07
K^+	5.00E+06	2.53E+07	3.76E+07	2.89E+07	1.83E+05	3.78E+08	4.52E+05	1.50E+08	
Li^+	0.00	0.00	5.60E+03	0.00	0.00	0.00	0.00	2.47E+04	
Mo^{+6}	0.00	0.00	8.52E+05	0.00	0.00	7.97E+05	0.00	4.03E+06	
Na^+	1.46E+10	2.11E+10	2.16E+09	1.16E+10	2.10E+09	2.94E+09	3.78E+09	6.07E+09	
NO_2^-	1.76E+09	8.01E+08	2.47E+08	2.06E+09	4.74E+05	8.89E+08	2.32E+08	1.95E+09	
NO_3^-	2.63E+10	4.55E+10	1.04E+09	1.89E+10	2.59E+08	2.20E+09	4.89E+09	4.45E+09	
Np-237	1.17E+04	1.56E+04	5.39E+02	7.04E+04	4.78E+02	6.40E+04	6.37E+02	2.02E+02	2.14E+06
Np-238	4.94E-08	3.58E-07	0.00	3.48E-07	3.69E-07	0.00	1.60E-07	0.00	2.12 days
OH^-	4.52E+08	2.30E+09	2.42E+08	1.04E+09	1.42E+09	7.57E+08	1.74E+08	1.02E+09	

Note:
Refer to Appendix A for inventory in curies.

9613409.1507

Table F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste) (cont'd)

Constituent	Inventory (grams) [2]								Half-Life (years)[1]
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS	
Rh-106	1.72E-14	4.78E-12	0.00	2.32E-11	2.74E-11	0.00	1.12E-10	0.00	29.8 sec
Rn-219	3.98E-13	3.28E-13	0.00	6.80E-13	1.19E-13	0.00	2.13E-14	0.00	4 sec
Rn-222	3.95E-13	3.26E-13	0.00	3.38E-13	1.94E-13	0.00	1.02E-13	0.00	3.5 days
Ru-106	1.83E-08	5.08E-06	0.00	2.47E-05	2.91E-05	0.00	1.19E-04	0.00	368 days
Se-79	1.39E+03	3.61E+03	0.00	7.49E+03	4.64E+02	0.00	1.37E+02	0.00	6.50E+04
SiO_3^{-2}	5.60E+08	2.39E+08	6.08E+06	4.04E+06	7.07E+05	1.45E+07	2.09E+06	2.09E+08	
SO_4^{-2}	6.34E+08	2.48E+08	4.18E+07	5.53E+08	1.34E+08	7.23E+07	8.35E+07	2.79E+08	
Tc-99	6.92E+04	1.79E+05	2.17E+05	3.72E+05	2.33E+04	9.73E+05	6.80E+03	9.46E+04	2.13E+05
U-233	1.24E-01	1.81E-01	0.00	6.13E-01	8.37E-02	0.00	1.22E-01	0.00	1.59E+05
U-234	7.86E+00	7.36E+00	0.00	6.91E+00	4.87E+00	0.00	4.04E+00	0.00	2.45E+05
U-235	3.34E+06	1.36E+06	0.00	3.20E+06	1.30E+06	0.00	3.23E+05	0.00	7.04E+08
U-236	3.35E+00	6.47E+00	0.00	5.67E+00	1.01E+01	0.00	9.55E+00	0.00	2.34E+07
U-237	1.18E-06	1.91E-06	0.00	2.54E-06	3.96E-06	0.00	3.33E-06	0.00	6.75 days
U-238	5.12E+08	1.93E+08	0.00	4.85E+08	1.92E+08	0.00	4.91E+07	0.00	4.47E+09
UO_2^{+2}	0.00	0.00	0.00	0.00	0.00	2.70E+07	0.00	2.98E+06	
V^{+5}	0.00	0.00	1.37E+04	0.00	0.00	1.66E+05	0.00	7.01E+04	
W^{+6}	3.42E+06	3.48E+06	0.00	4.38E+06	2.30E+06	0.00	6.68E+05	7.47E+05	
K_d Group 2 (K_d = 1.0 mL/g)									
Bi^{+3}	1.70E+08	279807	0.00	9.40E+07	5.95E+05	5.21E+05	0.00	1.74E+06	
Bi-210	1.21E-13	9.36E-14	0.00	1.08E-13	5.67E-14	0.00	2.27E-14	0.00	5.0 days
Ca^{+2}	1.98E+05	5.82E+06	6.22E+06	5.50E+07	6.60E+07	2.39E+06	1.54E+06	1.30E+07	
Cd^{+2}	0.00	0.00	2.42E+05	0.00	0.00	7.05E+04	0.00	5.87E+06	
Ce^{+3}	1.16E+08	3.16E+07	2.64E+05	8.82E+07	2.64E+05	0.00	1.75E+06	2.80E+06	

Table F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste) (cont'd)

Constituent	Inventory (grams) [2]								Half-Life (years)[1]
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS	
Cr^{+3}	1.26E+06	8.33E+07	2.40E+07	7.25E+05	1.65E+05	7.84E+05	8.24E+05	9.31E+06	
Fe^{+3}	1.70E+08	8.18E+07	1.24E+07	1.42E+08	5.55E+07	2.74E+06	1.78E+08	1.35E+08	
Mg^{+2}	0.00	0.00	5.09E+05	0.00	0.00	1.39E+06	0.00	1.01E+07	
Ni^{+2}	5.02E+06	3.33E+06	1.66E+06	1.25E+08	4.40E+07	6.11E+05	9.93E+05	8.37E+06	
Ni-63	1.16E+02	8.27E+02	0.00	9.02E+02	9.99E+02	0.00	1.85E+03	0.00	1.00E+02
Pa-231	2.04E-01	1.55E-01	0.00	3.23E-01	7.16E-02	0.00	1.35E-02	0.00	3.28E+04
Pa-233	3.99E-04	5.31E-04	0.00	2.40E-03	1.63E-05	0.00	2.17E-05	0.00	27 days
K_d Group 3 (K_d = 10.0 mL/g)									
Mn^{+4}	2.10E+07	1.13E+07	3.71E+06	1.31E+07	5.12E+07	1.10E+06	2.34E+07	2.09E+07	
Pb	2.35E+06	3.86E+06	0.00	4.20E+08	6.82E+06	0	1.03E+05	0.00	
Pb^{+4}	0.00	0.00	3.34E+05	0.00	0.00	1.39E+06	0.00	3.51E+06	
Pb-210	1.97E-10	1.52E-10	0.00	1.75E-10	9.20E-11	0.00	3.68E-11	0.00	2.23E+01
Pd^{+4}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20E+06	
Pd-107	1.76E+04	4.53E+04	0.00	9.64E+04	7.13E+03	0.00	1.90E+03	0.00	6.50E+06
PO_4^{-3}	2.67E+09	1.10E+08	0.00	1.81E+09	2.98E+07	0.00	8.61E+05	0.00	
Pu-238	1.23E+01	1.73E+01	6.15E+01	1.08E+01	1.16E+01	9.98E+00	1.31E+01	1.14E+01	8.78E+01
Pu-239	3.36E+04	5.80E+04	3.45E+04	4.69E+04	7.82E+04	7.99E+04	7.42E+04	2.07E+04	2.41E+04
Pu-240	1.80E+03	3.48E+03	3.36E+03	3.06E+03	5.46E+03	5.60E+03	5.15E+03	1.58E+03	6.57E+03
Pu-241	3.80E+01	6.17E+01	1.80E+02	8.21E+01	1.28+02	1.05E+02	1.08E+02	1.00E+02	1.44E+01
Pu-242	3.37E-03	2.44E-02	0.00	2.37E-02	2.52E-02	0.00	1.09E-02	0.00	3.76E+05
Ra-223	1.01E-07	8.32E-08	0.00	1.73E-07	3.03E-08	0.00	5.41E-09	0.00	11.43 days
Ra-225	4.40E-11	7.34E-11	0.00	1.54E-10	5.73E-11	0.00	7.24E-11	0.00	1.48E+01
Ra-226	6.15E-08	5.09E-08	0.00	5.27E-08	3.02E-08	0.00	1.60E-08	0.00	1.60E+03

9613409.1508

Table F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste) (cont'd)

Constituent	Inventory (grams) [2]								Half-Life (years)[1]
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS	
Ra-228	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.75E+00
Sn-126	2.00E+03	5.88E+03	0.00	1.69E+03	3.52E+03	0.00	9.07E+03	0.00	1.00E+05
Sr^{+2}	9.38E+02	6.98E+04	0.00	3.59E+07	2.53E+04	0.00	5.78E+04	0.00	
Sr-90	1.08E+04	1.03E+05	4.39E+02	5.99E+04	3.53E+04	7.89E+04	1.37E+05	5.01E+02	2.86E+01
Th-229	8.14E-06	1.36E-05	0.00	2.84E-05	1.06E-05	0.00	1.34E-05	0.00	7.34E+03
Th-230	4.45E-04	3.89E-04	0.00	3.72E-04	2.23E-04	0.00	1.54E-04	0.00	7.70E+04
Th-232	1.68E-07	3.24E-07	0.00	2.85E-07	5.08E-07	0.00	4.79E-07	0.00	1.41E+09
Th-234	7.44E-03	2.80E-03	0.00	7.06E-03	2.79E-03	0.00	7.14E-04	0.00	24.1 days
Zn^{+2}	0.00	0.00	1.35E+06	0.00	0.00	2.42E+06	0.00	7.00E+05	
K_d Group 4 (K_d = 50.0 mL/g)									
Ac-225	2.97E-11	4.96E-11	0.00	1.04E-10	3.87E-11	0.00	4.89E-11	0.00	10 days
Ac-227	7.16E-05	5.89E-05	0.00	1.22E-04	2.15E-05	0.00	3.83E-06	0.00	2.18E+01
Al^{+3}	7.10E+07	7.20E+08	1.40E+07	5.90E+08	5.80E+08	1.10E+07	2.50E+07	4.30E+07	
Am-241	4.96E+02	2.76E+03	3.47E+03	2.18E+03	2.83E+03	1.71E+04	1.35E+03	1.45E+02	4.32E+02
Am-242	3.33E-04	2.41E-03	0.00	2.34E-03	2.48E-03	0.00	1.08E-03	0.00	16.02 hours
Am-242m	2.77E-01	2.00E+00	0.00	1.95E+00	2.07E+00	0.00	8.97E-01	0.00	1.52E+02
Am-243	5.10E+00	3.93E+01	0.00	4.81E+01	5.85E+01	0.00	1.57E+01	0.00	7.38E+03
Ba^{+2}	3.58E+04	1.70E+05	3.26E+04	1.02E+05	1.09E+05	7.42E+05	1.90E+05	3.11E+06	
Cm-242	6.73E-04	4.87E-03	0.00	4.73E-03	5.02E-03	0.00	2.18E-03	0.00	163.2 days
Cm-244	3.98E-02	2.96E-01	0.00	6.20E-01	6.61E-01	0.00	8.91E-02	0.00	1.81E+01
Cm-245	1.21E-03	1.01E-02	0.00	2.22E-02	2.38E-02	0.00	3.20E-03	0.00	8.50E+03
Cs-135	1.80E+04	5.90+04	0.00	4.58E+04	1.40E+03	0.00	1.85E+03	0.00	2.30E+06
Cs-137	1.03+04	4.62E+04	4.24E+04	4.33E+04	1.54E+03	2.53E+05	1.67E+03	4.51E+04	3.02E+01

Table F.2.2.2 Inventory of Contaminants for the No Action Alternative (Tank Waste) (cont'd)

Constituent	Inventory (grams) [2]								Half-Life (years)[1]
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS	
Cu^{+2}	0.00	0.00	3.42E+05	0.00	0.00	1.04E+05	0.00	4.78E+05	
Eu-154	0.00	0.00	1.62E+00	0.00	0.00	2.72E+02	0.00	1.97E+00	8.80E+00
La^{+3}	1.48E+06	0.00	9.89E+04	3.99E+05	0.00	1.35E+06	0.00	1.98E+07	
Nb-93m	3.25E-01	2.57E+00	0.00	1.41E+00	1.54E+00	0.00	5.72E+00	0.00	1.46E+01
Sm-151	2.37E+03	7.00E+03	0.00	2.08E+03	3.84E+03	0.00	9.43E+03	0.00	9.00E+01
Tl-209	9.11E-17	1.52E-16	0.00	3.18E-16	1.19E-16	0.00	1.50E-16	0.00	2.2 min
Y-90	2.80E+02	2.68E+03	1.19E+03	1.55E+03	9.14E+02	2.13E+03	3.54E+03	1.35E+01	64.1 hours
Zr^{+4}	1.40E+07	2.31E+07	1.85E+05	6.50E+06	2.03E+08	2.58E+08	1.28E+05	1.87E+07	
Zr-93	1.81E+04	3.18E+05	0.00	9.62E+04	2.24E+05	0.00	9.11E+05	0.00	1.53E+06

Notes:
[1] Half-life reported in years unless otherwise noted
[2] Refer to Appendix A for inventory in curies
Source: Jacobs 1996

Table F.2.2.3 Radionuclides Excluded from Vadose Zone and Groundwater Modeling

Radionuclide	Rationale	Radionuclide	Rationale	Radionuclide	Rationale
At-217	a	Np-239	a,b	Sb-126	a
Ba-135	a,b	Pa-234	a	Th-227	a,b
Ba-137	a	Pb-209	a,b	Th-231	a
Bi-211	a	Pb-211	a	Th-233	a
Bi-212	a,b	Pb-214	a	Tl-207	a
Bi-213	a	Po-212	a,b		
Bi-214	a	Po-213	a		
Fr-221	a	Po-214	a		
Fr-223	a	Po-215	a		
		Po-218	a		

Source: Droppo et al. 1991, pg. A.12, unless noted otherwise
Notes:
[a] Radionuclide has too short of a half-life for concern
[b] Radionuclide is also in a decay chain such that the contribution from this decay product will normally be minimal compared to the exposure from the parent.

F.2.2.2.4 In Situ Vitrification Alternative

Under this alternative, all tank waste would be vitrified and disposed of in tank. A Hanford Barrier would then be placed over the tanks. Potential releases to the groundwater system would all be associated with the contaminants in the waste tanks, but the waste form and inventory differ from the No Action alternative. The In Situ Vitrification alternative would volatize certain materials that are present in the No Action alternative inventory. The resulting estimated components of the glass, the mass of these components, and the ionic form for the stable isotopes are provided in Table F.2.2.4.

For groundwater modeling purposes, it was assumed that the vitrified waste form had the same composition as that produced for the Ex Situ No Separations alternative, discussed in Section F.2.2.2.6 (WHC 1995c). The exact composition has not been determined. Contaminants in Table F.2.2.4 are also grouped based on their K_d value.

F.2.2.2.5 Ex Situ Intermediate Separations Alternative

Under this alternative waste would be retrieved from the tanks, HLW would be separated from the LAW and both HLW and LAW would be vitrified. The HLW would then be shipped to a potential geologic repository. The LAW would be disposed of onsite, and a Hanford Barrier would be placed over the tanks. Potential releases to the groundwater system are associated with 1) releases during retrieval from the waste tanks; 2) releases from waste not removed from the tanks (residuals); and releases from the LAW disposal facility. The list of potential contaminants associated with the tank retrieval and residual releases is the same as that provided for the No Action alternative (Table F.2.2.2) and the contaminant inventory is provided in Appendix A. The mass associated with tank residual for each contaminant released is 1 percent of that shown in Appendix A (i.e., 99 percent of the initial inventory is assumed to be retrieved). The amount and type of waste that would remain in the tanks after retrieval is uncertain. The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 1994) set a goal of no more than 1 percent residuals and the ex situ alternatives have been developed to attempt to achieve that goal. However, achieving this level of tank

Table F.2.2.4 Inventory of Contaminants for the In Situ Vitrification Alternative

Group 1 (K_d = 0)		Group 2 (K_d = 1)		Group 3 (K_d = 10)		Group 4 (K_d = 50)	
Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]
Tc_2O_7	2.94E+06	Bi_2O_3	2.94E+08	PbO_2	6.05E+06	BaO	4.33E+06
NpO_2	1.66E+05	Ni_2O_3	1.50E+07	PuO_2	5.16E+05	Cs_2O	9.65E+05
U-233	1.13E+00	NiO	2.27E+08	MnO_2	2.31E+08	Al_2O_3	1.79E+10
U-234	3.10E+01	CaO	3.58E+10	SrO	4.33E+07	Am_2O_3	3.32E+04
U-235	9.53E+06	CdO	1.14E+07	ZnO	5.56E+06	ZrO_2	7.07E+08
U-236	3.52E+01	CuO	1.16E+06				
U-238	1.43E+09	Fe_2O_3	1.23E+09				
Ag_2O	1.83E+06	MgO	1.98E+07				
As_2O_5	1.95E+06	P_2O_5	3.71E+09				
B_2O_3	4.87E+06						
BeO	2.48E+05						
Li_2O	6.53E+04						
Na_2O	8.94E+10						
V_2O_5	4.46E+05						
WO_2	4.41E+05						
WO_3	9.42E+05						
Cr_2O_3	2.68E+08						
MoO_3	8.51E+06						

Notes:
[1] Refer to Appendix A for inventory in curies

waste retrieval may require extraordinary efforts and cost and it may not be practical to achieve 99 percent retrieval. Conversely, the contaminants that are not recovered are likely to be those that are insoluble in water since substantial quantities of water would be used in an attempt to dissolve or suspend the waste in water during retrieval. Since neither of these issues can be resolved a conservative assumption was made to bound the impacts of the residual waste. For purposes of this analysis it was assumed that 99 percent recovery would be achieved but that the residual would contain 1 percent of all the contaminants including the water soluble contaminants.

The contaminants and groupings for the eight tank source areas are the same as discussed in Section F.2.2.2.1. Based on the above assumptions, the estimated mass released during retrieval operations at each source area is provided in Table F.2.2.5.

The LAW disposal facility would contain LAW, which has been retrieved from the tanks, vitrified, placed in disposal vaults, and capped. The vitrification process requires adding materials for glass formers. Also, the organic and other volatile materials present in the retrieved waste would be destroyed or vaporized during vitrification. The estimated components of the glass, the mass of these components, and their ionic form for stable isotopes are provided in Table F.2.2.6 (WHC 1995j and Jacobs 1996).

9613409.1510

Table F.2.2.5 Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
K_d Group 1 (K_d = 0.0 mL/g)					
C-14	5.29E-01	5.67E-01	4.74E+00	1.63E+01	4.56E-01
I-129	8.01E+01	1.28E+02	5.99E+02	1.15E+03	1.08E+01
Rn-219	3.30E-15	1.69E-15	7.84E-15	4.04E-14	2.37E-16
Rn-222	3.27E-15	1.68E-15	3.90E-15	6.54E-14	1.14E-15
Ru-106	1.52E-10	3.00E-08	2.80E-07	9.85E-06	1.32E-06
Sb-126m	5.99E-09	1.00E-08	7.05E-09	4.30E-07	4.00E-08
Se-79	1.16E+01	1.86E+01	8.64E+01	1.57E+02	1.52E+00
Tc-99	5.74E+02	9.24E+02	4.29E+03	7.86E+03	7.58E+01
U-233	1.03E-03	9.37E-04	7.07E-03	2.83E-02	1.36E-03
U-234	6.52E-02	3.79E-02	7.97E-02	1.64E+00	4.50E-02
U-235	2.77E+04	7.00E+03	3.70E+04	4.40E+05	3.60E+03
U-236	2.77E-02	3.33E-02	6.55E-02	3.42E+00	1.06E-01
U-237	9.76E-09	9.85E-09	3.00E-08	1.34E-06	4.00E-08
U-238	4.24E+06	9.92E+05	5.60E+06	6.49E+07	5.47E+05
Cl^-	1.81E+05	2.78E+04	1.45E+05	1.35E+04	6.72E+02
CO_3^{-2}	7.06E+06	1.60E+06	6.40E+06	6.19E+05	3.80E+05
Cr^{+3}	1.05E+04	4.29E+05	8.35E+03	5.56E+04	9.19E+03
CrO_4^{-2}	2.59E+03	1.06E+05	2.07E+03	1.38E+04	2.28E+03
F^-	1.19E+06	1.55E+05	2.67E+06	1.35E+08	3.44E+03
$Fe(CN)_6^{-4}$	1.82E+04	7.03E+03	2.86E+06	2.36E+07	5.90E+02
Hg^+	0.00	0.00	0.00	0.00	0.00
Na^+	1.21E+08	1.09E+08	1.33E+08	7.07E+08	4.21E+07
NO_2^-	1.46E+07	4.12E+06	2.37E+07	1.60E+05	2.59E+06
NO_3^-	2.18E+08	2.34E+08	2.18E+08	8.72E+07	5.45E+07
Np-237	9.73E+01	8.05E+01	8.12E+02	1.62E+02	7.10E+00
Np-238	4.10E-10	1.84E-09	4.01E-09	1.20E-07	1.78E-09
Rh-106	1.43E-16	2.46E-14	2.68E-13	9.26E-12	1.25E-12
SO_4^{-2}	5.26E+06	1.28E+06	6.37E+06	4.51E+07	9.31E+05
W^{+6}	3.42E+04	3.48E+04	4.38E+04	2.30E+06	6.68E+03
K_d Group 2 (K_d = 1.0 mL/g)					
Bi-210	1.00E-15	4.82E-16	1.25E-15	1.92E-14	2.53E-16
Ni-63	9.63E-01	4.26E+00	1.04E+01	3.38E+02	2.07E+01

Table F.2.2.5 Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative (cont'd)

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
Pa-231	1.69E-03	7.99E-04	3.73E-03	2.42E-02	1.50E-04
Pa-233	3.31E-06	2.74E-06	2.76E-05	5.50E-06	2.40E-07
Po-210	2.77E-14	1.33E-14	3.44E-14	5.29E-13	6.98E-15
Po-211	1.13E-18	5.76E-19	2.68E-18	1.38E-17	8.10E-20
Bi^{+3}	1.38E+06	1.44E+03	1.09E+06	2.00E+05	0.00
Ca^{+2}	1.65E+03	3.00E+04	6.30E+05	2.22E+07	1.72E+04
Cd^{+2}	0.00	0.00	0.00	0.00	0.00
Fe^{+3}	1.41E+06	4.21E+05	1.63E+06	1.87E+07	1.99E+06
Ni^{+2}	4.17E+04	1.72E+04	1.44E+06	1.48E+07	1.11E+04
K_d Group 3 (Kd = 10.0 mL/g)					
Pb-210	1.63E-12	7.82E-13	2.02E-12	3.11E-11	4.10E-13
Pd-107	1.46E+02	2.33E+02	1.11E+03	2.41E+03	2.11E+01
Pu-238	1.02E-01	8.92E-02	1.25E-01	3.93E+00	1.46E-01
Pu-239	2.79E+02	2.99E+02	5.40E+02	2.64E+04	8.27E+02
Pu-240	1.49E+01	1.79E+01	3.53E+01	1.85E+03	5.74E+01
Pu-241	3.15E-01	3.18E-01	9.47E-01	4.33E+01	1.20E+00
Pu-242	2.80E-05	1.26E-04	2.74E-04	8.51E-03	1.22E-04
Ra-223	8.38E-10	4.28E-10	1.99E-09	1.00E-08	6.03E-11
Ra-225	3.65E-13	3.78E-13	1.77E-12	1.94E-11	8.07E-13
Ra-226	5.10E-10	2.62E-10	6.08E-10	1.00E-08	1.78E-10
Ra-228	0.00	0.00	0.00	0.00	0.00
Sn-126	1.66E+01	3.03E+01	1.95E+01	1.19E+03	1.01E+02
Sr-90	8.95E+01	5.30E+02	6.90E+02	1.19E+04	1.52E+03
Th-229	7.00E-08	7.00E-08	3.30E-07	3.58E-06	1.50E-07
Th-230	3.69E-06	2.01E-06	4.29E-06	7.55E-05	1.72E-06
Th-232	1.39E-09	1.67E-09	3.28E-09	1.70E-07	5.34E-09
Th-234	6.17E-05	1.44E-05	8.14E-05	9.44E-04	7.96E-06
Mn^{+4}	1.74E+05	5.81E+04	1.51E+05	1.72E+07	2.62E+05
Pb^{+4}	1.95E+04	1.99E+04	4.87E+06	2.30E+06	1.15E+03
PO_4^{-3}	2.22E+07	5.67E+05	2.09E+07	1.00E+07	9.60E+03
Sr^{+2}	7.78E+00	3.59E+02	4.13E+05	8.53E+03	6.44E+02
K_d Group 4 (K_d = 50.0 mL/g)					
Ac-225	2.47E-13	2.55E-13	1.20E-12	1.31E-11	5.46E-13
Ac-227	5.90E-07	3.00E-08	1.41E-06	7.26E-06	4.00E-08
Am-241	4.11E+00	1.42E+01	2.52E+01	9.58E+02	1.50E+01
Am-242	2.76E-06	1.24E-05	2.70E-05	8.40E-04	1.20E-05

9613409.1511

Table F.2.2.5 Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative (cont'd)

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
Am-242m	2.30E+03	1.03E-02	2.25E-02	6.99E-01	1.00E-02
Am-243	4.23E-02	2.03E-01	5.55E-01	1.98E+01	1.75E-01
Ce^{+3}	9.62E+05	1.63E+05	1.02E+06	8.90E+04	1.95E+04
Cm-242	5.58E-06	2.51E-05	5.46E-05	1.70E-03	2.43E-05
Cm-244	3.30E-04	1.52E-03	7.15E-03	2.23E-01	9.94E-04
Cm-245	1.00E-05	5.22E-05	2.57E-04	8.04E-03	3.57E-05
La^{+}	1.23E+04	0.00	4.60E+03	0.00	0.00
Nb-93m	2.69E-03	1.32E-02	1.63E-02	5.20E-01	6.38E-02
Cs-135	1.49E+02	3.04E+02	5.29E+02	4.74E+02	2.06E+01
Cs-137	8.56E+01	2.38E+02	4.99E+02	5.22E+02	1.86E+01
Sm-151	1.97E+01	3.60E+01	2.40E+01	1.30E+03	1.05E+02
Y-90	2.32E+00	1.38E+01	1.79E+01	3.09E+02	3.95E+01
Zr-93	1.50E+02	1.64E+03	1.11E+03	7.58E+04	1.02E+04
Tl-209	7.55E-19	7.83E-19	3.67E-18	4.01E-17	1.67E-18
Al^{+3}	5.90E+05	3.73E+06	6.81E+06	1.95E+08	2.83E+05
Ba^{+2}	2.97E+02	8.73E+02	1.18E+03	3.68E+04	2.12E+04
Sn	0.00	0.00	6.18E+01	0.00	0.00
Zr^{+4}	1.16E+05	1.19E+05	7.48E+04	6.82E+07	1.42E+03

Notes:
[1] Refer to Appendix A for inventory in curies.

Table F.2.2.6 Inventory of Contaminants for the Low-Activity Waste Vaults - Ex Situ Intermediate Separations Alternative

Group 1 (K_d = 0)		Group 2 (K_d = 1)		Group 3 (K_d = 10)		Group 4 (K_d = 50)	
Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]
Tc_2O_7	2.39E+06	Bi_2O_3	7.52E+07	MnO_2	2.16E+07	Am_2O_3	2.76E+03
U-233	5.75E-02	CaO	3.87E+10	PbO_2	2.26E+06	BaO	8.81E+05
U-234	1.58E+00	CdO	2.83E+06	PuO_2	3.26E+04	Ce_2O_3	2.79E+06
U-235	4.86E+05	CuO	2.21E+05	SrO	4.00E+05	Cs_2O	6.83E+03
U-236	1.80E+00	Fe_2O_3	2.06E+07	ZnO	4.46E+06	La_2O_3	2.58E+05
U-238	7.30E+07	MgO	1.60E+06			ZrO_2	6.49E+05
Ag_2O	3.52E+05	Ni_2O_3	5.72E+06				
As_2O_5	1.18E+06	NiO	1.50E+04				
B_2O_3	1.67E+06	P_2O_5	3.09E+09				
BeO	2.27E+05						
WO_2	2.91E+01						
WO_3	9.40E+05						
Cr_2O_3	2.11E+08						
K_2O	2.65E+05						
Li_2O	1.24E+04						
MoO_3	7.29E+06						
Na_2O	9.86E+10						
NpO_2	1.66E+04						
SiO_2	2.29E+11						
V_2O_5	1.11E+05						

Notes:
[1] Refer to Appendix A for inventory in curies

F.2.2.2.6 Ex Situ No Separations Alternative

Under this alternative, both HLW and LAW waste would be retrieved from the tanks, vitrified or calcined, and shipped to a potential geologic repository. Potential releases to the groundwater system are associated with 1) releases during retrieval from the waste tanks; and 2) releases from residuals that cannot be removed from the waste tanks (residuals). The list of potential contaminants associated with the retrieval and residual releases is the same as that provided for the No Action alterative (Table F.2.2.2). The mass associated with the residual for each contaminant released is 1 percent of that shown in Appendix A (i.e., 99 percent of the initial inventory is assumed to be retrieved). The contaminants and groupings for the eight tank source areas are the same as discussed in Section F.2.2.2.1. The estimated mass released during retrieval operations at each source area is provided in Table F.2.2.5.

F.2.2.2.7 Ex Situ Extensive Separations Alternative

This alternative is similar to the Ex Situ Intermediate Separation alternative, with the major difference being that a more extensive HLW and LAW separations process would be used. Under this alternative, waste would be retrieved from the tanks, HLW would be separated from the LAW, and both HLW and LAW would be vitrified. The extensive separations processes would result in less waste volume and more activity (i.e., curies) being shipped offsite to a potential geologic repository, and a smaller contaminant source would be associated with the LAW vaults. A Hanford Barrier would be placed over the tanks and the vaults. Potential releases to the groundwater system are associated with

1) releases during tank waste retrieval; 2) releases from residuals; and 3) releases from the LAW disposal facility.

The list of potential contaminants associated with the retrieval and residual releases is the same as that provided for the No Action alternative (Table F.2.2.2). The mass associated with residual for each contaminant released is 1 percent of that shown in Appendix A (i.e., 99 percent of the initial inventory is assumed to be retrieved). The contaminants and groupings for the eight tank source areas are the same as discussed in Section F.2.2.2.1. The estimated mass released during retrieval operations at each source area is provided in Table F.2.2.5.

The LAW vault contaminant inventory would be less than that associated with the vault contaminants from the Ex Situ Intermediate Separations alternative because of the more extensive separations. Table F.2.2.7 lists the LAW vault constituents by K_d group, and the initial inventory.

Table F.2.2.7 Inventory of Contaminants for the LAW Vaults - Ex Situ Extensive Separations Alternative

Group 1 (K_d = 0)		Group 2 (K_d = 1)		Group 3 (K_d = 10)		Group 4 (K_d = 50)	
Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]
Tc_2O_7	1.41E+04	Bi_2O_3	2.90E+07	MnO_2	1.31E+08	Am_2O_3	3.41E+01
U-235	2.57E+03	CaO	3.86E+10	PbO_2	1.35E+06	BaO	8.76E+05
U-238	3.64E+05	CdO	1.13E+07	PuO_2	5.42E+03	Ce_2O_3	2.75E+08
Ag_2O	4.07E+05	CuO	2.57E+05	SrO	4.41E+03	Cs_2O	8.85E+02
As_2O_5	4.33E+05	Fe_2O_3	3.74E+09	ZnO	3.17E+07	ZrO_2	6.99E+07
B_2O_3	4.82E+06	MgO	1.96E+07				
BeO	5.53E+04	Ni_2O_3	2.62E+08				
WO_2	1.09E+00	NiO	1.06E+03				
WO_3	2.10E+05	P_2O_5	3.68E+09				
Cr_2O_3	2.67E+08						
K_2O	2.55E+07						
Li_2O	6.53E+04						
MoO_3	1.03E+07						
Na_2O	9.65E+10						
NpO_2	6.52E+03						
SiO_2	2.16E+11						
V_2O_5	9.92E+04						

Notes:
[1] Refer to Appendix A for inventory in curies.
Source: Jacobs 1996

F.2.2.2.8 Ex Situ/In Situ Combination Alternative

Under this alternative, tanks would be selected for one of two types of remediation based on their contents. Waste would be removed from the tanks containing most of the mobile radionuclides using the same process as described for Ex Situ Intermediate Separations Alternative. The remaining tanks would be remediated in situ as described for the In Situ Fill and Cap alternative.

Contaminants for selecting tanks for waste removal were identified based on the following criteria:

- High mobility in the groundwater;
- Persistence in the environment; and
- Toxicity.

The contaminants that met these criteria are Tc-99, C-14, I-129, and the isotopes of the uranium series. Reviewing the tank waste inventory identified a total of 70 tanks (60 SSTs and 10 DSTs) that contain approximately 90 percent of these contaminants. Under this alternative, these 70 tanks would be remediated as described for the Ex Situ Intermediate Separations alternative, where the waste would be retrieved, separated into HLW and LAW, the HLW vitrified and transported to an offsite potential geologic repository, and the LAW vitrified and disposed of in onsite LAW vaults. The mass of waste disposed of in vaults would be approximately 49 percent of the mass associated with LAW vaults for the Ex Situ Intermediate Separations Alternative (Table F.2.2.6). The potential contaminants associated with the retrieval and residual releases for this group of tanks are provided in Table F.2.2.8, and the overall contaminant inventory is provided in Appendix A. The 1 percent residual waste assumed remaining in tanks that would be retrieved was added to the inventory that would result from the eventual leaching of the tanks that are remediated in situ. The contaminants and groupings for the eight tank source areas are the same as discussed in Section F.2.2.2.1.

The remaining 107 waste tanks would be processed as described for the tank waste In Situ Fill and Cap alternative. Because of the selective nature of this alternative, the inventory of Tc-99, C-14, I-129, and the isotopes of the uranium series within the 107 tanks would be 10 percent of the original inventory of all 177 tanks. The potential contaminants associated with the tanks remediated in situ (including the 1 percent from tanks retrieved) are provided in Table F.2.2.9.

F.2.2.2.9 Phased Implementation

Phase 1

In Phase 1 of this alternative, waste from the DSTs would be retrieved, vitrified, and stored temporarily onsite. There are no potential contaminants from this phase since it is assumed that there will be no retrieval losses from the DSTs due to the nature of their construction. In addition, the storage of the vitrified waste is temporary.

Total Alternative

In Phase 2 of this alternative, the plants constructed for Phase 1 would continue to operate, and in addition the remainder of the tank waste would be retrieved and treated in the same way as in the Ex Situ Intermediate Separations alternative. Potential releases to groundwater are associated with retrieval, residuals remaining in tanks, and the LAW disposal facility. The list of potential contaminants from retrieval is provided in Table F.2.2.5. The list of contaminants for tank residuals is 1 percent of the amounts given in Table F.2.2.2., and the contaminant inventory is provided in Appendix A. The inventory of contaminants associated with the LAW vaults is provided in Table F.2.2.6.

Table F.2.2.8 Inventory of Contaminants Released During Retrieval - Ex Situ/In Situ Combination Alternative

Constituent	Inventory (grams) [2]							
	1WSS	2WSS	3WDS[1]	1ESS	2ESS	3EDS[1]	4ESS	5EDS[1]
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	1.82E-01	2.54E-01		1.84E+00	1.25E+01		5.08E-01	
Cl^-	4.89E+04	1.32E+04		7.50E+04	1.19E+00		2.34E+02	
Cr^{+3}	1.96E+03	1.32E+05		4.11E+03	5.09E+03		1.34E+02	
CrO_4^{-2}	4.85E+02	3.27E+04		1.02E+03	1.26E+03		3.32E+01	
F^-	3.90E+05	6.99E+04		1.48E+06	5.27E+07		8.44E+02	
$Fe(CN)_6^{-4}$	6.64E+03	2.33E+03		1.98E+06	6.87E+03		9.20E+00	
Hg^+	3.84E+02	7.00E+02		1.27E+03	1.86E+04		1.35E+02	
I-129	2.60E+01	5.77E+01		2.31E+02	8.65E+02		8.74E+00	
Na^+	3.60E+07	3.61E+07		7.36E+07	2.68E+08		1.69E+07	
NO_2^-	4.91E+06	1.84E+06		1.51E+07	4.75E+02		8.44E+05	
NO_3^-	6.54E+07	8.18E+07		1.25E+08	3.27E+07		2.18E+07	
Np-237	3.21E+01	3.29E+01		3.10E+02	2.76E+01		6.86E+00	
Np-238	1.42E-10	7.52E-10		1.59E-09	9.80E-08		1.78E-09	
OH-	7.51E+05	3.64E+06		6.96E+06	1.67E+08		6.24E+05	
Rh-106	4.96E-17	7.78E-15		1.01E-13	6.52E-12		1.32E-12	
Rn-219	1.15E-15	5.33E-16		2.96E-15	2.84E-14		2.51E-16	
Rn-222	1.14E-15	5.31E-16		1.47E-15	4.60E-14		1.21E-15	
Ru-106	5.71E-11	5.90E-09		1.12E-07	7.75E-06		1.43E-07	
Sb-126m	2.26E-09	2.77E-09		2.69E-09	3.26E-07		3.11E-08	
Se-79	3.76E+00	8.35E+00		3.33E+01	1.18E+02		1.23E+00	
SiO_3^-	1.45E+06	1.50E+05		3.34E+06	6.28E+02		6.89E+03	
SO_4^{-2}	1.56E+06	6.72E+05		3.54E+06	1.74E+07		3.76E+05	
Tc-99	1.87E+02	4.15E+02		1.65E+03	5.92E+03		6.13E+01	
U-233	2.76E-04	2.33E-04		2.60E-03	1.60E-02		1.56E-06	
U-234	2.24E-02	1.14E-02		2.96E-02	1.17E+00		4.25E-02	
U-235	1.05E+04	2.66E+03		1.42E+04	3.08E+05		3.69E+03	
U-236	1.05E-02	1.27E-02		2.51E-02	2.40E+00		1.09E-01	
U-237	3.69E-09	3.75E-09		1.13E-08	9.39E-07		3.81E-08	
U-238	1.61E+06	3.82E+05		2.15E+06	4.53E+07		5.70E+05	
W^{+4}	6.50E+03	1.12E+04		2.04E+04	2.99E+05		2.16E+03	
K_d Group 2 (K_d = 1.0 mL/g)								
Bi^{+3}	2.19E+05	7.78E+02		5.72E+05	8.26E-12		0.00E+00	
Bi-210	3.51E-16	1.53E-16		4.70E-16	1.27E-14		1.91E-16	
Ca^{+2}	3.12E-02	9.23E+03		4.57E+05	3.93E+04		2.42E+02	
Cd^{+2}	1.64E+03	2.98E+03		5.39E+03	7.95E+04		5.76E+04	
Fe^{+3}	2.97E+05	1.69E+05		9.03E+05	5.34E+06		7.14E+05	
Ni^{+2}	1.11E+04	6.21E+03		1.01E+06	1.47E+06		2.81E+03	
Ni-63	2.66E-01	9.47E-01		3.87E+00	2.50E+02		2.15E+01	
Pa-231	5.95E-04	3.52E-04		1.40E-03	1.78E-02		1.33E-04	

Table F.2.2.8 Inventory of Contaminants Released During Retrieval - Ex Situ/In Situ Combination Alternative (cont'd)

Constituent	Inventory (grams) [2]							
	1WSS	2WSS	3WDS[1]	1ESS	2ESS	3EDS[1]	4ESS	5EDS[1]
Pa-233	1.09E-06	1.12E-06		1.05E-05	9.32E-07		2.33E-07	
Pa-234m	7.86E-10	1.87E-10		1.05E-09	2.22E-08		2.79E-10	
Po-211	3.94E-19	1.83E-19		1.01E-18	9.04E-18		5.92E-20	
K_d Group 3 (K_d =1 0.0 mL/g)								
Mn^{+4}	3.42E+04	2.65E+04		8.31E+04	6.73E+06		8.39E+04	
Pb-210	5.70E-13	2.48E-13		7.63E-13	2.06E-11		3.09E-13	
Pb-212	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	
Pd-107	4.75E+01	1.05E+02		4.30E+02	1.83E+03		1.68E+01	
PO_4^{-3}	4.66E+06	2.50E+05		1.04E+07	2.06E+06		3.05E+03	
Pu-238	3.23E-02	2.53E-02		4.48E-02	2.78E+00		1.22E-01	
Pu-239	7.83E+01	8.84E+01		1.88E+02	1.91E+04		8.28E+02	
Pu-240	4.44E+00	5.33E+00		1.27E+01	1.34E+03		5.64E+01	
Pu-241	1.09E-01	9.75E-02		3.52E-01	3.22E+01		1.05E+00	
Pu-242	7.85E-06	3.72E-05		9.54E-05	6.15E-03		1.22E-04	
Ra-223	2.89E-10	1.89E-10		7.38E-10	7.47E-09		5.11E-11	
Ra-224	0.00E+00	0.00E+00		0.00E+00	0.00E+00		0.00E+00	
Ra-225	9.43E-14	8.38E-14		6.30E-13	1.13E-11		9.72E-13	
Ra-226	1.77E-10	8.28E-11		2.29E-10	7.17E-09		1.88E-10	
Sn-126	6.28E+00	7.68E+00		7.45E+00	9.03E+02		8.63E+01	
Sr^{+2}	2.96E+00	2.07E+02		2.86E+05	7.19E+01		2.62E+02	
Sr-90	3.04E+01	1.2E+02		2.58E+02	8.99E+03		1.13E+03	
Th-229	1.75E-08	1.55E-08		1.17E-07	2.09E-06		1.80E-07	
Th-230	1.27E-06	6.08E-07		1.60E-06	5.13E-05		1.88E-06	
Th-232	5.26E-10	6.36E-10		1.26E-09	1.20E-07		5.48E-09	
Th-234	2.33E-05	5.56E-06		3.13E-05	6.59E-04		8.29E-06	
K_d Group 4 (K_d = 50.0 mL/g)								
Ac-225	6.38E-14	5.67E-14		4.26E-13	7.64E-12		6.57E-13	
Ac-227	2.04E-07	1.34E-07		5.23E-07	5.29E-06		3.62E-08	
Al^{+3}	1.89E+05	1.66E+06		4.26E+06	7.63E+07		8.81E+04	
Am-241	1.45E+00	5.20E+00		9.95E+00	7.46E+02		1.65E+01	
Am-242	9.93E-07	4.75E-06		1.07E-05	6.58E-04		1.32E-05	
Am-242m	8.26E-04	3.96E-03		8.93E-03	5.48E-01		1.10E-02	
Am-243	1.47E-02	8.27E-02		2.19E-01	1.55E+01		1.75E-01	
Ce^{+3}	2.05E+05	5.41E+04		6.31E+05	9.42E-01		6.92E+03	
Cm-242	2.01E-06	9.61E-06		2.17E-05	1.33E-03		2.66E-05	
Cm-244	1.04E-04	7.10E-04		2.77E-03	1.76E-01		6.81E-04	
Cm-245	3.12E-06	2.44E-05		9.93E-05	6.33E-03		2.45E-05	
Cs-135	4.60E+01	1.26E+02		1.94E+02	2.08E+02		1.79E+01	
Cs-137	2.84E+01	1.03E+02		1.86E+02	2.45E+02		1.41E+01	
Nb-93m	9.23E-04	3.86E-03		6.33E-03	3.88E-01		5.87E-02	

9613409.1514

Table F.2.2.8 Inventory of Contaminants Released During Retrieval - Ex Situ/In Situ Combination Alternative (cont'd)

Constituent	Inventory (grams) [2]							
	1WSS	2WSS	3WDS[1]	1ESS	2ESS	3EDS [1]	4ESS	5EDS [1]
Sm-151	7.29E+00	9.06E+00		9.01E+00	9.67E+02		9.05E+00	
Tl-209	2.60E-19	3.45E-19		1.36E-18	2.92E-17		1.42E-18	
Y-90	7.88E-01	3.22E+00		6.69E+00	2.33E+02		2.92E+01	
Zr-93	4.44E+01	3.79E+02		4.20E+02	5.73E+04		8.12E+03	

Notes:
[1] There are no retrieval losses from DST sources (i.e., source areas 3WDS, 3EDS, and 5EDS).
[2] Refer to Appendix A for inventory in curies.
Source: Jacobs 1996

Table F.2.2.9 Inventory of Contaminants in Tanks Remediated In Situ - Ex Situ/In Situ Combination Alternative

Constituent	Inventory (grams) [1]							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K_d Group 1 (K_d = 0.0 mL/g)								
Ag^{+}	- -	- -	5.80E-04	- -	- -	6.98E-04	- -	1.08E+06
As^{+5}	- -	- -	2.01E-05	- -	- -	2.60E-04	- -	2.28E-04
B^{+3}	- -	- -	6.55E-04	- -	- -	6.64E-04	- -	7.39E-05
Be^{+2}	- -	- -	0.00E+00	- -	- -	2.23E-04	- -	2.94E-03
C-14	8.74E+00	1.03E+01	1.18E-01	2.55E+01	2.21E+00	5.23E+00	4.86E+00	8.42E-01
Cl^{-}	6.88E+06	1.21E+06	4.69E+06	4.36E+06	4.01E-02	3.06E+07	9.93E-03	1.82E+06
CO_3^{-2}	1.59E+08	1.32E+07	1.85E+07	1.81E+08	1.01E+01	8.46E+08	2.19E+06	8.58E+07
Cr^{+3}	6.60E-05	4.15E+07	3.32E+06	2.72E-05	1.27E-01	7.84E-05	7.95E-05	9.21E+06
CrO_4^{-2}	1.64E-05	1.03E+07	9.62E+06	6.74E-02	3.16E-02	9.89E+06	1.97E-05	1.82E+06
F^{-}	2.44E+07	7.83E+06	3.52E+06	6.92E+07	8.25E+00	3.20E+08	1.27E-05	6.92E+06
$Fe(CN)_6^{-4}$	1.58E-05	6.26E-05	- -	2.97E+07	6.99E+01	- -	5.10E-04	- -
Hg^{+}	8.44E-04	1.78E-04	0.00E+00	1.33E-05	4.64E-03	2.80E-02	1.27E-04	1.14E-03
I-129	1.76E+03	2.29E+03	- -	3.61E+03	2.08E+02	- -	3.51E+02	- -
K^{+}	- -	- -	8.17E+06	- -	- -	2.02E+08	- -	5.74E+06
Li^{+}	- -	- -	5.60E-03	- -	- -	0.00E+06	- -	6.20E-02
Mo^{+6}	- -	- -	4.22E-04	- -	- -	5.55E-05	- -	1.11E-05
Na^{+}	3.50E+09	9.69E+09	1.19E+08	3.46E+09	1.09E+02	1.97E+09	1.39E+08	4.02E+08
NO_2^{-}	2.56E+08	2.18E+08	2.07E+07	3.95E+08	4.70E-01	4.59E+08	5.06E+07	1.05E+08
NO_3^{-}	6.24E+09	1.96E+10	1.31E+08	5.10E+09	1.58E+01	1.30E+09	1.99E+08	3.02E+08
Np-237	2.00E+03	2.70E+03	5.38E+02	5.63E+03	3.77E+02	6.57E+02	1.50E+02	2.01E+02
Np-238	6.31E-09	6.21E-08	- -	1.56E-08	8.21E-09	- -	3.35E-08	- -
OH^{-}	2.22E+08	1.15E+09	2.75E+07	2.73E+08	1.75E+02	3.93E+08	4.01E+07	5.36E+07
Rh-106	2.17E-15	1.72E-02	- -	2.09E-12	3.42E-12	- -	1.84E-11	- -
Rn-219	5.01E-14	1.18E-13	- -	6.13E-14	1.49E-14	- -	3.51E-15	- -
Rn-222	4.97E-14	1.18E-13	- -	3.05E-14	2.41E-14	- -	1.69E-14	- -
Ru-106	9.72E-10	2.76E-06	- -	1.19E-06	5.99E-07	- -	1.09E-04	- -
Sb-126m	3.58E-08	1.03E-06	- -	4.85E-08	7.01E-08	- -	1.06E-06	- -
Sc-79	2.54E+02	3.27E+02	- -	5.21E+02	2.94E+01	- -	4.91E+01	- -
SiO_3^{-}	1.17E+08	1.92E+08	2.46E+06	3.60E+07	7.02E-01	1.30E+07	6.08E-05	1.93E+08
$SO4_4^{-2}$	1.57E+08	3.50E+07	5.23E+06	1.63E+08	4.67E+00	6.79E+07	2.96E+06	2.87E+07
Tc-99	1.26E+04	1.64E+04	2.17E+03	2.60E+04	1.47E+03	4.36E+04	2.45E+03	5.87E+04
U-233	4.07E-02	9.04E-02	- -	6.94E-02	2.50E-02	- -	1.14E-02	- -
U-234	1.08E+00	2.88E+00	- -	7.18E-01	5.47E-01	- -	1.02E+00	- -
U-235	1.64E+05	3.12E+05	- -	2.35E+05	1.66E+05	- -	6.09E+04	- -
U-236	1.64E-01	1.49E+00	- -	4.16E-01	1.30E+00	- -	1.80E+00	- -
U-237	5.78E-08	4.40E-07	- -	1.86E-07	5.07E-07	- -	6.28E+06	- -
U-238	2.47E+07	4.23E+07	- -	3.52E+07	2.52E+07	- -	8.63E+06	- -
UO_2^{+2}	- -	- -	0.00E+06	- -	- -	2.63E+07	- -	2.48E+06
V^{+5}	- -	- -	1.37E-04	- -	- -	1.66E-05	- -	1.35E-03

Table F.2.2.9 Inventory of Contaminants in Tanks Remediated In Situ - Ex Situ/In Situ Combination Alternative (cont'd)

Constituent	Inventory (grams)[1]							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
W^{+4}	1.43E+06	2.85E-05	0.00E+06	2.14E+06	7.46E-02	0.00E+06	2.03E-05	1.49E-04
K_d Group 2 (K_d = 1.0 mL/g)								
Bi-210	1.46E-14	3.34E-14	- -	9.71E-15	1.00E-14	- -	9.17E-15	- -
Bi^{+3}	9.90E+07	3.30E-06	0.00E+06	3.12E+07	5.95E-01	1.04E-04	0.00E+06	5.42E-04
Ca^{+2}	1.98E+05	5.81E+06	1.70E+06	4.26E+06	6.56E+01	2.25E+06	1.49E+06	6.98E+06
Cd^{+2}	3.61E+05	7.56E-04	2.42E-05	5.65E-05	1.98E-02	6.54E-04	5.40E+06	2.71E-05
Cu^{+2}	- -	- -	3.42E-06	- -	- -	2.07E-05	- -	1.09E-05
Fe^{+3}	7.88E+07	2.82E+07	6.12E+06	4.22E+07	1.58E+01	2.55E+06	2.45E+07	7.44E+06
Mg^{+2}	- -	- -	4.58E-05	- -	- -	1.17E+06	- -	9.17E+06
Ni^{+2}	1.63E+06	1.36E+06	1.90E-05	1.37E+07	3.31E+01	6.11E-05	3.89E-05	1.82E+06
Ni-63	3.55E+01	4.55E+02	- -	9.29E+01	7.71E+01	- -	3.28E+02	- -
Pa-231	2.30E-02	1.71E-02	- -	3.03E-02	5.86E-03	- -	4.08E-03	- -
Pa-233	6.79E-05	9.17E-05	- -	1.91E-04	1.28E-05	- -	5.11E-06	- -
Pa-234	1.21E-08	2.07E-08	- -	1.72E-08	1.24E-08	- -	4.23E-09	- -
Po-211	1.63E-17	3.99E-17	- -	2.09E-17	7.48E-18	- -	3.06E-18	- -
Po-216	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
K_d Group 3 (K_d = 10.0 mL/g)								
Mn^{+4}	1.05E+07	2.85E+06	2.25E+06	3.92E+06	1.12E+00	9.93E-05	5.44E+06	1.40E+07
Pb^{+4}	- -	- -	3.34E-05	- -	- -	1.16E-05	- -	1.82E+06
Pb-210	2.37E-11	5.43E-11	- -	1.58E-11	1.62E-11	- -	1.49E-11	- -
Pb-212	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
Pd-107	3.16E+03	3.97E+03	- -	6.44E+03	3.96E+02	- -	7.00E+02	- -
PO_4^{-3}	1.24E+09	3.07E+07	1.76E+07	6.63E+08	1.45E+01	6.60E+07	2.04E-05	2.45E+07
Pu-238	2.45E+00	7.39E+00	6.34E+01	1.45E+00	1.39E+00	3.91E-01	4.40E+00	1.17E+01
Pu-239	9.86E+03	2.33E+04	3.36E+04	7.41E+03	7.85E+03	4.34E+04	1.54E+04	1.99E+04
Pu-240	4.54E+02	1.39E+03	3.30E+03	4.00E+02	5.18E+02	2.97E+03	1.15E+03	1.53E+03
Pu-241	4.93E+00	2.35E+01	2.18E+02	8.57E+00	9.31E+00	1.59E+01	3.32E+01	1.21E+02
Pu-242	9.89E-04	9.79E-03	- -	3.75E-03	2.53E-03	- -	2.26E-03	- -
Ra-223	1.36E-08	8.96E-09	- -	1.82E-08	2.82E-09	- -	1.78E-09	- -
Ra-224	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
Ra-225	1.54E-11	4.05E-11	- -	2.19E-11	1.57E-11	- -	3.44E-12	- -
Ra-226	7.74E-09	1.84E-08	- -	4.75E-09	3.76E-09	- -	2.63E-09	- -
Ra-228	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
Sn-126	9.93E+01	2.86E+03	- -	1.35E+02	1.94E+02	- -	2.95E+03	- -
Sr^{+2}	3.00E-01	4.19E-03	- -	4.38E+06	2.48E-02	- -	1.39E-03	- -
Sr-90	1.58E+03	5.42E+04	2.31E+02	5.97E+03	2.17E+03	1.74E+04	5.68E+04	5.24E+02
Th-228	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
Th-229	2.84E-06	7.48E-06	- -	4.05E-06	2.89E-06	- -	6.38E-07	- -
Th-230	5.87E-05	1.51E-04	- -	3.62E-05	3.44E-05	- -	2.02E-05	- -

Table F.2.2.9 Inventory of Contaminants in Tanks Remediated In Situ - Ex Situ/In Situ Combination Alternative (cont'd)

Constituent	Inventory (grams) [1]							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
Th-232	8.24E-09	7.46E-08	- -	2.09E-08	6.50E-08	- -	9.02E-08	- -
Th-234	3.60E-04	6.15E-04	- -	5.12E-04	3.67E-04	- -	1.26E-04	- -
Zn^{+2}	- -	- -	1.45E-05	- -	- -	1.09E+06	- -	3.67E-05
K_d Group 4 (K_d = 50.0 mL/g)								
Ac-225	1.04E-11	2.73E-11	- -	1.48E-11	1.06E-11	- -	2.31E-12	- -
Ac-227	9.59E-06	6.34E-06	- -	1.29E-05	1.99E-06	- -	1.26E-06	- -
Al^{+3}	1.32E+07	1.97E+08	1.07E+07	1.22E+08	1.20E+01	1.05E+07	6.41E+06	2.32E+07
Am-241	5.67E+01	7.21E+02	3.33E+03	1.02E+02	8.84E+01	2.77E+03	1.73E+02	1.06E+02
Am-242	3.15E-05	5.41E-04	- -	9.59E-05	6.03E-05	- -	1.44E-04	- -
Am-242m	2.63E-02	4.50E-01	- -	7.98E-02	5.02E-02	- -	1.20E-01	- -
Am-243	6.50E-01	6.83E+00	- -	2.16E+00	1.30E+00	- -	3.27E+00	- -
Ba^{+2}	- -	- -	6.48E-02	- -	- -	7.02E-05	- -	2.01E+06
Ce^{+3}	5.31E+07	1.44E+07	2.64E-05	1.87E+07	2.64E-01	0.00E+06	2.65E-05	2.21E+06
Cm-242	6.37E-05	1.09E-03	- -	1.94E-04	1.22E-04	- -	2.91E-04	- -
Cm-244	8.20E-03	1.68E-02	- -	4.07E-07	1.34E-02	- -	4.08E-02	- -
Cm-245	2.64E-04	5.71E-04	- -	1.47E-03	4.79E-04	- -	1.47E-03	- -
Cs-135	4.00E+03	9.71E+03	- -	5.26E+03	6.34E+02	- -	5.85E+02	- -
Cs-137	1.71E+03	5.58E+03	5.26E+03	4.29E+03	6.43E+02	3.26E+04	6.66E+02	2.76E+04
Eu-154	- -	- -	2.24E+00	- -	- -	9.99E+01	- -	2.73E+00
La^{+3}	- -	- -	1.97E-03	- -	- -	1.35E+06	- -	1.68E+07
Nb-93m	4.45E-02	1.05E+00	- -	8.62E-02	1.11E-01	- -	1.55E+00	- -
Sm-151	1.60E+02	3.44E+03	- -	1.94E+02	2.81E+02	- -	3.01E+03	- -
Tl-208	0.00E+00	0.00E+00	- -	0.00E+00	0.00E+00	- -	0.00E+00	- -
Tl-209	1.22E-17	1.64E-17	- -	3.36E-17	1.10E-17	- -	4.94E-17	- -
Y-90	4.09E+01	1.41E+03	6.25E+00	1.55E+02	5.63E+01	4.69E+02	1.47E+03	1.42E+01
Zr^{+4}	5.85E+06	1.71E+06	1.00E-05	3.17E+06	6.57E+00	2.58E+08	3.88E-04	2.97E+06
Zr-93	4.62E+03	1.70E+05	- -	8.34E+03	1.31E+04	- -	3.35E+05	- -

Notes:
[1] Refer to Appendix A for inventory in curies.
- - Indicates a value was not reported in the original data package (WHC 1995c).
Source: Jacobs 1996

F.2.2.3 Source Terms

The numerical modeling approach used to assess groundwater impacts requires understanding and quantifying when, what, and how much (mass or activity) contaminants are released. The quantification of this information is the source term. Also included in this section is the water flux into the vadose zone. Flux is the time-variable volume of water that enters the vadose zone and may be from natural sources such as infiltrating precipitation or artificial sources, such as releases from the tanks during retrieval operations.

F.2.2.3.1 No Action Alternative (Tank Waste)

The source term for this alternative is derived from the eventual failure of the tanks and release of their inventory into the vadose zone. Water flux versus time diagrams are provided for this alternative and for the In Situ Vitrification alternative only, to illustrate diagrammatically when and how much water is estimated to be passing through the waste, which ultimately impacts contaminant concentrations in the underlying groundwater.

Developing the source term requires an understanding of the expected operating conditions at the eight tank source areas and is discussed in the following text. The discussion will first focus on the water flux, followed by the estimation of contaminant concentrations.

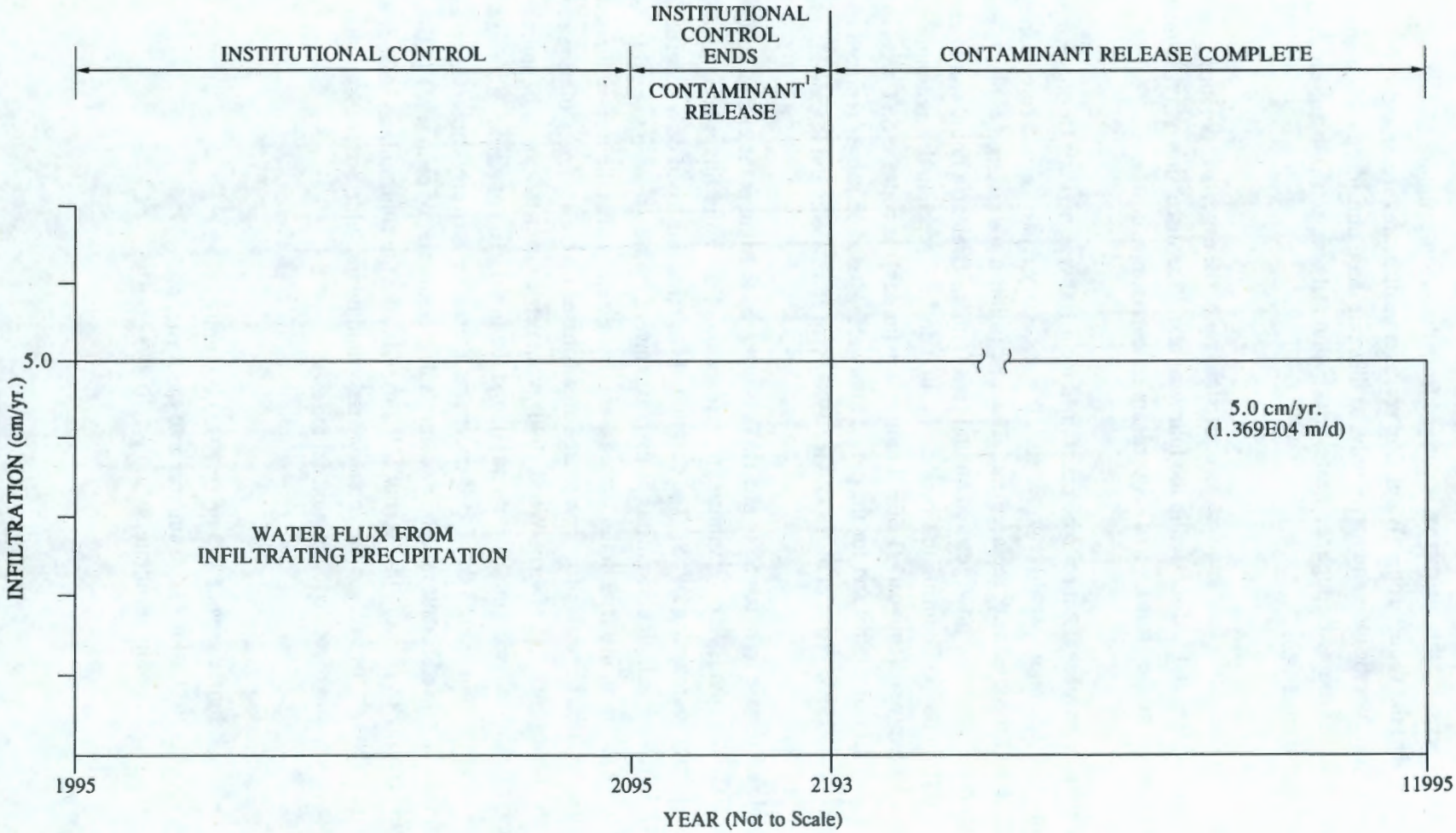
Institutional control is assumed to be maintained for a 100-year period. During this period, waste management operations would continue such that necessary repairs would be performed, but there would be no scheduled tank replacement. The tank facilities are assumed to be maintained in their current condition (e.g., no vegetation around tank farms). Drainable liquid would continue to be removed from the SSTs during this period. Infiltration from precipitation is assumed to be 5.0 centimeters/year (cm/year) (1.36E-4 meters/day [m/day]) at both the SST and DST source areas during institutional control and for the period afterwards, based on ranges reported in the literature (Kincaid et al. 1995, Wood et al. 1995, Gee 1987, Gee et al. 1992, and Rockhold et al. 1990).

Contaminant release from the SSTs and DSTs is assumed to begin at the end of institutional control. Figure F.2.2.1 provides a diagrammatic representation of the water flux used in modeling contaminant transport from source area 1WSS. The duration of the release is based on a congruent dissolution model. In this model, all constituents in the waste inventory are assumed to be released in proportion to the most abundant material in the waste inventory, nitrate, and at the rate of nitrate dissolution. Thus, the duration of release for each source area is based on the solubility of nitrate, which is assumed to be 360 grams/liter (g/L) (Serne-Wood 1990), volumetric water flux (area of source times 5.0 cm/year [2.0 in./year {inches per year}]), and the initial mass of nitrate in the inventory. It should be noted that the source term developed under this alternative is overly conservative for many of the contaminants modeled because solubility controls in groundwater of neutral pH (7.0-8.0) and relatively oxidizing conditions (EH of 300-400 mv SHE) would cause the contaminants to be leached at a rate less than nitrate (NO_3^{-1}), or because the contaminants would be insoluble under these conditions. A simple example of the congruent dissolution model follows:

Given the following data:

- Source area of 100 m^2 (=1,000,000 cm^2);
- Infiltration of 5.0 cm/year into the waste; and
- Solubility of nitrate = 360 g/L (0.360 g/cm^3).

Figure F.2.2.1 Water Flux versus Time for Tank Source 1WSS, No Action Alternative (Tank Waste)



NOTE: [1]Contaminant release is assumed to occur for a 98 year period, from 2095 through 2193 at tank source area 1WSS.

939\K471-130.CDR

The volumetric flux into the waste is 1,000,000, $cm^2 \cdot 5.0$ cm/year = 5,000,000 cm^3/year. The time required to dissolve the inventory is 7.2E+08 g/(0.360 $g/cm^3 \cdot$ 5.0E+06 cm^3/year) = 400 years. In this example, the rate of release for nitrate and technetium is 7.20E+08/400 = 1.8E+06 g/year and 3.6E+04/400 = 90 g/year, respectively. Note that chromium, a potentially high-risk contaminant, has a solubility limit that controls its dissolution rate. Its solubility is substantially lower than would be calculated by the congruent dissolution release model. For this case, the solubility of chromium was used in predicting release rather than that of the congruent dissolution release model.

The release durations and total mass of nitrate released for each of the eight source areas are provided in Table F.2.2.10 for the No Action alternative. The contaminant concentrations for each of the eight source areas are provided in Table F.2.2.11. Contaminant concentrations are provided for the K_d groups that reach groundwater within the period of interest (i.e., K_d groups 1 and 2).

Table F.2.2.10 Contaminant Releases Modeled for the No Action Alternative (Tank Waste)

Site	Duration of Contaminant Release	Total Mass of Nitrate Released (grams)
1WSS	98 years	2.63E+10
2WSS	158 years	4.55E+10
3WDS	23.5 years	1.04E+09
1ESS	70.5 years	1.89E+10
2ESS	2.85 years	2.59E+08
3EDS	27 years	2.20E+09
4ESS	66 years	4.89E+09
5EDS	43 years	4.45E+09

F.2.2.3.2 Long-Term Management Alternative

The source term for the Long-Term Management alternative is nearly identical to that described for the No Action alternative. The only difference is that contaminant release for the DSTs begins 100 years later than the time assumed for the No Action Alternative. This would occur because under the Long-Term Management Alternative, the DSTs would be replaced with new tanks every 50 years, with the last group of new DSTs being completed in 100 years. A 100-year effective life is assumed for the new DSTs. The release durations and total mass of nitrate released for the simulations performed for each of the eight source areas are provided in Table F.2.2.12. The contaminant concentrations are the same as provided for the No Action alternative (Table F.2.2.11).

F.2.2.3.3 In Situ Fill and Cap Alternative

The source term for this alternative is a result of releases from the waste stored within the tanks. There is no retrieval from the tanks, thus the initial contaminant inventory is the same as assumed for the No Action alternative (Appendix A). The tanks would be filled with gravel to provide structural stability, and a Hanford Barrier would be constructed over the tanks to reduce the infiltration of precipitation.

Table F.2.2.11 Concentration of Contaminants Released for the No Action Alternative (Tank Waste)

Constituent	Concentration (grams/liter)							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K_d Group 1 (K_d = 0.0 mL/g)								
C-14	8.73E-07	8.71E-07	6.27E-08	7.83E-06	6.74E-05	8.55E-05	3.01W-06	9.51E-08
I-129	1.32E-04	1.97E-04	0.00	9.89E-04	4.73E-03	0.00	7.15E-05	0.00
Rn-219	5.95E-21	2.59E-21	0.00	1.30E-20	1.67E-19	0.00	1.57E-21	0.00
Rn-222	5.45E-21	2.59E-21	0.00	1.29E-20	1.66E-19	0.00	7.53E-21	0.00
Ru-106	2.50E-16	4.01E-14	0.00	4.70E-13	4.06E-11	0.00	8.74E-12	0.00
Sb-126m	9.88E-15	1.67E-14	0.00	1.16E-14	1.77E-12	0.00	2.40E-13	0.00
Se-79	1.90E-05	2.85E-05	0.00	1.42E-04	6.47E-04	0.00	1.00E-05	0.00
Tc-99	9.47E-04	1.41E-03	7.49E-02	7.08E-03	3.24E-02	1.53E-01	5.00E-04	7.65E-03
U-233	1.70E-09	1.43E-09	0.00	1.16E-08	1.16E-07	0.00	8.99E-09	0.00
U-234	1.07E-07	5.82E-08	0.00	1.31E-07	6.79E-06	0.00	2.97E-02	0.00
U-235	4.57E-02	1.07E-02	0.00	6.10E-02	1.81E+00	0.00	2.37E-02	0.00
U-236	4.57E-08	5.11E-08	0.00	1.08E-07	1.41E-05	0.00	7.03E-07	0.00
U-237	1.61E-14	1.51E-14	0.00	4.84E-14	5.52E-12	0.00	2.45E-13	0.00
U-238	7.00E+01	1.52E+00	0.00	9.24E+00	2.67E+02	0.00	3.61E+00	0.00
Ag^{+}	5.62E-10	5.10E-10	2.01E-02	3.80E-09	1.23E-08	3.43E-02	1.97E--10	1.16E-01
As^{+5}	0.00	0.00	6.97E-02	0.00	0.00	4.26E-03	0.00	8.42E-02
B^{+2}	0.00	0.00	1.48E-01	0.00	0.00	1.09E-02	0.00	8.23E-02
Be^{+2}	0.00	0.00	0.00	0.00	0.00	3.66E-03	0.00	5.43E-03
Cl^{-}	2.99E-01	4.27E-02	2.59E+01	2.40E-01	5.57E-02	8.59E+00	4.43E-03	1.19E+01
CrO_4^{-2}	4.28E-03	1.63E-01	2.08E+1	3.42E-3	5.69E-02	8.7E+00	1.50E-02	3.28E+00
Cr^{+3}	1.72E-02	6.59E-01	8.32E+00	1.37E-02	2.29E-01	1.28E-01	6.06E-02	7.53E-01
F^{-}	1.97E+00	2.37E-01	3.11E+00	4.41E+00	5.55E+02	5.24E+01	2.27E-02	2.93E+00
$Fe(CN)_6^{-4}$	3.00E-02	1.08E-02	0.00	4.72E+00	9.72E+01	0.00	3.90E-03	0.00
Hg^{+}	2.77E-03	1.90E-03	0.00	5.19E-03	1.99E-01	1.54E-04	0.00	4.65E-03
Li^{+}	0.00	0.00	1.94E-03	0.00	0.00	0.00	0.00	2.00E-03
Na^{+}	1.99E+02	1.67E+02	7.48E+02	2.20E+02	2.91E+03	4.81E+02	2.78E+02	4.91E+02
NO_{2-}	2.41E+01	6.33E+00	8.51E+01	3.91E+01	6.58E-01	1.46E+02	1.71E+01	1.57E+02
NO_3^{-}	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02
Np-237	1.60E-04	1.23E-04	1.86E-04	1.34E-03	6.67E-04	1.04E-02	4.68E-05	1.63E-05
Np-238	6.76E-16	2.82E-15	0.00	6.61E-15	5.14E-13	0.00	1.17E-14	0.00
Rh-106	2.35E-22	3.78E-20	0.00	4.42E-19	3.82E-17	0.00	8.22E-18	0.00
SO_4^{-2}	8.68E+00	1.96E+00	1.45E+01	1.05E+01	1.85E+02	1.18E+01	6.15E+00	2.26E+01
UO_2^{+2}	0.00	0.00	0.00	0.00	0.00	4.42E+00	0.00	6.04E-02
V^{+5}	0.00	0.00	4.74E-03	0.00	0.00	2.72E-02	0.00	5.67E-03
Mo^{+6}	0.00	0.00	2.90E-01	0.00	0.00	1.31E-01	0.00	3.26E-01
W^{+4}	4.44E-02	3.04E-02	0.00	8.33E-02	3.20E+00	0.00	4.92E-02	6.04E-02
W^{+6}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.04R-02

Table F.2.2.11 Concentration of Contaminants Released for the No Action Alternative (Tank Waste) (cont'd)

Constituent	Concentration (grams/liter)							
	1WSS	2WSS	3WDS	1ESS	2ESS	3EDS	4ESS	5EDS
K^+	0.00	0.00	1.30E+01	0.00	0.00	6.19E+01	0.00	1.21E+01
Co_3^{-2}	9.68E+0	1.27E+0	0.00	1.22E+01	8.62E+01	0.00	2.80E+00	0.00
OH^-	6.20E0	1.82E+01	0.00	1.98E+01	1.97E+03	0.00	1.28E+01	0.00
SiO_3^{-2}	7.67E+0	1.90E+00	2.10E+0	7.68E+00	9.83E-01	2.37E+00	1.54E+02	1.69E+01
K_d Group 2 (K_d = 1.0 mL/g)								
Bi-210	1.65E-21	7.40E-22	0.00	2.05E-21	7.90E-20	0.00	1.67E-21	0.00
Ni-63	1.59E-06	6.53E-06	0.00	1.71E-05	1.39E-03	0.00	1.36E-04	0.00
Pa-231	2.78E-09	1.23E-09	0.00	6.15E-09	9.98E-08	0.00	9.94E-10	0.00
Pa-233	5.46E-12	4.20E-12	0.00	4.56E-11	2.27E-11	0.00	1.59E-12	0.00
Pa-234m	3.43E-15	7.46E-16	0.00	4.52E-15	1.31E-13	0.00	1.77E-15	0.00
Po-211	1.86E-24	8.84E-25	0.00	4.42E-24	5.68E-24	0.00	5.35E-25	0.00
Po-216	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bi^{+3}	2.28E+00	2.21E-03	0.00	1.79E+00	8.27E-01	8.53E-02	0.00	1.40E-01
Ca^{+2}	2.71E-03	4.60E-02	2.15E+00	1.04E+00	9.16E+01	3.92E-01	1.13E-01	1.06
Cd^{+2}	1.82E-02	8.07E-03	8.36E-02	2.21E-02	8.49E-01	1.16E-02	1.31E-02	4.75E-01
Fe^{+3}	2.32E+00	6.47E-01	4.31E+00	2.69E+00	7.71E+01	4.48E-01	1.31E+01	1.09E+01
Mg^{+2}	0.00	0.00	1.76E-01	0.00	0.00	2.28E-01	0.00	8.13E-01
Ni^{+2}	6.88E-02	2.63E-02	5.75E-01	2.37E+00	6.11E+01	1.00E-01	7.31E-02	6.77E-01

Table F.2.2.12 Contaminant Releases Modeled for the Long-Term Management Alternative

Site	Duration of Contaminant Release	Total Mass of Nitrate Released (grams)
1WSS	98 years	2.92E+10
2WSS	158 years	5.10E+10
3WDS	23.5 years	1.16E+09
1ESS	70.5 years	2.10E+10
2ESS	2.85 years	2.88E+08
3EDS	27 years	2.45E+09
4ESS	66 years	5.44E+09
5EDS	43 years	4.95E+09

Initially, there would be a 28-year construction phase in which the tanks would be structurally stabilized (i.e., filled with gravel) and a Hanford Barrier would be installed over each source area. Activities at the Site such as removing snow, diverting runoff, and protecting the open tanks from incident rainfall are assumed to lower infiltration from the base value of 5.0 cm/year to 0.5 cm/year during this 28-year period. Contaminant releases from the tanks during this 28-year period are assumed not to occur, thus, the total water flux is from infiltrating precipitation and is 0.5 cm/year (1.36E-05 m/day).

For the next 1,000 years, infiltration through the Hanford Barrier is assumed to be approximately 0.05 cm/year (1.37E-06 m/day). As a man-made structure, the Hanford Barrier is not expected to maintain its design functions indefinitely. A simplifying assumption used in this analysis is that the infiltration through the Hanford Barrier would double to approximately 0.1 cm/year, which is 2.74E-06 m/day, 1,000 years after the Hanford Barrier was initially constructed. Infiltration is assumed to remain at this level for the remainder of the period of interest, 10,000 years from the present. For all tanks, releases to the vadose zone from the waste are assumed to begin 500 years after completing the Hanford Barrier. The waste inventory and constituent concentrations are the same as those for the No Action alternative (Appendix A and Table F.2.2.11). The principal constituent of the waste is nitrate, and the congruent dissolution release model is used to estimate release from the waste, which is the same approach as described for the No Action alternative. The dissolution rate of nitrate is assumed to remain constant at 360 g/L (360,000 mg/L) (Serne-Wood 1990), regardless of the water flux. For 500 years, the water flux through the intact Hanford Barrier is limited to 0.05 cm/year (1.37E-06 m/day). The mass flux is estimated as follows:

$$1.37\text{E-6 m/day} \cdot 360{,}000 \text{ mg/L} = 0.49 \text{ g/day-m}^2.$$

After 500 years, when the water flux is assumed to double to 0.1 cm/year (2.74E-06 m/day), the dissolution rate remains constant at 360,000 mg/L, resulting in a doubling of the mass flux to approximately 0.98 g/day-m^2 until the mass of nitrate has been depleted. Table F.2.2.13 provides the contaminant release durations and the total mass of nitrate released for each of the eight source areas. The source term developed for the In Situ Fill and Cap alternative is very conservative for many of the contaminants modeled because solubility constraints in groundwater of neutral pH (7.0-8.0) and relatively oxidizing conditions (Eh 300-400 mv SHE) will cause the contaminants to be either leached at a rate less than nitrate, or to be insoluble.

F.2.2.3.4 In Situ Vitrification Alternative

The source term for this alternative is a result of release from in-tank vitrified waste. Both SSTs and DSTs are discussed together in the following text because the vitrified waste inventory is similar (i.e., the contaminants and their relative concentrations are assumed to be approximately the same in each tank).

9613409.1519

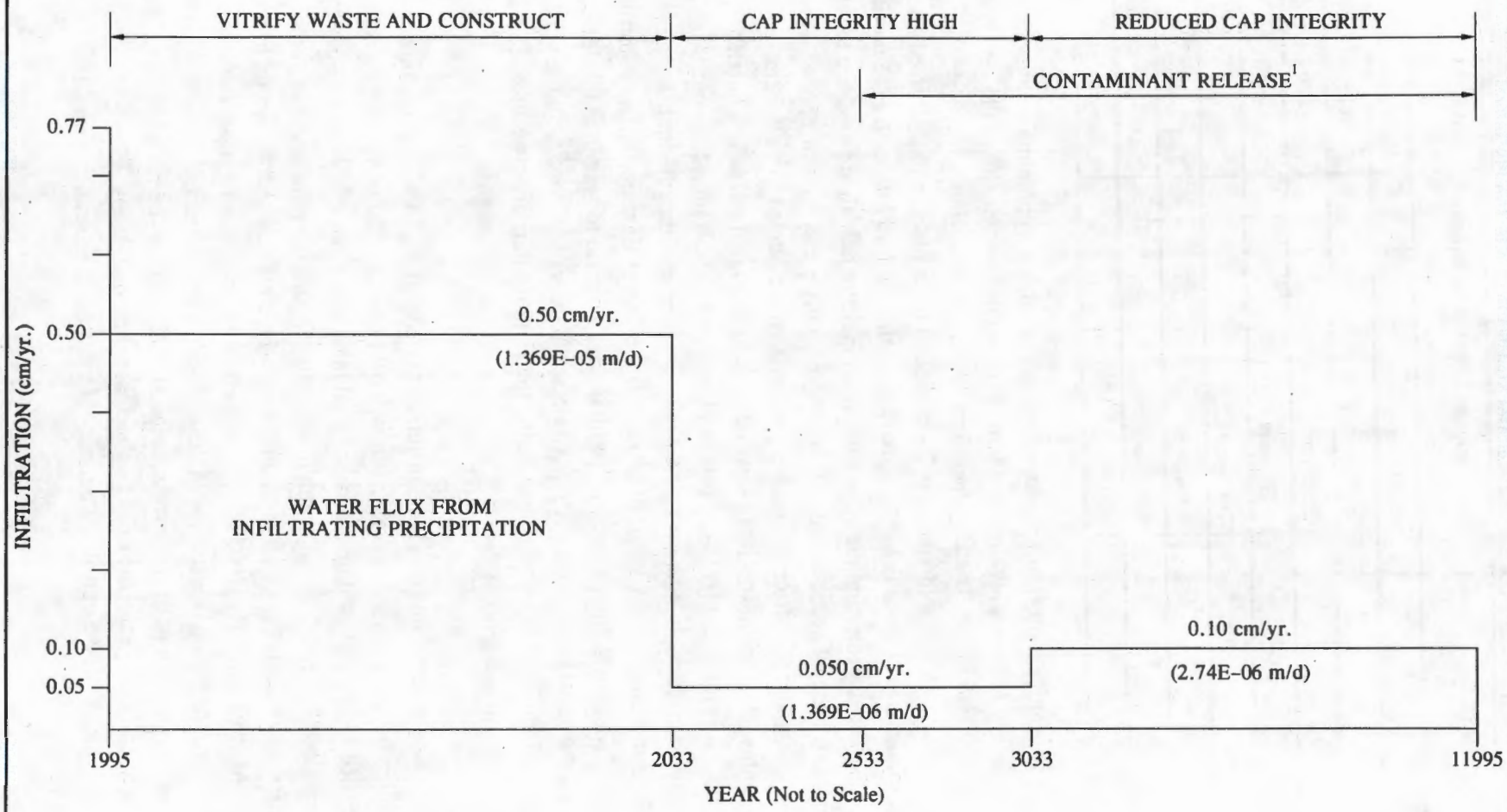
Table F.2.2.13 Contaminant Releases Modeled for the In Situ Fill and Cap Alternative

Site	Duration of Contaminant Release	Total Mass of Nitrate Released (grams)
1WSS	5,153 years	2.92E+10
2WSS	8,096 years	5.06E+10
3WDS	2,600 years	1.16E+09
1ESS	3,778 years	2.10E+10
2ESS	285.5 years	2.88E+08
3EDS	1,604 years	2.45E+09
4ESS	3,563 years	5.44E+09
5EDS	2,404 years	4.96E +09

Developing the source term requires understanding the expected operating conditions at the eight tank source areas. The following discussion will first focus on the water flux, followed by the estimate of contaminant concentrations. Initially, there is a 38-year construction phase where the in situ vitrification equipment is tested and set up, vitrification takes place, and a Hanford Barrier is installed over each source area (Figure F.2.2.2). Activities at the Hanford Site such as removing snow, diverting runoff, and protecting the open tanks from incident rainfall are assumed to reduce the infiltration from the base value of 5.0 to 0.50 cm/year during this 38-year period. During the 38-year period, the total water flux from infiltrating precipitation is assumed to be 0.5 cm/year, which equals 1.36E-05 m/day. For the next 1,000 years, infiltration through the Hanford Barrier is assumed to be 0.05 cm/year (1.36E-06 m/day). As a man-made structure, the Hanford Barrier is not expected to maintain its design function indefinitely. An assumption used is that the infiltration through the Hanford Barrier increases by a factor of two 1,000 years after Hanford Barrier construction to 0.10 cm/year, which is 2.74E-06 m/day. Infiltration is assumed to remain at this level for the remainder of the period of interest. All tank releases to the vadose zone from the vitrified waste form are assumed to begin 500 years after completing the Hanford Barrier, in accordance with the Nuclear Regulatory Commission (NRC 1994).

The vitrification process requires adding materials to make glass. Also, the organic and other volatile materials initially present in the waste inventory would be destroyed or vaporized. The release model for the vitrified mass was based on a constant total mass loss rate of 1E-03 $g/m^2 \cdot day$ (Shade et al. 1995). This mass loss rate is independent of the water flux from recharge. The composition of the vitrified mass was assumed to be identical to the soda-lime glass, which is formed in the Ex Situ No Separations Alternative (WHC 1995c). The concentration of the contaminants released is then assumed to be proportional to their concentration in the soda-lime glass. Because the total mass loss rate is constant, the composition of the released solution is unaffected by the recharge rate. As the recharge rate doubles after 1,000 years, the mass flux increases proportionately. The low value of the total mass loss rate, combined with the very large quantity of vitrified mass results in a release time measured in millions of years.

Figure F.2.2.2 Water Flux versus Time for All Tank Sources, In Situ Vitrification Alternative



NOTE: [1]Contaminant release is assumed to begin in the year 2533 and continue beyond the period of interest.

The release durations and total mass of SiO_2 released for each of the eight source areas are provided in Table F.2.2.14 for the In Situ Vitrification alternative. The initial contaminant concentrations for each of the eight source areas are provided in Table F.2.2.15. Contaminant concentrations are provided for K_d Group 1. The other K_d groups do not reach groundwater within the period of interest.

Table F.2.2.14 Contaminant Releases Modeled for the In Situ Vitrification Alternative

Site	Duration of Contaminant Release	Total Mass of SiO_2 Released [1] (grams)
1WSS	9,462 years	3.18E+07
2WSS	9,462 years	3.22E+07
3WDS	9,462 years	2.46E+06
1ESS	9,462 years	3.62E+07
2ESS	9,462 years	1.19E+07
3EDS	9,462 years	1.09E+07
4ESS	9,462 years	9.93E+06
5EDS	9,462 years	1.11E+07

Notes:
[1] During 10,000-year period of interest

Table F.2.2.15 Concentrations of Contaminants for the In Situ Vitrification Alternative in K_d Group One (K_d=0)

Constituent	Concentration (g/L)	Constituent	Concentration (g/L)
Tc_2O_7	6.06E-06	B_2O_3	1.71E-05
U-233	5.10E-12	BeO	3.50E-07
U-234	1.40E-10	Li_2O	1.19E-07
U-235	4.39E-05	Na_2O	2.60E-01
U-236	1.56E-10	V_2O_5	9.80E-07
U-238	6.47E-03	WO_2	1.98E-06
Ag_2O	6.68E-06	WO_3	3.95E-06
As_2O_5	4.99E-06	NpO_2	5.73E-07
Cr_2O_3	2.57E-04	MoO_3	2.22E-05

F.2.2.3.5 Ex Situ Intermediate Separations Alternative

The source term for this alternative is a result of releases from SSTs, DSTs, and the LAW disposal facility. Each of these potential sources are discussed in the following text.

Single-Shell Tanks

The source term for the SSTs is based on contaminant releases from two events:

- Releases to the vadose zone during retrieval of waste from the SSTs; and
- Releases to the vadose zone from residual contaminants in the SSTs.

Developing the source term requires understanding the expected operating conditions at the eight tank source areas. The following discussion on operating conditions will focus on the water flux and later the estimated contaminant concentrations.

The waste would be retrieved from the SSTs over a 15-year period. Work is assumed to be ongoing at all of the eight sites during this period. The infiltration rate is assumed to decrease from 5.0 to 0.5 cm/year during the 15-year retrieval period because of construction and retrieval activities (e.g., removing snow and diverting runoff).

The retrieval operations within the SSTs are assumed to result in relatively early contaminant releases to the vadose zone. The release volume per tank is assumed to be 15,000 L (4,000 gal). Using source area 1WSS as an example, the water flux is calculated as follows:

Give the following data:

- Numbers of tanks = 40
- Combined area of tanks = 14,900 m^2
- Period over which release occurs = 15 years
- Release volume per tank = 15,000 L.

The water flux due to the retrieval release at 1WSS is estimated as:

- Total volume released = 15,000 L/tank · 40 tanks · 1 m^3/1,000 L = 600 m^3
- Flux from release = 600 m^3/(14,900 m^2 · 15 years · 365.25 day/year) = $7.42 \cdot 10^{-6}$ m/day.

Thus during the 15-year retrieval period, the water flux from tank releases at 1WSS is approximately 7.4E-06 m/day. The flux from infiltrating precipitation during this period is assumed to be 0.5 cm/year (1.4E-05 m/day). The total water flux infiltrating into the vadose zone during this period is the sum of the releases from the tanks and natural infiltration, which is 2.1E-05 m/day.

Following the retrieval period is a 14-year construction period when the Hanford Barrier would be built over the source areas. Water flux into the vadose zone in the vicinity of the source area is assumed to be approximately 0.5 cm/year (1.4E-05 m/day) during this period for the same reasons as used for the retrieval period. For the next 1,000 years infiltration through the Hanford Barrier is assumed to be approximately 0.05 cm/year (1.4E-06 m/day). As a man-made structure, the Hanford Barrier is not expected to maintain its design functions indefinitely. A simplifying assumption used herein is that the infiltration through the Hanford Barrier increases at some point in time. Thus, infiltration through the Hanford Barrier is assumed to double to approximately 0.1 cm/year (2.7E-06 m/day) 1,000 years after the Hanford Barrier was initially constructed. Infiltration is assumed to remain at this level for the remainder of the period of interest.

The other release that impacts groundwater is from waste tank residual contaminants. The retrieval process is assumed to be 99 percent effective, leaving within the tanks 1 percent of the waste inventory. Major assumptions used in developing the source term for the tank residuals are:

- The residual materials are assumed in a relatively saturated state;
- The Hanford Barrier limits the potential for infiltrating precipitation to mobilize the residuals;

- The solubility of each contaminant is proportional to the solubility of nitrate;
- Release to the vadose zone begins 500 years after the Hanford Barrier has been installed (NRC 1994); and
- The residuals are present in the same proportion as the initial inventory.

The release of residuals in the tanks is assumed to begin 500 years after barrier completion for all the SSTs. The congruent dissolution release model is used to estimate retrieval and residual releases of contaminants into the vadose zone following the same approach as described for the No Action alternative. Also, contaminant concentrations for residual release are the same as those used for the No Action alternative (Table F.2.2.11). The release durations and masses associated with retrieval and residuals for each source area are summarized in Table F.2.2.16.

Table F.2.2.16 Contaminant Releases Modeled for the Ex Situ Intermediate Separations Alternative

Site	Releases from Retrieval Operations		1 Percent Residual Releases	
	Duration of Contaminant Release	Mass Released [1] (grams)	Duration of Contaminant Release	Mass Released [1] (grams)
1WSS	15 years	2.42E+08	98 years	2.92E+08
2WSS	15 years	2.61E+08	156 years	5.04E+08
3WDS	No Release	0.00	47 years	1.16E+07
1ESS	15 years	2.42E+08	70 years	2.09E+08
2ESS	15 years	9.69E+07	3 years	3.04E+06
3EDS	No Release	0.00	48 years	4.13E+07
4ESS	15 years	6.06E+07	66 years	5.38E+07
5EDS	No Release	0.00	43 years	5.07E+07
LAW Vaults	N/A	0.00	9,461 years [2]	2.10E+10

Notes:
[1] Mass released is based on the unit concentration modeled (e.g., 400 g/L for the tank sources and 100 g/L for the LAW vaults). For the LAW vaults, release reported is vitrified waste rather than the 1 percent residual left in the tank.
[2] During 10,000-year period of interest. Mass remains after 10,000-year period of interest.
LAW = Low-activity waste
N/A = Not Applicable

Double-Shell Tanks

The source term for DSTs is based on contaminant releases to the vadose zone from residual contaminants. Releases are not expected from the DSTs during the retrieval process because of their double-shell construction and associated leak-capture systems.

The timing of the residual releases are similar to the SSTs. Release from residuals in the tanks begins 500 years after barrier completion for all the DSTs. The duration of the releases are for each DST source area and are also summarized in Table F.2.2.16. Again, the congruent dissolution release model and the No Action alternative contaminant concentrations are used (Table F.2.2.11).

Low-Activity Waste Disposal Facility

The Ex Situ Intermediate Separations alternative has a groundwater source associated with LAW disposal in addition to the eight tank source areas. The source term for the LAW disposal facility is a result of releases from the waste, which has been vitrified and placed in vaults.

Waste retrieval from the tanks, waste separation processes, waste vitrification, vault construction, and Hanford Barrier construction are assumed to occur over a 39-year period.

Activities at the LAW disposal site (such as removing snow and diverting runoff) are assumed to lower the infiltration from the base value of 5.0 to 0.5 cm/year (1.4E-05 m/day) during this 39-year period.

For the 1,000-year period after the Hanford Barrier is constructed, infiltration through the Hanford Barrier is assumed to be approximately 0.05 cm/year (1.4E-06 m/day). As a human-made structure, the Hanford Barrier is not expected to maintain its design functions indefinitely. A simplifying assumption used herein is that the infiltration through the Hanford Barrier doubles to approximately 0.1 cm/year (2.7E-06 m/day), 1,000 years after the Hanford Barrier is initially constructed. Releases to the vadose zone from the vitrified waste form are assumed to begin 500 years after completing the Hanford Barrier (NRC 1994).

The vitrification process requires adding materials for glass makeup. Also, organic and other volatile materials initially present in the waste inventory would be destroyed or vaporized. The release model for the glass waste form was based on a constant corrosion rate of 3E-06 cm/year (Jacobs 1996). The corrosion rate is independent of the water flux from recharge. The composition of the LAW glass is taken from the engineering date package for this alternative (WHC 1995j). The release concentration of the contaminants is assumed to be proportional to their concentration in the LAW glass. Because the total mass loss rate is constant, the composition of the released solution is unaffected by the recharge rate. As the recharge rate doubles after 1,000 years, the mass flux increases proportionately. The low value of the corrosion rate, combined with the very large quantity of vitrified mass, results in a calculated release time of 170,000 years.

The release duration for the LAW disposal facility goes beyond the period of interest. The contaminant concentrations for each of the eight source areas are provided in Table F.2.2.17. Contaminant concentrations are provided for K_d Group 1 (K_d=0), which is the only K_d group that reaches groundwater during the period of interest.

F.2.2.3.6 Ex Situ No Separations Alternative

The source term for this alternative is as described for the Tank Waste - Ex Situ Intermediate Separations alternative, except that all retrieved waste is disposed of offsite, thus there is no source from a LAW facility on the site. The source term for the SSTs is based on contaminant releases from two events:

- Releases to the vadose zone during retrieval of waste from the SSTs; and
- Releases to the vadose zone from residual contaminants in the SSTs.

Table F.2.2.17 Concentrations of Contaminants for the LAW Vault Source for K_d Group One (K_d=0) Ex Situ Intermediate Separations Alternative

Constituent	Concentration (g/L)	Constituent	Concentration (g/L)
Tc_2O_7	3.25E-04	Li_2O	1.50E-06
U-233	1.73E-11	Na_2O	1.89E+01
U-234	4.75E-10	V_2O_5	1.61E-05
U-235	1.46E-04	WO_2	8.65E-09
U-236	5.39E-10	WO_3	2.60E-04
U-238	2.20E-02	Cr_2O_3	2.5E-04
Ag_2O	8.49E-05	K_2O	5.70E-5
As_2O_5	1.99E-04	MoO_3	1.26E-03
B_2O_3	3.88E-04	SiO_2	2.77E+01
BeO	2.12E-05	NpO_2	3.79E-06

Notes:
[1] Derived from glass component Ni_2O_3
[2] Derived from glass component NiO

The source term for the DSTs is based on contaminant releases to the vadose zone from residual contaminants. Releases would not be expected from the DSTs during the retrieval process because of their double-shell construction and associated leak-capture systems. The details and assumptions associated with the source terms for both the SSTs and DSTs are provided earlier in the tank waste Ex Situ Intermediate Separations alternative section

F.2.2.3.7 Ex Situ Extensive Separations Alternative

The source term for this alternative is as described for the Ex Situ Intermediate Separations alternative, except waste inventory for the LAW facility is smaller because of the more extensive separations process. The source term for the SSTs is based on contaminant releases from two events:

- Releases to the vadose zone during retrieval of waste from the SSTs; and
- Releases to the vadose zone from residual contaminants in the SSTs.

The source term for the DSTs is based on contaminant releases to the vadose zone from residual contaminants. Releases would not be expected from the DSTs during the retrieval process because of their double-shell construction and associated leak-capture systems.

The source term for the LAW facility involves the same construction sequencing and physical parameters (e.g., infiltration rates, contaminant release mechanisms, and vadose zone hydrogeologic setting) as would apply to the Ex Situ Intermediate Separations alternative, except that the waste inventory in the LAW vaults would be smaller (Table F.2.2.7). The initial concentration of contaminants in the LAW vaults is provided in Table F.2.2.18. The details and assumptions associated with the source terms for both the SSTs and DSTs are provided earlier in the discussion on the Ex Situ Intermediate Separations alternative.

Table F.2.2.18 Concentration of Contaminants in K_d Group One (K_d=0) For the Ex Situ Extensive Separations Alternative (LAW Vaults)

Constituent (g/L)	Concentration (g/L)
Ag_2O	1.00E-04
As_2O_5	7.48E-05
B_2O_3	1.15E-03
BeO	5.28E-06
Cr_2O_3	4.48E-02
K_2O	5.61E-03
Li_2O	8.08E-06
MoO_3	1.82E-03
Na_2O	1.90E+01
NpO_2	1.52E-06
SiO_2	2.67E+01
Tc_2O_7	2.39E-06
U-235	5.66E-07
U-238	8.03E-05
V_2O_5	1.47E-05
WO_2	2.46E-10
WO_3	4.41E-05

Source: Jacobs 1996

F.2.2.3.8 Ex Situ/In Situ Combination Alternative

The source term for this alternative has three components:

- Releases to the vadose zone during retrieval from 60 SSTs. Waste from 10 DSTs would be retrieved, however, it is assumed there would be no retrieval losses because of the DST construction.
- Releases to the vadose zone from waste in the 107 tanks that would be remediated in situ using the fill and cap technology.
- Releases from a LAW disposal facility.

As with the Ex Situ Intermediate Separations Alternative, there is an assumed residual mass (1 percent of the original waste inventory) left in tanks where waste is retrieved. This residual waste has been added to the waste inventory of tanks that would be remediated in situ.

Retrieval Releases

Tank waste released during retrieval is based on the same rationale as was used for the Ex Situ Intermediate Separations Alternative. Retrieval releases are assumed to occur only from the 60 SSTs that would be selected for retrieval. Waste retrieved would be separated into HLW and LAW. Both would be vitrified with the HLW being sent to a potential geologic repository and LAW disposed of onsite in vaults. The initial concentrations of those contaminants assumed to be lost during retrieval

are provided in Table F.2.2.19. The contaminant release periods for the source areas and associated masses on which the release periods are based are provided in Table F.2.2.20.

In Situ Remediation Releases

The source term for this component of the alternative is the result of waste that is leached out of the 107 tanks that are remediated in situ. These tanks would be filled with gravel and covered with a Hanford Barrier as described for the In Situ Fill and Cap alternative.

The gravel fill would provide structural stability and a Hanford Barrier would be constructed over the tanks to reduce infiltration of precipitation. Eighty-nine SSTs and 18 DSTs would be remediated in this fashion.

Initially, there is a 28-year construction phase in which the tanks are structurally stabilized (i.e., filled with gravel) and a Hanford Barrier is installed over each source area. Activities at the Site such as removing snow, diverting runoff, and protecting the open tanks from incident rainfall are assumed to have the effect of lowering the infiltration from the base value of 5.0 cm/year to 0.50 cm/year during this 28-year period. Contaminant releases from the tanks during this 28-year period are assumed not to occur; thus, the total water flux is from infiltrating precipitation, which is 0.5 cm/year (1.36E-05 m/day).

For the next 1,000 years, infiltration thorough the Hanford Barrier is assumed to be approximately 0.05 cm/year (1.36E-06 m/day). The Hanford Barrier, as a man-made structure, is not expected to maintain its design functions indefinitely. A simplifying assumption used herein is that the infiltration through the Hanford Barrier doubles to approximately 0.10 cm/year (2.74E-06 m/day), 1,000 years after the Hanford Barrier was initially constructed. Infiltration is assumed to remain at this level for the remainder of the period of interest, 10,000 years from the present. For all tanks, releases to the vadose zone from the waste are assumed to begin 500 years after completing the Hanford Barrier.

The waste inventory was provided in Section F.2.2.2.8. The estimated constituent concentrations are provided in Table F.2.2.21. The principal constituent of the waste is nitrate, and the congruent dissolution release model is used to estimate release from the waste, which is the same approach as described for the No Action alternative. The dissolution rate of nitrate is assumed to remain constant at 360 g/L (360,000 mg/L) (Serne-Wood 1990), regardless of the water flux. From the 500-year period when the water flux through the intact Hanford Barrier is limited to 0.05 cm/year (1.37E-06 m/day), the mass flux for an area encompassing 1 m^2 is estimated as follows: 1.37E-06 m^3/day · 360,000 g/m^3 = 0.49 g/day. The release from this component has been adjusted upward by 1 percent of the waste retrieved to account for contaminants that might be left in the tanks and not removed during the retrieval process.

Table F.2.2.19 Concentration of Contaminants in K_d Group 1 (K_d=0) Associated with Waste Retrieval- Ex Situ/In Situ Combination Alternative

Constituent	1WSS (g/L)	2WSS (g/L)	3WDS (g/L)	1ESS (g/L)	2ESS (g/L)	3EDS (g/L)	4ESS (g/L)	5EDS (g/L)
C-14	9.99E-07	1.40E-06	0.00E+00	1.01E-05	6.89E-05	0.00E+00	2.80E-06	0.00E+00
Cr^{+3}	2.50E-04	2.50E-04	0.00E+00	2.50E-04	2.50E-04	0.00E+00	2.50E-04	0.00E+00
Cl^-	2.69E-01	5.82E-02	0.00E+00	2.15E-01	1.31E-05	0.00E+00	3.87E-03	0.00E+00
CrO_4^{-2}	2.67E-03	1.44E-01	0.00E+00	2.92E-03	1.39E-02	0.00E+00	5.48E-04	0.00E+00
F^-	2.15E+00	3.08E-01	0.00E+00	4.25E+00	5.80E+02	0.00E+00	1.39E-02	0.00E+00
$Fe(CN)_6^{-4}$	3.66E-02	1.03E-02	0.00E+00	5.69E+00	7.56E-02	0.00E+00	1.52E-04	0.00E+00
Hg^+	2.11E-03	3.08E-03	0.00E+00	3.64E-03	2.05E-01	0.00E+00	2.23E-03	0.00E+00
I-129	1.43E-04	3.18E-04	0.00E+00	1.27E-03	4.76E-03	0.00E+00	4.81E-05	0.00E+00
NO_2^-	2.70E+01	8.09E+00	0.00E+00	4.33E+01	5.23E-03	0.00E+00	1.39E+01	0.00E+00
NO_3^-	3.60E+02	3.60E+02	0.00E+00	3.60E+02	3.60E+02	0.00E+00	3.60E+02	0.00E+00
Np-237	1.77E-04	1.81E-04	0.00E+00	1.70E-03	1.52E-04	0.00E+00	3.78E-05	0.00E+00
Np-238	7.82E-16	4.14E-15	0.00E+00	8.73E-15	5.39E-13	0.00E+00	9.82E-15	0.00E+00
Na^+	1.98E+02	1.59E+02	0.00E+00	2.11E+02	2.95E+03	0.00E+00	2.80E+02	0.00E+00
Rn-219	6.32E-21	2.93E-21	0.00E+00	1.63E-20	1.56E-19	0.00E+00	1.38E-21	0.00E+00
Rn-222	6.26E-21	2.92E-21	0.00E+00	8.09E-21	2.53E-19	0.00E+00	6.63E-21	0.00E+00
Rh-106	2.73E-22	4.28E-20	0.00E+00	5.56E-19	3.59E-17	0.00E+00	7.24E-18	0.00E+00
Ru-106	3.14E-16	3.25E-14	0.00E+00	6.18E-13	4.26E-11	0.00E+00	7.89E-13	0.00E+00
SO_4^{-2}	8.56E+00	2.96E+00	0.00E+00	1.02E+01	1.91E+02	0.00E+00	6.20E+00	0.00E+00
Sb-126m	1.25E-14	1.52E-14	0.00E+00	1.48E-14	1.79E-12	0.00E+00	1.71E-13	0.00E+00
Se-79	2.07E-05	4.60E-05	0.00E+00	1.83E-04	6.50E-04	0.00E+00	6.79E-06	0.00E+00
Tc-99	1.03E-03	2.28E-03	0.00E+00	9.11E-03	3.26E-02	0.00E+00	3.37E-04	0.00E+00
U-233	1.52E-09	1.28E-09	0.00E+00	1.43E-08	8.78E-08	0.00E+00	8.59E-09	0.00E+00
U-234	1.23E-07	6.27E-08	0.00E+00	1.63E-07	6.46E-06	0.00E+00	2.34E-07	0.00E+00
U-235	5.77E-02	1.47E-02	0.00E+00	7.81E-02	1.70E+00	0.00E+00	2.03E-02	0.00E+00
U-236	5.77E-08	6.98E-08	0.00E+00	1.38E-07	1.32E-05	0.00E+00	6.01E-07	0.00E+00
U-237	2.03E-14	2.06E-14	0.00E+00	6.20E-14	5.17E-12	0.00E+00	2.10E-13	0.00E+00
U-238	8.83E+00	2.11E+00	0.00E+00	1.18E+01	2.49E+02	0.00E+00	3.14E+00	0.00E+00
W^{+4}	3.58E-02	4.93E-02	0.00E+00	5.85E-02	3.29E+00	0.00E+00	3.57E-02	0.00E+00
CO_3^{-2}	9.48E+00	2.04E+00	0.00E+00	1.20E+01	7.67E+01	0.00E+00	2.75E+00	0.00E+00
OH^-	4.14E+00	1.60E+01	0.00E+00	2.00E+01	1.84E+03	0.00E+00	1.03E+01	0.00E+00
SiO_3^{-2}	7.96E+00	6.62E-01	0.00E+00	9.58E+00	6.91E-03	0.00E+00	1.14E-01	0.00E+00

Source: Jacobs 1996

9613409.1524

Table F.2.2.20 Contaminant Releases Modeled for the Ex Situ/In Situ Combination Alternative

Site	Releases from Retrieval Operations		Releases from Tanks Remediated In Situ	
	Duration of Contaminant Release	Mass Released [1] (grams)	Duration of Contaminant Release	Mass Released [1] (grams)
1WSS	15 years	6.54E+07	1,912 years	6.24E+09
2WSS	15 years	8.1E+07	5,432 years	1.96E+10
3WDS	No Release	0.00	1,136 years	1.31E+08
1ESS	15 years	1.25E+08	2,487 years	5.10E+09
2ESS	15 years	3.27E+07	28 years	1.58E+07
3EDS	No Release	0.00	761 years	1.30E+09
4ESS	15 years	2.18E+07	449 years	1.99E+08
5EDS	No Release	0.00	927 years	3.02E+08
LAW Vaults	N/A [2]	0.00	9,461 years [3]	1.03E+10

Notes:
[1] Mass released is based on the unit concentration modeled (e.g., 400 g/L for the tank sources and 100 g/L for the LAW vaults). For the LAW vaults, release reported is vitrified waste rather than the 1 percent residual left in the tank.
[2] Not applicable
[3] During 10,000-year period of interest. Mass remains after 10,000-year period of interest.
Source: Jacobs 1996

Table F.2.2.21 Concentration of Contaminants in K_d Group One (K_d=0) Associated with Waste Tanks Remediated In Situ for the Ex Situ/In Situ Combination Alternative

Constituent	1WSS (g/L)	2WSS (g/L)	3WDS (g/L)	1ESS (g/L)	2ESS (g/L)	3EDS (g/L)	4ESS (g/L)	5EDS (g/L)
Ag^+	0.00E+00	0.00E+00	1.59E-01	0.00E+00	0.00E+00	1.92E-02	0.00E+00	1.29E+00
As^{+5}	0.00E+00	0.00E+00	5.52E-01	0.00E+00	0.00E+00	7.19E-03	0.00E+00	2.71E-02
B^{+3}	0.00E+00	0.00E+00	1.80E-01	0.00E+00	0.00E+00	1.84E-02	0.00E+00	8.81E-01
Be^{+2}	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.19E-03	0.00E+00	3.51E-03
C-14	5.05E-07	1.90E-07	5.00E-07	1.80E-06	5.05E-05	1.45E-06	8.77E-06	1.00E-06
Cl^-	3.97E-01	2.23E-02	1.29E+01	3.07E-01	9.16E-01	8.47E+00	1.79E-02	1.06E+01
Cr^{+3}	2.50E-04	2.50E-04	2.50E-04	2.50E-04	2.50E-04	2.50E-04	2.50E-04	2.50E-04
CrO_4^{-2}	9.45E-03	1.89E-01	2.64E+01	4.75E-03	7.21E-01	2.74E+00	3.56E-01	2.17E+00
F^-	1.41E+00	1.44E-01	9.68E+00	4.88E+00	1.88E+02	8.86E+01	2.29E-01	8.25E+00
$Fe(CN)_6^{-4}$	9.14E-03	1.15E-02	0.00E+00	2.09E+00	1.60E+03	0.00E+00	9.21E-02	0.00E+00
Hg^+	4.87E-03	3.27E-04	0.00E+00	9.39E-03	1.06E-01	7.77E-05	2.29E-02	1.36E-03
I-129	1.01E-04	4.21E-05	0.00E+00	2.55E-04	4.74E-03	0.00E+00	6.34E-04	0.00E+00
Li^+	0.00E+00	0.00E+00	1.54E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.39E-04
Na^+	2.02E+02	1.78E+02	3.27E+02	2.44E+02	2.48E+03	5.44E+02	2.51E+02	4.79E+02
NO_2^-	1.48E+01	4.00E+00	5.70E+01	2.79E+01	1.07E+01	1.27E+02	9.15E+01	1.25E+02
NO_3^-	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02	3.60E+02
Rh-106	1.25E-22	3.17E-20	0.00E+00	1.48E-19	7.80E-17	0.00E+00	3.33E-17	0.00E=00
Np-237	1.15E-04	4.97E-05	1.48E-03	3.97E-04	8.60E-03	1.82E-04	2.71E-04	2.40E-04
Np-238	3.64E-16	1.14E-15	0.00E+00	1.10E-15	1.87E-13	0.00E+00	6.05E-14	0.00E+00
Rn-219	2.89E-21	2.17E-21	0.00E+00	4.33E-21	3.40E-19	0.00E+00	6.34E-21	0.00E+00
Rn-222	2.87E-21	2.17E-21	0.00E+00	2.15E-21	5.51E-19	0.00E+00	3.05E-20	0.00E+00
Ru-106	5.61E-17	5.08E-14	0.00E+00	8.36E-14	1.37E-11	0.00E+00	1.96E-10	0.00E+00
SO_4^{-2}	9.08E+00	6.45E-01	1.44E+01	1.15E+01	1.07E+02	1.88E+01	4.85E+00	3.43E+01
Sb-126M	2.07E-15	1.90E-14	0.00E+00	3.42E-15	1.60E-12	0.00E+00	1.92E-12	0.00E+00
Se-79	1.47E-05	6.02E-06	0.00E+00	3.68E-05	6.71E-04	0.00E+00	8.87E-05	0.00E+00
Tc-99	7.28E-04	3.02E-04	5.99E-03	1.84E-03	3.36E-02	1.21E-02	4.43E-03	7.00E-02
U-233	2.35E-09	1.66E-09	0.00E+00	4.89E-09	5.70E-07	0.00E+00	2.06E-08	0.00E+00
U-234	6.24E-08	5.31E-08	0.00E+00	5.06E-08	1.25E-05	0.00E+00	1.85E-06	0.00E+00
U-235	9.47E-03	5.75E-03	0.00E+00	1.66E-02	3.80E+00	0.00E+00	1.10E-01	0.00E+00
U-236	9.48E-09	2.74E-08	0.00E+00	2.93E-08	2.96E-05	0.00E+00	3.25E-06	0.00E+00
U-237	3.34E-15	8.09E-15	0.00E+00	1.32E-14	1.16E-11	0.00E+00	1.13E-12	0.00E+00
U-238	1.43E+00	7.78E-01	0.00E+00	2.48E+00	5.76E+02	0.00E+00	1.56E+01	0.00E+00
UO_2^{+2}	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.28E+00	0.00E+00	2.95E+00
V^{+5}	0.00E+00	0.00E+00	3.76E-02	0.00E+00	0.00E+00	4.60E-02	0.00E+00	1.60E-03
W^{+4}	8.25E-02	5.24E-03	0.00E+00	1.51E-01	1.70E+00	0.00E+00	3.66E-01	1.77E-02

Table F.2.2.21 Concentration of Contaminants in K_d Group One (K_d=0) Associated with Waste Tanks Remediated In Situ for the Ex Situ/In Situ Combination Alternative (cont'd)

Constituent	1WSS (g/L)	2WSS (g/L)	3WDS (g/L)	1ESS (g/L)	2ESS (g/L)	3EDS (g/L)	4ESS (g/L)	5EDS (g/L)
Mo^{+6}	0.00E+00	0.00E+00	1.16E-01	0.00E+00	0.00E+00	1.54E-01	0.00E+00	1.32E-01
K^+	0.00E+00	0.00E+00	2.25E+01	0.00E+00	0.00E+00	5.58E+01	0.00E+00	6.85E+00
CO_3^{-2}	9.17E+00	2.42E-01	5.09E+01	1.28E+01	2.31E+02	2.34E+02	3.95E+00	1.02E+02
OH^-	1.28E+01	2.11E+01	7.55E+01	1.93E+01	4.00E+03	1.09E+02	7.23E+01	6.39E+01
SiO_3^{-2}	6.75E+00	3.53E+00	6.75E+00	2.54E+00	1.60E+01	3.61E+00	1.10E+00	2.30E+02

Source: Jacobs 1996

After 1,000 years, when the water flux is assumed to double to 0.1 cm/year (2.74E - 06 m/day), the dissolution rate remains constant at 360,000 mg/L. This results in a doubling of the mass flux for a 1 m^2 area to approximately 0.98 g/day, until the mass of nitrate is released for each of the eight source areas.

Low-Activity Waste Disposal Facility

The source term for the LAW disposal facility would be the result of releases from the waste, which has been vitrified and placed in vaults.

Waste retrieval from the tanks, waste separation processes, waste vitrification, vault construction, and Hanford Barrier construction are assumed to occur over a 39-year period. Activities at the LAW disposal site such as heavy equipment yards, parking lots, snow removal, and runoff diversion are assumed to have the effect of lowering the infiltration from the base value of 5.0 cm/year to 0.50 cm/year during this 39-year period. The vitrified waste is placed day thus during this 39-year period, the total water flux from infiltrating precipitation is assumed to be 0.5 cm/year (1.36E-05 m/day).

For the 1,000-year period after the Hanford Barrier has been constructed, infiltration through the Hanford Barrier is assumed to be approximately 0.05 cm/year (1.36E - 0.6 m/day). The Hanford Barrier, as a man-made structure, is not expected to maintain its design functions indefinitely. A simplifying assumption used herein is that the infiltration through the Hanford Barrier doubles 1,000 years after the Hanford Barrier was initially constructed to approximately 0.10 cm/year (2.74E-06 m/day). Infiltration is assumed to remain at this level for the remainder of the period of interest, 10,000 years from the present. Releases to the vadose zone from the vitrified waste form are assumed to begin 500 years after completing the Hanford Barrier.

The vitrification process requires the addition of materials for glass make-up. Also, the organic and other volatile materials initially present in the waste inventory are destroyed or vaporized. The release model for the glass waste form was based on a constant corrosion rate of 3E-06 cm/year. This corrosion rate is independent of the water flux from recharge. The composition of the low-activity glass is taken from the engineering data package for this alternative (WHC 1995j). The release

concentration of the contaminants is assumed to be proportional to their concentration in the low-activity glass. Because the total mass loss rate is constant, the composition of the released solution is unaffected by the recharge rate. As the recharge rate doubles after 1,000 years, the mass flux increases proportionately. The low value of the corrosion rate, combined with the very large quantity of vitrified mass, results in a calculated release time of approximately 83,000 years. The mass of contaminants placed in the LAW vaults is approximately 49 percent of the mass shown for the Ex Situ Intermediate Separations Alternative (Table F.2.2.6). The initial waste concentrations are assumed to be the same as the concentrations from the vaults for the Ex Situ Intermediate Separations alternative (Table 2.2.17).

It should be noted that the source term developed under this alternative may be overly conservative for many of the contaminants modeled because solubility controls in groundwater of neutral pH (7.0-8.0) and relatively oxidizing conditions (Eh of 300 to 400 mv SHE) will cause the contaminants to be leached at a rate less than nitrate, or because the contaminants would be insoluble under these conditions. This can be expected to effect the final results by increasing the maximum concentrations calculated in groundwater and narrowing the spread of the contaminants distribution with time.

F.2.2.3.9 Phased Implementation Alternative

There would be no contaminant release nor source of groundwater contamination under the first phase of this alternative as explained in Section F.2.1.9.

The source term for Phase 2 of this alternative would be the same as that for the Ex Situ Intermediate Separations alternative, discussed in Section F.2.2.3.5.

F.2.3 VADOSE ZONE MODELING

The approach used to predict contaminant transport through the vadose zone was to perform one-dimensional modeling through the vadose zone at each of the eight tank source areas and the LAW disposal facility. One-dimensional modeling through a uniformly porous media is a conservative approach that does not allow for lateral spreading in the vadose zone and tends to reduce the calculated time that it takes contaminants to reach the water table. This approach requires reducing the volumetric flux rates at the surface to one dimension by dividing by the area of the waste source. The corresponding model node(s) in the groundwater model were later assigned the appropriated area to allow the groundwater transport model to receive the volumetric flux for the source area.

Conceptual models were developed for each of the source areas, which included a Site-specific diagram of the model stratigraphy, the upper and lower boundaries, and a table of material units and corresponding flow and transport parameters. The conceptual model was used to guide the setup of the numerical model.

The first phase of the modeling effort entailed establishing the initial flow field (based on an assumed infiltration rate of 5.0 cm/year [2.0 in./year]) to be used to determine the initial velocity values throughout the vadose zone column. This was accomplished by performing a steady-state flow

simulation through the one-dimensional column at each site. The initialization file represents site conditions in the year 1995 (time equals zero), and was used as a startup file for each alternative.

Once the initial flow modeling was performed, the input file for each site was copied and modified to perform combined transient flow and transport modeling for each of the alternatives considered. The file at each site was modified appropriately to represent the transient fluid flux and contaminant source conditions conceptualized for each alternative. One node at the base (i.e., vadose zone and groundwater contact) of the model representing 1 m^2 (11 ft^2) in area was defined as an observation node.

The concentration and fluid flux exiting this node was tracked through time to generate a graph of concentration and fluid flux over time. From the graph, the contaminant mass entering the groundwater system from the entire source area was calculated and used to construct input records for the groundwater model.

F.2.3.1 Vadose Zone Conceptual Models

A conceptual model was developed for each of the eight tank waste sites and the LAW vault site. The conceptual model consists of Site-specific geometry, waste release information, and hydrostratigraphy, including the hydraulic parameters. The conceptual models were used to construct and run numerical transport simulations through the vadose zone. The results of the numerical modeling included the solute concentration and fluid flux released from the vadose zone to the top of the unconfined aquifer through time.

F.2.3.1.1 Hydrostratigraphy and Soil Properties

The Site-specific stratigraphy and subsequent model domain geometry were obtained from isopleth maps and boring logs contained in the 200 East Groundwater Aggregate Area Management Study Report (DOE 1993a) and 200 West Groundwater Aggregate Area Management Study Report (DOE 1993b). The basic hydrostratigraphy and hydraulic parameters for the 200 West Area sites have been extracted principally from Wood et al. (Wood et al. 1995). Hydrostratigraphy and hydraulic parameters for the 200 East Area sites and LAW vaults are based principally on Kincaid et al. (Kincaid et al. 1993). Depth and diameter values for the base of the tank were obtained from the document entitled Tank Characterization Reference Guide (WHC 1994f). Tank depths ranged from 11 to 17 m (37 to 57 ft). In cases where depths differed within a source area, the largest tank depth was used.

The basic hydrostratigraphic units (material types) consist of the following units:

Material Type	200 East Area	200 West Area
1	Hanford Formation, sandy sequence	Hanford Formation
2	Hanford Formation, gravel sequence	Early Palouse Soil
3	Ringold Formation	Pliocene/Pleistocene Unit
4	Not Applicable	Ringold Formation

Depths of tanks and major hydrostratigraphic sequences in the 200 Areas are provided in Table F.2.3.1 and Table F.2.3.2.

Table F.2.3.1 Tank Depths and Material Property Intervals Within the Vadose Zone at 200 East Source Areas

	1ESS [1]	2ESS [1]	3EDS/4ESS [1]	5EDS/ LAW Vault [1]
Tank	0 to 14	0 to 12	0 to 17	0 to 17
Hanford upper gravels (Material Type 2)	0 to 14	0 to 15	0 to 10	0 to 5
Hanford sandy sequence (Material Type 1)	14 to 65	15 to 75+	10 to 72	5 to 70
Hanford lower gravels (Material Type 2)	65 to 70+	---[2]	72 to 74	70 to 77
Ringold (Material Type 3)	---[2]	---[2]	74+	77+
Top of water table	70	75	75	85

Notes:
[1] Depth intervals are in meters belowground surface.
[2] Not present within vadose zone model profile.

Table F.2.3.2 Tank Depths and Material Property Intervals Within the Vadose Zone at 200 West Source Areas

	1WSS [1]	2WSS/3WDS [1]
Tanks	0 to 14	0 to 17
Hanford (Material Type 1)	0 to 24	0 to 37
Early Palouse Soil (Material Type 2)	24 to 28	37 to 44
Pliocene/Pleistocene Unit (Material Type 3)	28 to 33	44 to 48
Ringold (Material Type 4)	33+	48+
Top of water table	65	65

Notes:
[1] Depth intervals are in meters belowground surface.

For each of the source areas, a vertical grid spacing of 0.1 m (3.9 in.) was used. Figures F.2.3.1 and F.2.3.2 depict the system geometry used for modeling each of the source areas at 200 Areas source sites.

F.2.3.1.2 Flow Properties

Input parameters required by VAM2D for the variably saturated flow modeling include:

- Infiltration rate;
- Porous medium properties;
- Constitutive relationships for variably saturated flow; and
- Initial and boundary conditions.

These parameters and the values used for the vadose zone modeling effort are described in the following subsections.

9613409.1527

Figure F.2.3.1 Conceptual Profiles of the Vadose Zone for Source Areas in the 200 West Area

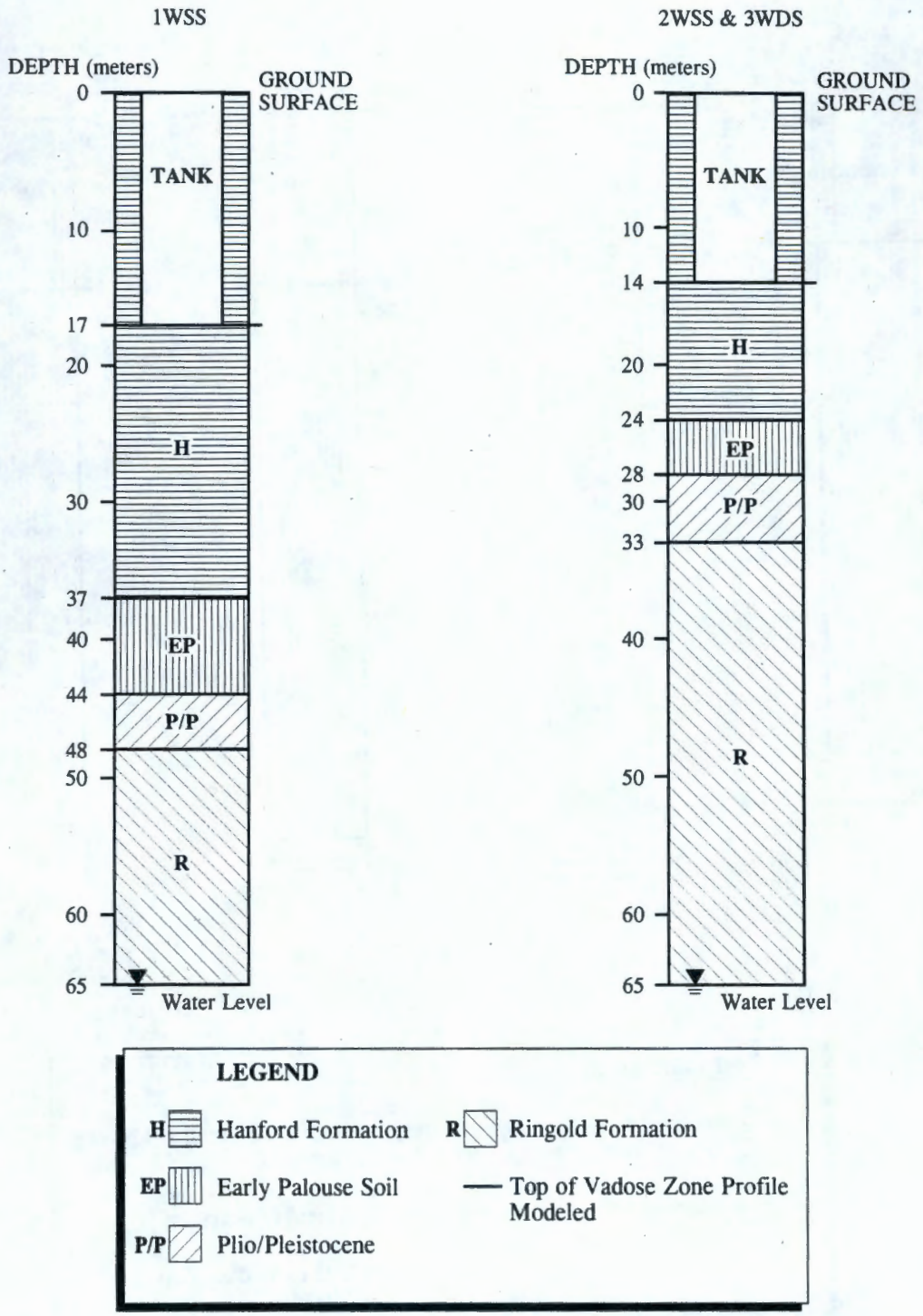
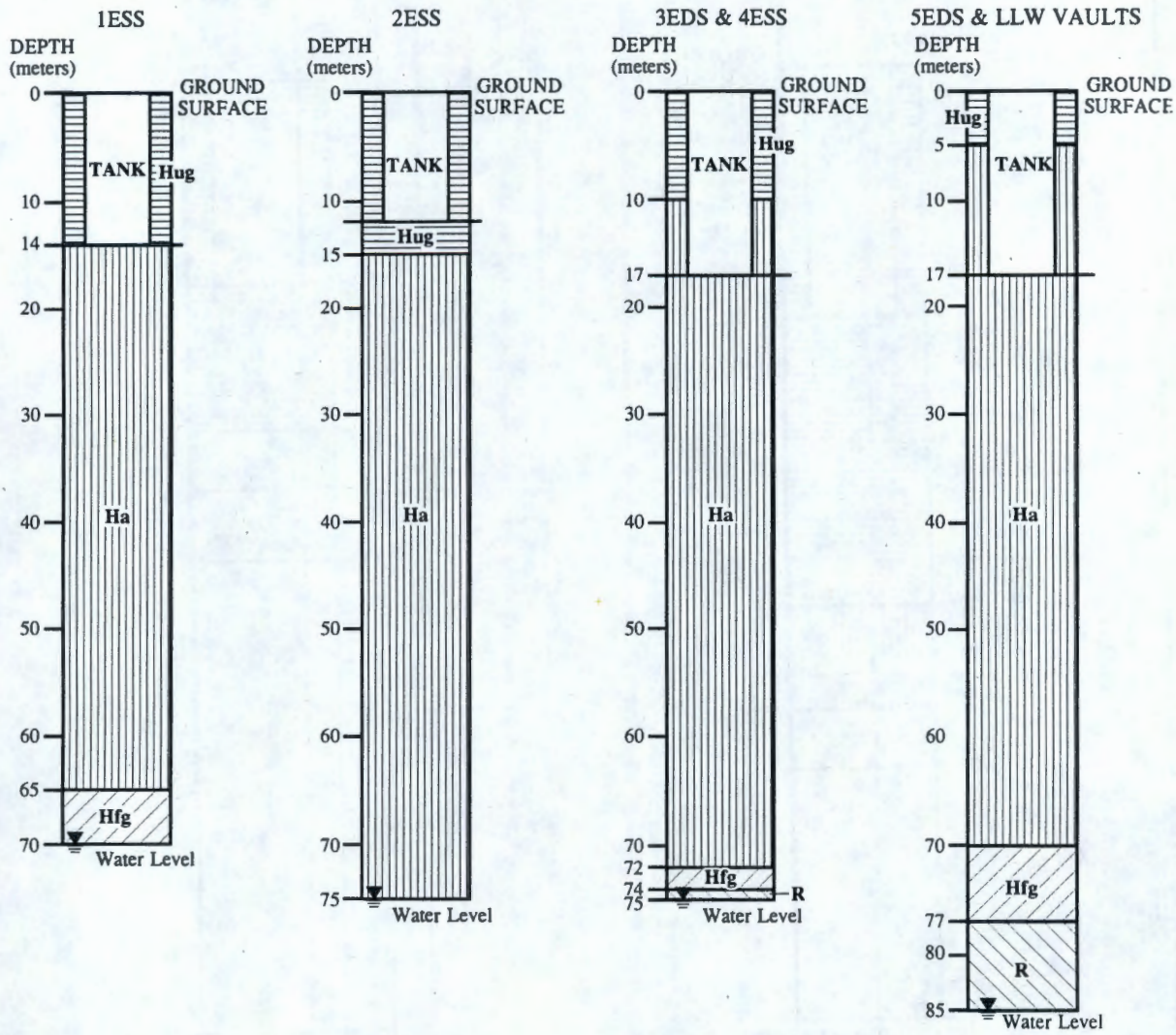


Figure F.2.3.2 Conceptual Profiles of the Vadose Zone for Source Areas in the 200 East Area



LEGEND

Hug — Hanford Formation Upper Gravel Unit	Hfg — Hanford Formation Lower Gravel Unit
Ha — Hanford Formation Sandy Unit	R — Ringold Formation
	— Top of Vadose Zone Profile Modeled

Infiltration Rate

Flow through the vadose zone is primarily controlled by the degree of water saturation in the pore space and the unsaturated hydraulic conductivity function, which is in turn affected by the quantity of infiltration (recharge) coming from the surface. As used here, the infiltration rate is the amount of precipitation that enters the soil, is not removed by evaporation or plant transpiration, and eventually reaches the groundwater table. This input of water to the model is also referred to as fluid flux.

The annual infiltration rate assumed at the Hanford Site is 5.0 cm/year (2.0 in./year) based on work reported by Gee et al. (Gee et al. 1992) and Rockhold et al. (Rockhold et al. 1990). Previous studies indicate that infiltration rates at the Hanford Site vary from 0 to 10 cm/year (3.9 in./year) depending primarily on precipitation amounts and vegetative cover. As discussed in a recent report (Rockhold et al. 1990), gravel-covered lysimeters designed to simulate tank farm conditions on the 200 Area plateau drained approximately 4.3 cm (1.7 in.) of water from an initially dry condition for the previous year. The assumed infiltration rate of 5.0 cm/year (2.0 in./year) is also consistent with vadose zone modeling for the performance assessment for the disposal of LAW in the 200 West Area (Wood et al. 1995). For additional discussion on infiltration rate, refer to Sections F.4.3.5 and Section F.4.4.

An initial steady-state velocity field was established for each site modeled. This velocity field was based on an infiltration rate of 5.0 cm/year (2.0 in./year) and was used to represent initial conditions for each alternative at time equals zero years. Infiltration conditions throughout the 10,000-year period of interest varied according to the fluid flux source term developed for the alternative, as described in Section F.2.2.3.

Porous Medium Properties

Input parameters describing porous medium properties include the vertical component of saturated hydraulic conductivity (K_s) residual saturation (S_{wr}) and the saturated and residual water content, (θ_s and θ_r, respectively). Saturated hydraulic conductivity, K_s, is defined as the rate of flow of water through a unit cross-sectional area of the aquifer under a unit hydraulic gradient at the prevailing temperature and density of the water (Walton 1985). The saturated water content, θ_s, (also referred to as the total porosity), is defined as a percentage, representing the volume of a soil or rock occupied by void spaces (pores) divided by the total volume of the soil or rock (Freeze-Cherry 1979). Residual saturation, S_{wr}, (also called specific retention) is a measure of the water retaining capacity of the rock and is expressed quantitatively as the percentage of the total volume of rock occupied by groundwater that will be retained in interstices against the force of gravity (Walton 1985). Residual water content, θ_r, is defined as the water content that remains under a relative permeability of zero. In other words, the water content that cannot be removed even under extreme levels of suction. These parameters are related according to the following equation:

$$S_{wr} = \frac{\theta_r}{\theta_s}$$

Input values for each of these parameters for each material type in the 200 East Area were primarily obtained or calculated from Kincaid et al. (Kincaid et al. 1993). These values are presented in Table F.2.3.3. Input values for the 200 West Area (Table F.2.3.4) were obtained from Wood et al. (Wood et al. 1995).

Table F.2.3.3 Porous Medium Properties for Each Material Type in the 200 East Area

	K_s (m/day) [1]	θ_s [1]	θ_r [2]	S_{wr} [1]
Hanford sandy sequence (Material Type 1)	4.330	0.420	0.023	0.055
Hanford upper/lower gravels (Material Type 2)	1.320	0.358	0.021	0.059
Ringold (Material Type 3)	0.660	0.32	0.025[3]	0.078[3]

Notes:
[1] Source: Kincaid et al. 1993, pages 3.124 to 3.128
[2] θ_r is calculated as $(S_{wr})\cdot(\theta_s)$. Source: Kincaid et al. 1993, pages 3.124 to 3.128
[3] Ringold values related to porosity were changed to reflect those in the 200 West Area.

Table F.2.3.4 Porous Medium Properties for Each Material Type in the 200 West Area

	K_s (m/day) [1]	θ_s [1]	θ_r [1]	S_{wr} [1]
Hanford Formation (Material Type 1)	10.36	0.30	0.001[3]	0.0033
Early Palouse Soil (Material Type 2)	1.42	0.39	0.056	0.14
Pliocene/Pleistocene Unit (Material Type 3)	5.18	0.46	0.13	0.28
Ringold (Material Type 3)	1.73	0.32	0.025	0.078

Notes:
[1] Source: Wood et al. 1995, page 3-24.
[2] S_{wr} is calculated as θ_r/θ_s.
[3] Value was reported as 0.0 Wood et al. 1995, and assumed to be 0.001 for this study.

Kincaid et al. (1993) specified a value of 0.498 for θ_s in the Ringold Formation in the vicinity of the 200 East Area. This value was considered unrealistically high; therefore θ_s and the related S_{wr} and θ_r values were changed to the values reported for the Ringold Formation in the 200 West Area.
The value reported for θ_r in Wood et al. (Wood et al. 1995) was 0.0. It was assumed that the reported value was below detection and was reported as a zero. Therefore, a small number (0.001) was assumed in its place to maintain the relationship between θ_s and S_{wr} stated previously.

Constitutive Relationships for Variably Saturated Flow

Two alternative functional expressions are used to describe the unsaturated hydraulic conductivity function (relationship of relative permeability versus moisture content). These functions are the Brooks-Corey relation and the van Genuchten relations. The van Genuchten relations α, β, and γ, were used for the vadose zone modeling. These parameters were selected over the Brooks-Corey parameters because they were available in the published literature at the Site.

The van Genuchten curve shape parameters (α, β, and γ) are used to characterize the hysteretic saturation-pressure head relation (i.e., hysteresis). The relation is bounded by wetting and drying

curves; thus α, ß, and γ have different values for wetting and drying. The parameter α is an empirical value, defined as the inverse of the air entry pore water pressure. The ß and γ parameters are dimensionless empirical shape factors for the wetting/drying curve.

By using several simplifying assumptions (e.g., the wet and dry values for β are equal, the wet and dry values for γ are equal, and $\gamma = 1\text{-}1/\beta$), only five parameters are necessary to characterize hysteresis; porosity, residual saturation, and shape parameters α (wet), α (dry), and β (Huyakorn et al. 1991).

Input values for the vadose zone modeling effort at the 200 Areas source areas are provided on Tables F.2.3.5 and F.2.3.6. For the 200 East Area, α and β were obtained from Table 3.42 in Kincaid et al. (Kincaid et al. 1993) and γ was calculated using the following equation, obtained from Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils (van Genuchten-Leij 1989):

$$\gamma = 1 - (1/\beta)$$

Table F.2.3.5 Van Genuchten Parameters for Each Material Type in the 200 East Area

	α (1/m) [1]	6 [2]	γ
Hanford sandy sequence (Material Type 1)	19.43	1.868	0.465
Hanford upper/lower gravels (Material Type 2)	2.90	1.613	0.380
Ringold (Material Type 3)	1.76	1.338	0.253

Notes:
[1] Source: Kincaid et al. 1993, pages 3.124 to 3.128
[2] 6 is listed as *n* of the Brooks-Corey relation (Kincaid et al. 1993).

Table F.2.3.6 Van Genuchten Parameters for Each Material Type in the 200 West Area

	α (1/m) [1]	6 [2]	γ
Hanford Formation (Material Type 1)	9.45	1.25	0.20
Early Palouse Soil (Material Type 2)	0.90	2.09	0.52
Pliocene/Pleistocene Unit (Material Type 3)	4.86	1.35	0.26
Ringold (Material Type 4)	9.16	1.81	0.45

Notes:
[1] Source: Wood et al. 1995, page 3-24
[2] 6 is listed as *n* of the Brooks-Corey relation (Wood et al. 1995).

For the 200 West Area, α and β were obtained from Table F.19 in Wood et al. (Wood et al. 1995) and γ was calculated using the preceding equation.

Initial and Boundary Conditions

Initial and boundary conditions required to define the flow field for the vadose zone simulation include:

- Initial distribution of pressure head, ψ_o;
- Prescribed values of pressure head at the water table, ψ; and
- Prescribed values of nodal fluid flux at the surface, Q.

Pressure head distribution was initialized at 0.0 for the first steady-state simulation, which assumes the soil column is fully saturated. The VAM2D model developers recommended using full saturation as an initial condition and allowing the model to adjust pressure to achieve steady-state unsaturated conditions.

Prescribed (fixed) values of 0.0 pressure head were assumed for node values at the water table (i.e., the bottom of the soil column). As stated previously, a prescribed fluid flux (recharge) of 5 cm/year (2.0 in./year) was assumed for the initial steady-state runs. This fluid flux value was also used throughout the period of interest for the No Action alternative. However, fluid flux conditions varied through time with the other alternatives, consistent with activities expected at the Hanford Site.

F.2.3.1.3 Contaminant Transport Properties

Transport parameters required by VAM2D for the vadose zone modeling effort include:

- Free water molecular diffusion coefficient, D_m;
- Longitudinal dispersivity, α_L:
- Effective porosity, ϕ;
- Bulk density, ρ_B;
- Distribution coefficient, K_d;
- Darcy velocity components of the fluid phase considered, v_1 and v_2; and
- Prescribed values of solute flux at boundary nodes, q_c.

Decay of radioisotopes was accounted for during post processing. Daughter products were not considered. A brief description of these parameters and the initial values used for the vadose zone modeling effort is provided as follows.

Free Water Molecular Diffusion Coefficient

Diffusion is the process where ionic or molecular constituents move under the influence of their concentration gradient from zones of high concentrations to zones of lower concentrations, even in the absence of groundwater flow. As a result of diffusion, concentrations will tend to equalize in all parts of the aquifer system over time (Walton 1985). For the VAM2D model, the free water molecular diffusion coefficient, D_m, is input as a porous medium property with the units of length squared per time.

Molecular diffusion coefficients depend on the solute, solute concentration, and temperature. For major ions in water (e.g., Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, SO_4^{2-}), diffusion coefficients range from 1E-09 to 2E-09 m^2/s at 25 °C (Walton 1985). Diffusion coefficients in porous materials are commonly 0.5 to 0.01 times the values of the diffusion coefficient in water, thus they typically range from 5E-11 to 1E-13 m^2/s (4.3E-06 to 8.6E-09 m^2/day) (Walton 1985). A value of 4.0E-06 m^2/day was selected to be used for transport modeling in the vadose zone.

Longitudinal Dispersivity

Mechanical dispersion is the process of the individual groundwater particles and chemical constituents traveling at variable velocities through irregular-shaped interstices and meandering streamlines. The result of this movement is the arrival of the chemical constituents at an earlier time than predicted by groundwater flow velocity alone. The VAM2D model requires longitudinal dispersivity, α_L, with units of length, to be input as porous medium properties. Because one-dimensional modeling was performed in the vadose zone, transverse dispersivity was not relevant.

Values of longitudinal dispersivity are best determined by field studies at a particular site. A discussion of longitudinal dispersivity in the unsaturated zone at Hanford is presented in the environmental setting data document (Schramke et al. 1994). This document recommends that if no value is available from the site data, the estimate to be used for longitudinal dispersivity in the vadose zone is based on the following equation:

$$\alpha_L = 0.01\ (Th)$$

Where: Th is the thickness of the layer (material unit).

Longitudinal dispersivity values used for vadose zone modeling (Table F.2.3.7) were taken from Schramke et al. (Schramke et al. 1994). These values have been calculated by Schramke (Schramke et al. 1994) and appear to be based on the reported thickness of the material unit and not determined by field studies.

Table F.2.3.7 Longitudinal Dispersivity Values for the 200 East and 200 West Areas

200 East Sites		200 West Sites	
Material	**α_L (m)**	**Material**	**α_L (m)**
Hanford sandy sequence	0.500	Hanford	0.250
Hanford upper/lower gravels	0.101	Early Palouse soil	0.150
Ringold	0.060	Pliocene	0.046
		Top of Ringold	0.060

Source: Schramke et al. 1994

Effective Porosity

Total porosity is defined as a percentage, representing the volume of a soil or rock occupied by void spaces (pores) divided by the total volume of the soil or rock (Freeze-Cherry 1979). Effective porosity, ϕ_e, is the percentage volume of soil through which flow occurs and is often quantified as the specific yield, representing the volume of water that will drain from the pore spaces of a saturated soil or rock material (aquifer). Effective porosity is typically somewhat less than the total porosity due to adhesion of water molecules to the aquifer material and cohesion of water molecules to one another and the presence of dead end pore spaces. Effective porosity was estimated from saturated and residual water content data using the relationship $\phi_e = \theta_s - \theta_r$. Calculated values are presented in Tables F.2.3.8 and F.2.3.9.

Bulk Density

Bulk density, ρ_B, is the weight per unit volume of a dry soil mass. Estimates of bulk density for the 200 Areas are provided in the Table F.2.3.10.

Table F.2.3.8 Effective Porosity Values for the 200 East Area

	θ_s [1]	θ_r [1]	ϕ_e
Hanford sandy sequence (Material Type 1)	0.42	0.023	0.397
Hanford upper/lower gravels (Material Type 2)	0.358	0.021	0.337
Ringold (Material Type 3) [2]	0.317	0.025	0.292

Notes:
[1] Source: Kincaid et al. 1993, pages 3.124 to 3.128
[2] Ringold values were changed to reflect those in the 200 West Area.

Table F.2.3.9 Effective Porosity Values for the 200 West Area

	θ_s [1]	θ_r [1]	ϕ_e
Hanford Formation (Material Type 1)	0.30	0.001	0.2999
Early Palouse Soil (Material Type 2)	0.39	0.056	0.334
Pliocene/Pleistocene Unit (Material Type 3)	0.46	0.13	0.330
Ringold (Material Type 4)	0.32	0.025	0.295

Notes:
[1] Source: Wood et al. 1995, page 3-24

Table F.2.3.10 Bulk Density Values for the 200 East and 200 West Areas

200 East Sites			200 West Sites		
Material	ρ_B (g/cm^3)	ρ_B (mg/L)	Material	ρ_B (g/cm^3)	ρ_B (mg/L)
Hanford sandy sequence	1.60	1.60E+06	Hanford	1.75	1.75E+06
Hanford upper/lower gravels	1.76	1.76E+06	Early Palouse Soil	1.65	1.65E+06
			Pliocene/Pleistocene Unit	1.65	1.65E+06
Ringold	1.64	1.64E+06			
			Top of Ringold	1.90	1.90E+06

Source: Schramke et al. 1994, Tables B.5 and B.6

Distribution Coefficient

The movement of chemical species is retarded within the aquifer due to sorption, which may include the processes of adsorption on aquifer materials, ion exchange, colloid filtration, reversible precipitation, and irreversible mineralization (Walton 1985). The distribution coefficient, K_d, quantifies the sorption process and is the slope of the curve representing the amount of solute in the solid phase to the concentration of solute in solution as follows (Walton 1985):

$$K_d = \frac{\text{mass of solute on the solid phase per unit mass of solid phase}}{\text{concentration of solute in solution}}$$

Higher values of K_d indicate lower mobility of the solute. Radionuclides were grouped into categories according to mobility (represented by the distribution coefficient) to limit the number of simulations. K_d groups are summarized in Section F.2.2.2. For additional discussion on distribution coefficient, refer to Section F.4.3.5 and F.4.4.

Darcy Velocity Components of the Fluid Phase

For the vadose zone, the Darcy velocity refers to the rate of flow of the solute through a cross-sectional area of a porous medium (the vadose zone) in response to differences in pressure. This pressure is the sum of chemical, capillary, and gravitational forces. The designations v_1 and v_2 correspond to the Darcy velocities in the x and y dimensions, respectively. Units of Darcy velocity are length per time. Because the vadose zone model was one-dimensional, only the y (vertical) component of Darcy flow was used. The average linear velocity (the average velocity of unretarded contaminant migration) can be calculated by dividing the Darcy velocity by the effective porosity.

The initial values of Darcy velocity (used as input for the combined contaminant flow and transport model) were obtained by the steady-state flow simulation through the vadose zone for the assumed infiltration rate of 5.0 cm/year (2.0 in./year) (refer to Section F.2.3.1.2). The values of Darcy velocity are written to an output file from the steady-state flow model. This output file is subsequently used as input for the transient, combined flow and transport model. The model calculates Darcy velocity at each timestep for the transient model run, based on the fluid flux source term developed for each specific alternative modeled.

Prescribed Values of Solute Flux at Boundary Nodes

Solute flux refers to the mass of solute entering the model at boundary nodes. Solute flux has the units of mass of solute per volume per time. Input for solute flux for the vadose zone model was developed for each alternative modeled. Section F.2.2.3 discusses the development of source terms for each alternative.

Decay Coefficient

Radioactive decay is the spontaneous disintegration of radionuclide atoms into new nuclides (also called daughter products), which may be stable or undergo further decay until a stable nuclide is finally created. Contaminant concentrations were adjusted in post processing as described in Section F.2.4.2 to account for radioactive decay. This was done because each radionuclide decays at a different rate. Accounting for radioactive decay during modeling would have necessitated a separate model run for each radioactive constituent.

F.2.3.2 Post-Processing for Groundwater Model Input

Vadose zone modeling results included a graph of concentration and flux values at the vadose zone and groundwater interface throughout the 10,000-year period of interest. This information was subsequently post-processed in the following manner:

- A graph was generated to represent the solute flux exiting the vadose zone for the 1 m^2 (11 ft^2) area represented by the observation node. This was compared to modeling

results for other alternatives at the Hanford Site and results from nearby source areas for the same alternatives to ensure the modeled results appeared to be valid. In particular, the times of first arrival of solute flux at the water table and the peak concentration of contaminants were evaluated.

- The concentration and fluid flux with time were imported into a spreadsheet and mass balance was calculated to verify the results adequately represented the modeled scenario. In most cases, the mass of solute flux exiting the vadose zone at the observation node was within 1 percent of the calculated mass entering the top of the vadose zone column from the source area. Mass balance could not be verified for several of the alternatives because solute was still present within the vadose zone column at the end of the time period modeled.
- The vadose zone model results generally included more than 10,000 values representing the concentration and flux at each time step. From this information, up to 12 values (Figure F.2.3.3) were selected to represent a step function for input to the groundwater model. The total mass represented by these selected values was calculated to ensure they represented the total mass exiting the vadose zone. Generally, the selected values slightly underestimated the total mass, therefore two additional time values were selected before and after the peak of the curve to flatten out the peak and achieve 100 percent of the total mass. Figure F.2.3.3 illustrates the process of choosing the values to represent input to the groundwater model.
- Based on the time versus concentration points selected previously, the mass representing 1 m^2 (11 ft^2) of the source area was multiplied by the total area, defined as the sum of tank bottom areas, to determine the total mass entering groundwater from the source. This mass was next divided by the number of nodes in the groundwater model used to represent the source area (one to four nodes, depending on the size and geometry of the source). Transient flux records were then generated for input to the groundwater model based on this information.

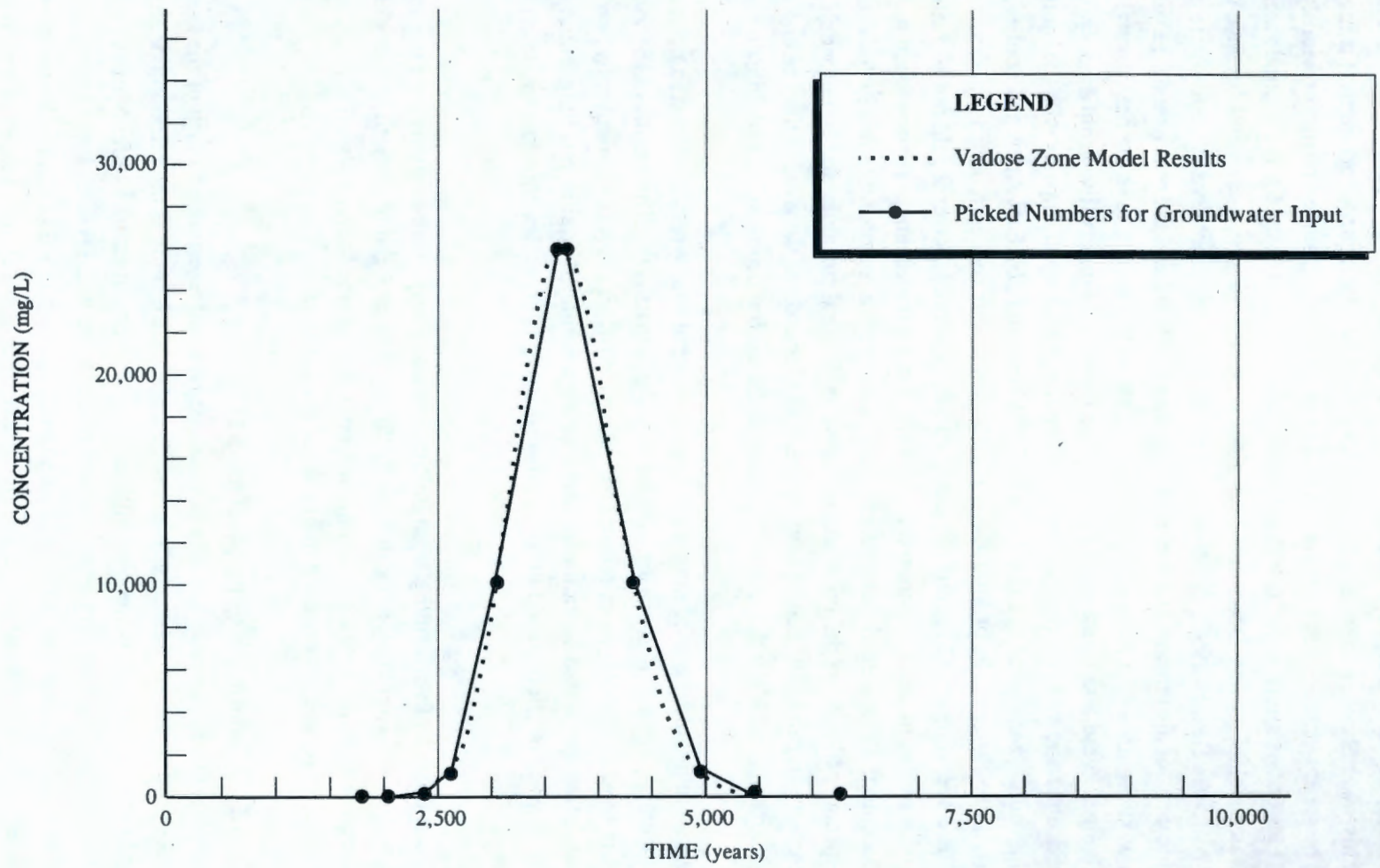
F.2.4 GROUNDWATER MODELING

Contaminant transport through the saturated unconfined aquifer was simulated with the VAM2D model at each of the eight tank source areas and the LAW disposal facility.

A conceptual model was developed for the unconfined aquifer that included stratigraphy, the upper and lower aquifer boundaries, and a table of material units and corresponding flow and transport parameters. The conceptual model was used to guide the setup of the numerical model. A grid spacing of 250 m (820 ft) was established for the Hanford Site and overlain onto a Site map containing physical features and the source area boundaries. Node numbers of model boundaries (e.g., basalt outcrop and subcrop areas, river nodes, wastewater effluent discharge points, the eight tank source areas, and the LAW disposal facility) were determined to allow numerical representation of these features for the modeling effort.

9613409.1532

Figure F.2.3.3 Example of Groundwater Model Input Development from Vadose Model Results



942\K471-135.CDR

The first phase of the modeling effort entailed establishing the steady-state flow field that was consistent with previous Site-wide groundwater flow simulations (Wurstner-Devary 1993). This was accomplished by adopting, as closely as possible, the hydraulic parameters from the previous effort. This was necessary to generate the velocity field for subsequent contaminant transport simulations. The steady-state results with the VAM2D model clearly matched results previously reported. The steady-state flow field, which is one of the principal bases for the groundwater impacts assessment, was developed using December 1979 sitewide water level measurements because it was determined (Wurstner-Devary 1993) that this data set was most representative of steady-state conditions. Using this data set also meant that the mounding from U-Pond and B-Pond would be evident. The mounding was recognized as a present-day condition that may dissipate over the next several decades with changes in the Site waste management practices. It is conservative from an overall groundwater concentration and risk perspective to determine groundwater impacts with the mounds in place because the vadose zone would be thinner in the 200 West and 200 East Areas and contaminant travel times would be faster to the groundwater, resulting in higher concentrations in groundwater and higher risk. The travel time in the unconfined aquifer to the Columbia River would not be materially affected by the groundwater mounds, compared to the vadose zone travel time. The approach based on the December 1979 water level data provides conservative, comparable results for each alternative, especially in light of the uncertainties of waste disposal practices and how it would affect the present groundwater mounds, future land use such as irrigation to the west of the site and on the site, uncertainty in the depth of contamination in the unconfined aquifer, and climate change.

Once the initial flow modeling was completed, input files were developed to perform transient transport modeling from each source area for each of the alternatives. The results of the vadose zone modeling were used to develop input records for the groundwater model. Consequently, each groundwater simulation calculated contaminant levels in the unconfined aquifer resulting from a single source area. These were later combined during post-processing to represent contaminant levels from all source areas.

The approach of performing separate contaminant transport simulations for each source area and each K_d group and later combining the results during post-processing allowed one model simulation to represent all contaminants with similar mobility from one source area. This significantly decreased the number of model runs needed to assess each alternative.

F.2.4.1 Groundwater Conceptual Model

Previous groundwater modeling efforts at the Hanford Site formed much of the basis for developing the conceptual model of the unconfined aquifer. One such study is the recent modeling effort and ongoing study for the Ground-Water Surveillance Project, performed by Pacific Northwest National Laboratory (PNL). This ongoing project includes two dimensional (2-D) modeling of regional groundwater flow using the Coupled Fluid, Energy, and Solute Transport (CFEST) code. Several documents describing this effort have been published, the most recent being the Hanford Site Ground-Water Model: Geographic Information System Linkages and Model Enhancements, FY 1993, hereafter referred to as the CFEST model document (Wurstner-Devary 1993).

A second published document specifies modeling parameter data to be used for modeling efforts in support of the U.S. Department of Energy (DOE) Programmatic Environmental Impact Statement (PEIS). This document is the Hanford Site environmental setting data developed for the Unit Risk Factor Methodology in Support of the PEIS, hereafter referred to as the environmental setting data document (Schramke et al. 1994). This document was used primarily as a source of information for the contaminant transport parameters.

F.2.4.1.1 Geology

The geology of the Hanford Site is described in detail in a number of reports (Thorne-Chamness 1992 and Tallman et al. 1979). Detailed geologic information can be obtained from these reports. Information for the following summary was obtained primarily from the environmental setting data document (Schramke et al. 1994) and the CFEST Model document (Wurstner-Devary 1993).

The Hanford Site is located on the Columbia Plateau within a structural depression known as the Pasco Basin (Schramke et al. 1994). Structural features within the Pasco Basin include two synclinal areas know as the Cold Creek and Dry Creek valleys (Kincaid et al. 1993) and three anticlinal structures known as the Rattlesnake Hills, Yakima Ridge, and Gable Mountain structures (Wurstner-Devary 1993).

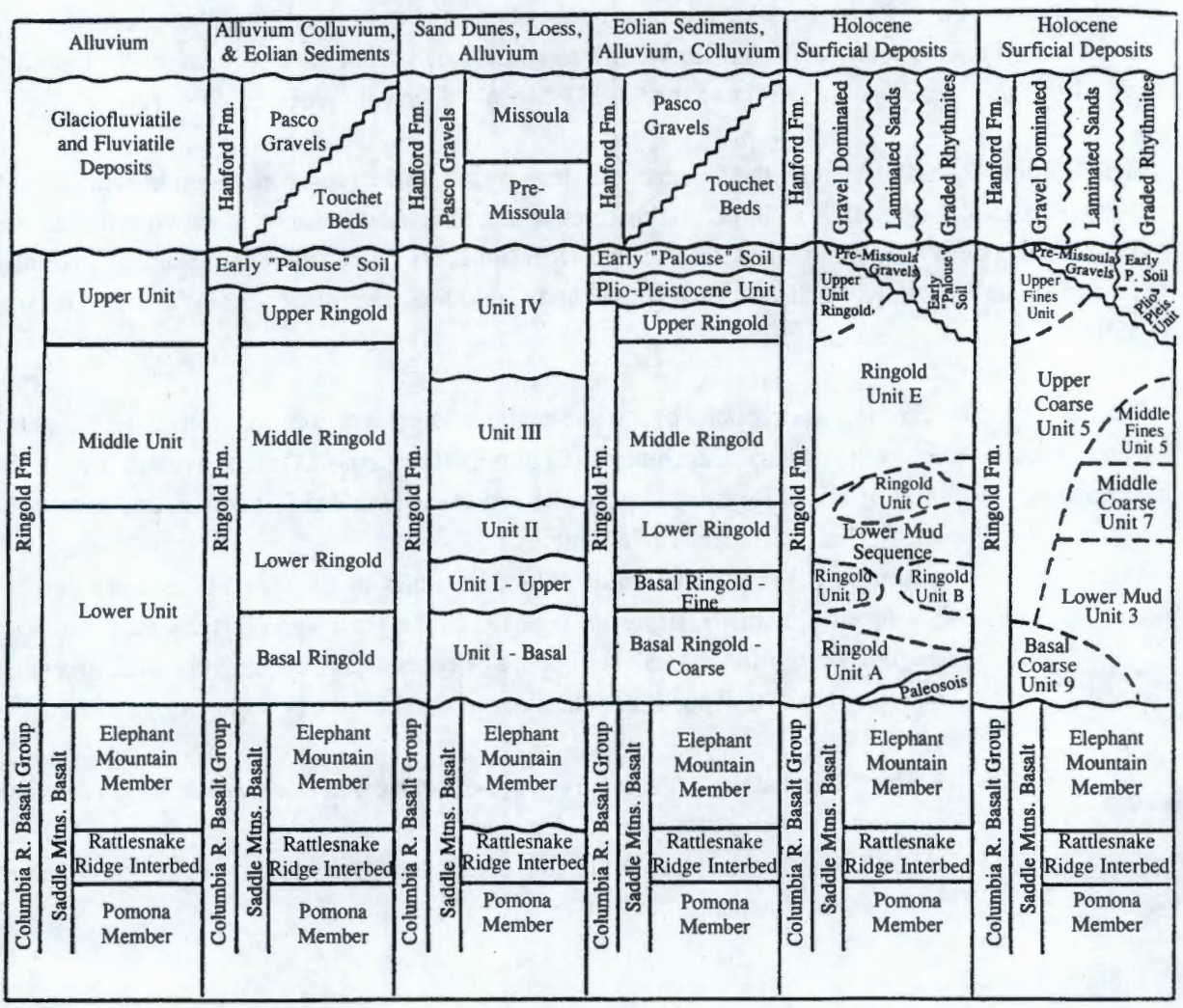
The stratigraphic column, as described by various authors, is presented in Figure F.2.4.1. Local formations, from oldest to youngest, include the Columbia River Basalt Group, overlain by the Ringold Formation, glaciofluviatile and fluviatile deposits known as the Hanford Formation, and recent alluvial and eolian sediments. These include the following:

- **Columbia River Basalt Group**. Flood basalts with associated Ellensburg Formation sedimentary interbeds, deposited 6 to 17 million years ago (Tertiary Period).
- **Ringold Formation.** A thick sequence of coarser-grained (gravel, sand, and silt) migrating channel deposits and the finer-grained overbank deposits of ancestral river systems.
- **Hanford Formation.** A complex series of coarse and fine-grained layers deposited by cataclysmic floods during the last ice age.
- **Recent deposits.** Recent alluvial and eolian deposits, primarily reworked Hanford Formation sediments.

F.2.4.1.2 Hydrology

In general, the unconfined aquifer is located within the Ringold and Hanford formations, in consolidated to semi-consolidated sediments overlying the Columbia River Basalt. Because of deposition in a structural depression, the Ringold Formation is up to 366 m (1,200 ft) thick within the Pasco Basin. The Ringold formation is up to 38 m (125 ft) thick at the 200 East Area and up to 84 m (274 ft) thick at the 200 West Area. In addition, the upper portion of the aquifer is more transmissive than the finer-grained lower portion.

Figure F.2.4.1 Stratigraphic Column for the Hanford Site Showing Nomenclature from Previous Investigations



SOURCE: Schramke et al. 1994

Historically, the unconfined aquifer was located almost exclusively in the Ringold Formation, except for a few areas near the Columbia River. A confining bed at the base of the Ringold Formation serves as an aquitard and inhibits the vertical migration of contaminants downward from the unconfined aquifer. However, wastewater discharges occurring since 1944 (Kincaid et al. 1993) have raised the water table, causing water levels to enter the Hanford Formation in the 200 East Area and in a wider area near the Columbia River (Wurstner-Devary 1993). Because of the increase in groundwater elevation, the water table is now in the Hanford Formation over much of the eastern portion of the Hanford Site (Thorne-Newcomer 1992). In general, water levels have increased at least 15 m (49 ft) in the vicinity of the 200 West Area and 5 m (16 ft) in the vicinity of the 200 East Area. The groundwater mounding created a vertical downward gradient in the areas of wastewater discharge. However, this downward gradient does not extend to the area between Gable Butte and Gable Mountain where there is an erosional window in the aquitard.

The change of the water table elevation is important to the modeling effort because the Hanford Formation is 10 to 100 times more permeable than the Ringold Formation (Wurstner-Devary 1993). Groundwater mounds of approximately 28 and 9 m (90 and 30 ft) have developed under wastewater discharge areas at the 200 Areas. Although more water has been discharged at the 200 East Area, the mound is higher at the 200 West Area because of a lower aquifer hydraulic conductivity.

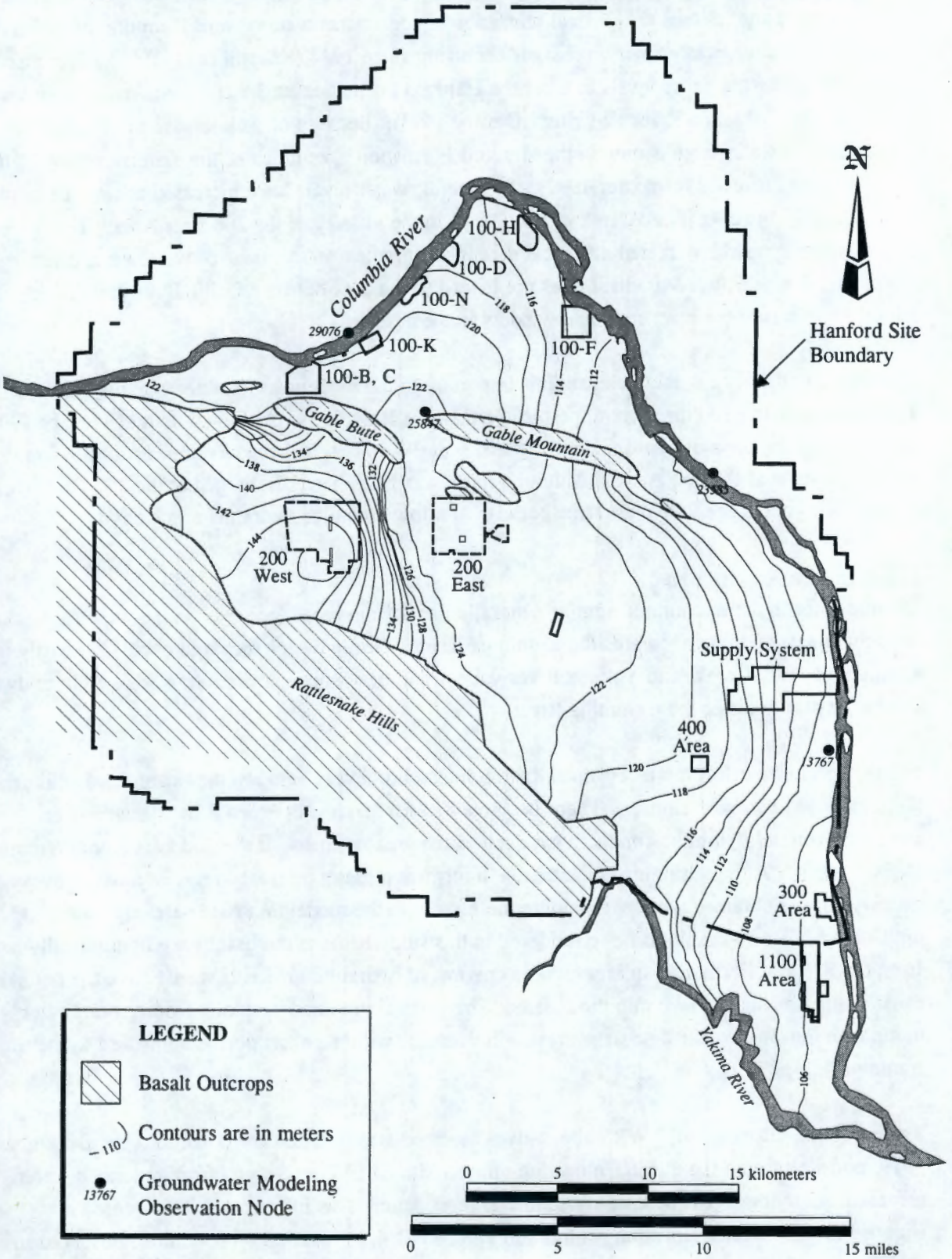
F.2.4.1.3 Flow Properties

Groundwater in the unconfined aquifer generally flows from recharge areas on the western boundary of the region east and north towards the Columbia River. Groundwater recharge occurs primarily in the Cold Creek, Dry Creek, and Yakima River valleys and in wastewater discharge areas. Groundwater discharge occurs along the Columbia River.

For the modeling effort it was assumed that no interaction exists between the unconfined aquifer and the underlying confined aquifer. There is a potential for leakage between these systems in areas of increased vertical hydraulic conductivity, such as the area northeast of the 200 East Area (Wurstner-Devary 1993). Although limited quantitative information exists on these areas, adequate flow system calibration was obtained without including these areas in the model (Wurstner-Devary 1993). Flow in the Columbia River Basalts is not considered in this study because the basalts are hydraulically isolated from the Ringold Formation in areas where downward hydraulic gradients would have the potential to cause contaminants to move into the basalts. The vertical gradients resulting from groundwater mounds in the wastewater discharge areas will dissipate within a short period compared to the time frame of interest.

The modeling effort for all TWRS alternatives assumed steady-state flow conditions for December 1979, consistent with the CFEST modeling effort. The CFEST modeling effort generated water elevation contours as part of a steady-state 2-D model run. This information is presented in Figure F.2.4.2. Water elevation contours in Figure F.2.4.2 are based on conditions observed in December 1979 (Wurstner-Devary 1993).

Figure F.2.4.2 Results of CFEST Steady-State Simulations for December 1979



SOURCE: Wurstner and Devary, 1993

Although fluid flux volumes (based on infiltration) change at the eight source sites in accordance with Hanford Site activities for each alternative, these changes in infiltration are not important to groundwater elevations and flow velocities at the Site. For example, a steady-state run based on an infiltration of 0.5 cm/year (0.2 in./year) at the tank source areas locally affected groundwater elevations by approximately 1.0E-05 m (3.2E-05 ft), compared with no infiltration at the source areas.

Transmissivity and saturated water content were based on values used for the CFEST modeling effort. Transmissivity values ranged from 5.5 to 6.5E+03 m/day (18 to 2.1E+04 ft/day). Transmissivity values used for CFEST are presented in Figure 4.2.8 of the CFEST model document (Wurstner-Devary 1993). Saturated water content was set at 0.5.

Boundary Conditions

The conceptual flow model includes several areas defined as no flow, fixed head, and fixed flux boundaries. These conditions reflect the physical conditions at the Site affecting flow. Physical boundaries include the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, and the Columbia and Yakima rivers. The boundary conditions for the modeling effort are consistent with previously published groundwater modeling efforts performed by PNL (Wurstner-Devary 1993).

The Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge are outcrop areas of the Columbia River Basalt. These three features follow the axes of anticlines (the Rattlesnake Hills Structure, Yakima Ridge Structure, and Gable Mountain Structure, respectively--see Appendix I). The Columbia River Basalt where it occurs as an outcrop or subcrop acts as a flow barrier. Consequently, the model boundary adjacent to these features is defined as a no-flow boundary. The two synclinal areas between these structures, known as the Cold Creek and Dry Creek valleys (Kincaid et al. 1993), recharge the aquifer. To achieve model calibration with the CFEST model, the Cold Creek drainage was defined as a constant head boundary, and the Dry Creek drainage was defined as a fixed flux boundary.

The Yakima River recharges the unconfined aquifer in the southern part of the AOI, creating a hydraulic gradient in this area from west to east (Wurstner-Devary 1993). The model boundary adjacent to this river is set as a constant head boundary. The Columbia River, located along the northern and eastern perimeter of the AOI, drains the unconfined aquifer and is set as a constant head boundary.

Four interior boundaries are defined by outcrops of the Columbia River Basalt. These consist of Gable Butte, Gable Mountain, and two unnamed basalt outcrop areas south of Gable Mountain. These areas are defined as no flow boundaries.

The average wastewater discharge quantities for 1979 were used as part of the flow conceptual model. These discharges influence flow conditions in the 200 Areas. Wastewater discharge areas are defined as fixed flux boundaries. Fluid flux quantities are summarized in Table F.2.4.1.

Table F.2.4.1 Summary of Fixed Flux Boundaries from CFEST Model

Flux Site Name	Flux (m^3/day)
216-B-3 (B Pond)	6.94E+03
216-B-63	8.81E+02
216-S-19	1.48E+02
216-U-10 (U Pond)	1.20E+04
216-A-10	7.0E+01
216-A-30	4.31E+02
216-A-37-1	5.4E+01
216-B-55	1.8E+02
216-B-62	4.4E+01
216-S-25	6.3E+01
West Area Ash Pit	4.7E+01
216-T-1	1.1E+01
216-T-4-2	1.4E+01
Rattlesnake Mountain Springs	1.33E+03

Additional fixed flux boundary conditions were established to allow contaminant input from the source areas. Although these boundary conditions are not defined as part of the CFEST model, their effect on groundwater elevations is inconsequential. The source area boundary conditions assumed an infiltration rate of 0.5 cm/year (0.20 in./year) would originate from the tank areas. The volumetric fluid fluxes were calculated in m^3/day by multiplying the infiltration rate by the area of the source. Fluid flux quantities of the source areas are summarized in Table F.2.4.2.

Table F.2.4.2 Source Area Fixed Flux Boundaries

Flux Site Name	Flux (m^3/day)
1WSS	4.08E-02
2WSS	4.44E-02
3WDS	3.37E-03
1ESS	4.08E-02
2ESS	1.38E-02
3EDS	1.24E-02
4ESS	1.12E-02
5EDS	3.37E-03

F.2.4.1.4 Saturated Zone Contaminant Transport Properties

Once contaminants move through the vadose zone and enter the unconfined aquifer, they migrate in the groundwater until they are intercepted by a well or discharged to the Columbia River. Generally, contaminants will move from source locations at the 200 East Area towards the east, and from source locations at the 200 West Area towards the north and east, eventually discharging to the Columbia River or one of the springs located adjacent to the river.

Previous simulations of contaminant transport in the unsaturated zone and unconfined aquifer have shown the time of travel within the vadose zone is much greater than in the aquifer (Kincaid et al. 1993). Existing tritium contaminant plumes originating in the 200 East Area reached the Columbia River in 25 to 30 years.

9613409.1536

Saturated zone contaminant transport parameters required by VAM2D for the modeling effort include:

- Free water molecular diffusion coefficient, D_m;
- Longitudinal and transverse dispersivity, α_L and α_T;
- Effective porosity, ϕ_e;
- Bulk density, ρ_B;
- Distribution coefficient, K_d;
- Darcy velocity components of the fluid phase considered, v_1 and v_2; and
- Prescribed values of solute flux at boundary nodes, q_c.

Contaminant concentrations were adjusted in post processing (Section F.2.4.2) to account for radioactive decay. A brief description of each of the above parameters is provided in the following text.

Free Water Molecular Diffusion Coefficient

Groundwater flow across the Hanford Site is sufficient to make a molecular diffusion coefficient value in the range of 2E-9 to 1E-11 m^2/second insignificant to contaminant transport simulation. Therefore, this value was set to 0.0 for the saturated zone model runs. A more detailed discussion of the molecular diffusion coefficient is provided in Section F.2.3.1.3.

Dispersion Parameters

A discussion of longitudinal and transverse dispersivity in the saturated zone is presented in the environmental setting data document (Schramke et al. 1994). If no value is available from the site data, the recommended estimate to be used for longitudinal dispersivity is based on the following equation (Walton 1985):

$$\alpha_L = 0.1\ (\mathrm{Tr})$$

Where:

Tr is the length of the travel path (plan view) from the center of the waste site to the receptor point.

Transverse dispersivity should be calculated as 1/5 of the longitudinal dispersivity (Walton 1985):

$$\alpha_T = 0.2\ (\alpha_L)$$

Walton (Walton 1985) states that the equation for α_L applies to mean travel distances less than about 305 m (1,000 ft). However, the actual relationship is not linear. Consequently, the equation may not be valid for transport simulation across the Hanford Site and should only be considered an upper bound to dispersivity. In the field, dispersivity approaches a maximum asymptotic value (Walton 1985), and the equation used to estimate longitudinal dispersivity is:

$$\alpha_L = A_d \left[1 - \frac{B_a}{L_d + B_a} \right]$$

Where:

A_d = asymptotic or maximum dispersivity (L)
B_a = mean travel distance corresponding to $A_d/2$ (L)
L_d = mean travel distance (L).

Walton (Walton 1985) also presents a graph depicting field measurements of α_L versus the mean travel distance of the plume (Figure F.2.4.3). In this graph, the maximum dispersivity value approaches approximately 125 m (400 ft). Due to the large travel distances modeled at this site, the maximum dispersivity value presented by Walton (Walton 1985) was selected for the groundwater modeling effort.

A second factor affected by the value used for dispersivity is the Peclet number, which is defined as:

$$P_e = \frac{\Delta_x}{\alpha}$$

Where α = (longitudinal) dispersivity
Δ_x = largest grid dimension in model

In groundwater modeling, the local Peclet number criterion should not exceed a value of 4, or, in cases where the flow is steady-state, it should not exceed 2 or 3 (Huyakorn et al. 1985). Applying this formula to fix the Peclet number at 2 and the longitudinal dispersivity at 125 m (400 ft) yields a maximum grid of 250 m (820 ft). Thus, the selected value of 125 m (410 ft) satisfies the Peclet number and is consistent with values observed in the field.

Effective Porosity

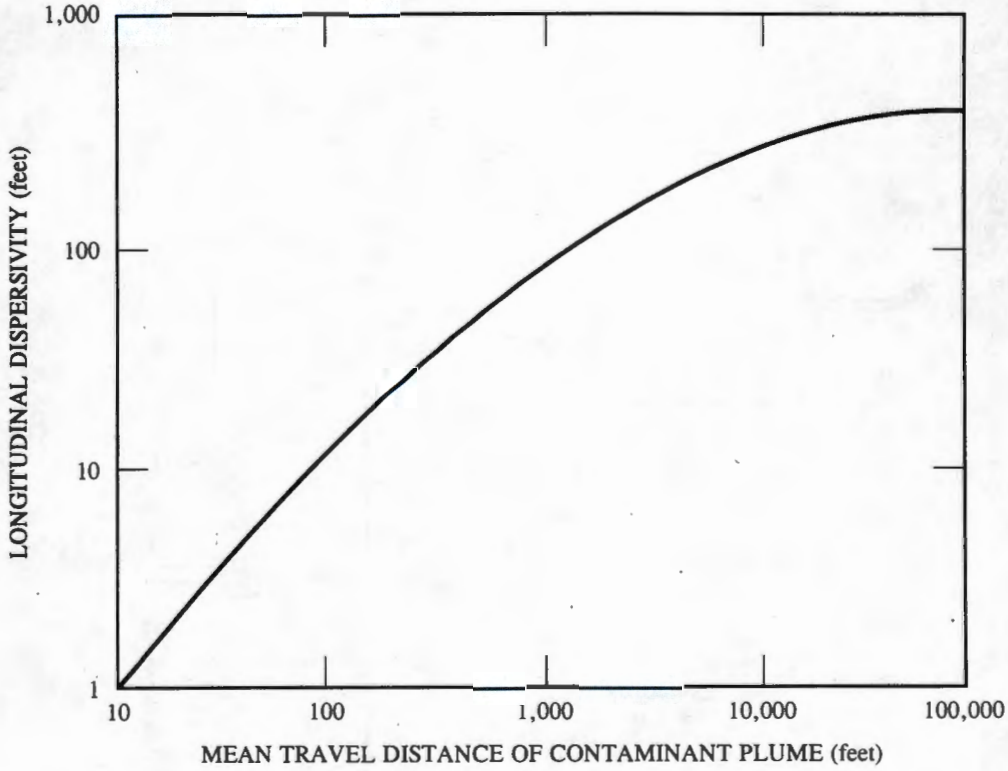
Effective porosity values estimated for the Hanford Site were presented in the environmental settings data document (Schramke et al. 1994). These values are presented by environmental setting areas, (Figure F.2.4.4) defined within the document. Table F.2.4.3 presents effective and total porosity values reported in a number of tables within Appendix B of the environmental settings data document. These data were recommended by Schramke (Schramke et al. 1994) to be used for the saturated zone at each area.

Bulk Density

Bulk density values estimated for the Hanford Site were presented in the environmental setting data document (Schramke et al. 1994). These values are presented by environmental setting areas, defined within the document and shown in Figure F.2.4.4. Table F.2.4.4 presents bulk density values reported in a number of tables within Appendix B of the environmental settings data document. These data were recommended by Schramke (Schramke et al. 1994) to be used for the saturated zone at each area.

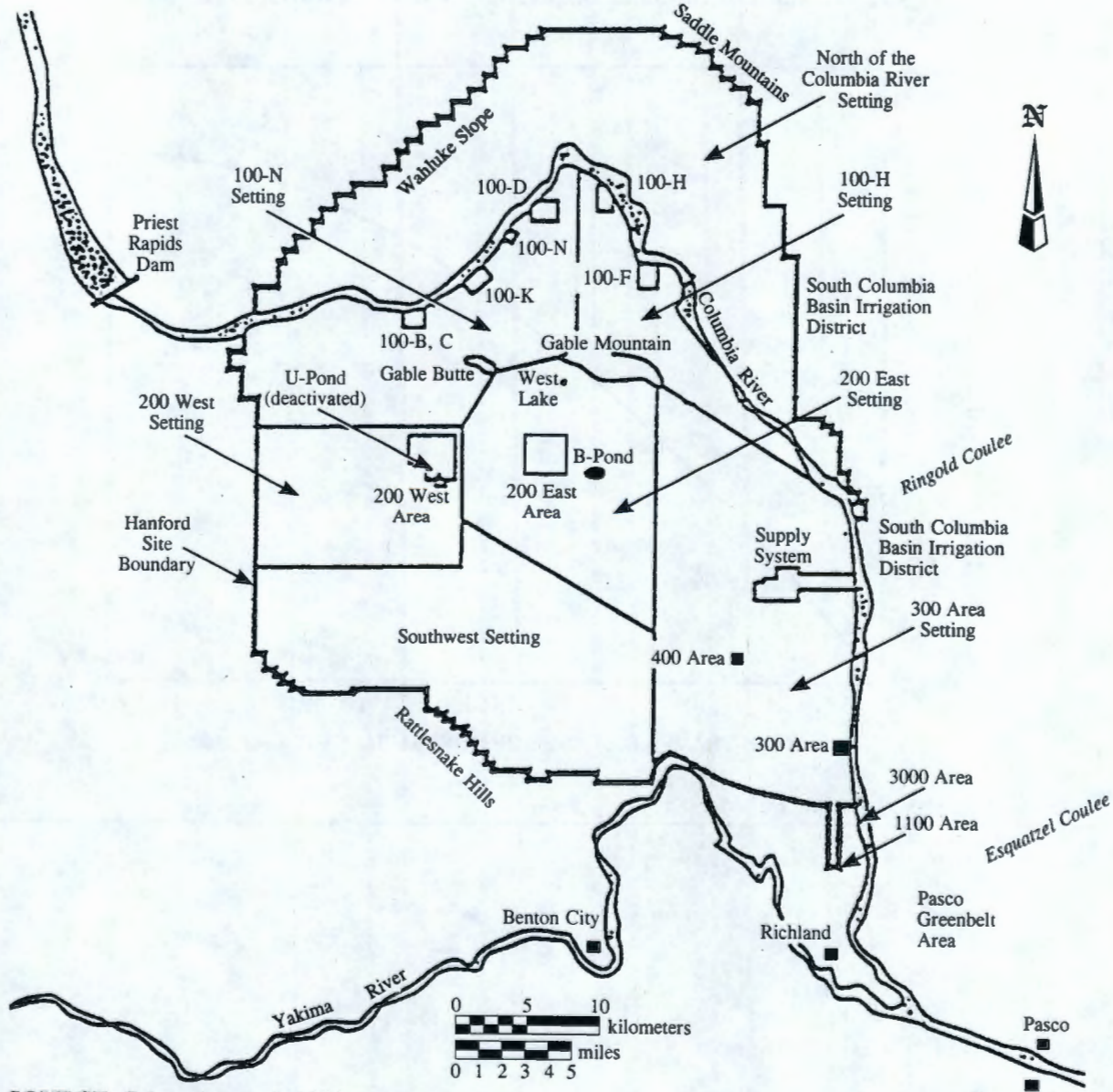
9613409.1537

Figure F.2.4.3 Longitudinal Dispersivity Values Observed in the Field



SOURCE: Modified from Walton 1985

Figure F.2.4.4 Hanford Environmental Settings Areas



SOURCE: Schramke et al. 1994

9613409.1538

Table F.2.4.3 Effective Porosity Values Recommended for the Hanford Site

Source Area	Effective Porosity	Total Porosity	Soil Classification	Percent Sand/silt/clay/organics	(pH)
100-N [1]	11.0	30.0	Loamy Sand	87/11/2/0	7.7
100-H [2]	26.0	38.0	Sand	91/6/3/0	7.5
200-East [1]	10.0	18.0	Loamy Sand	86/12/2/0	7.7
200-West [3]	11.0	36.0	Loamy Sand	87/11/2/0	7.9
300 [2]	23.2	26.0	Sand	92/6/2/0	7.1
SW setting [1]	11.0	36.0	Loamy Sand	87/11/2/0	7.64

Source: Schramke et al. 1994.
Notes:
[1] Saturated zone is reported as Ringold Formation.
[2] Saturated zone is reported as Hanford Formation - Gravels.
[3] Saturated zone is reported as Middle Ringold Formation.

Table F.2.4.4 Bulk Density Values Recommended for the Hanford Site

Source Area	Bulk Density (g/m^3)
100-N	1.90E+06
100-H	1.64E+06
200-East	1.64E+06
200-West	1.76E+06
300	2.06E+06
SW setting	1.76E+06

Source: Schramke et al. 1994.

Distribution Coefficient

To limit the number of modeling runs, radionuclides and nonradiologic tank constituents were grouped according to mobility (represented by the distribution coefficient [K_d]). These contaminant groups are summarized in Section F.2.2.2.

Darcy Velocity Components of the Fluid Phase

The Darcy velocity refers to the rate of groundwater flow through a cross-sectional area of a porous medium (the aquifer) in response to differences in hydraulic head. The designations of v_1 and v_2 correspond to the Darcy velocities in the x and y dimensions, respectively. For the groundwater modeling effort, the orientation can be thought of as an areal view, with the x component of flow oriented in an east to west direction and the y component of flow oriented north to south. This orientation differs from the vadose zone model, where the y component of flow represented vertical flow and the x component (representing lateral flow) was not used.

For the groundwater modeling effort, the flow was modeled as steady-state; therefore Darcy velocity remains constant over time. These values were obtained by performing a steady-state flow simulation of the unconfined aquifer using VAM2D. The values of Darcy velocity are written to an output file from the steady-state flow. This output file is subsequently used as input for the transient transport model.

Prescribed Values of Solute Flux at Boundary Nodes

Input for solute flux for the groundwater model was developed from the vadose zone model results at each source area for each alternative model. Section F.2.3.2, Post-Processing for Groundwater Model Input, discusses the development of the source term for groundwater.

F.2.4.2 Post-Processing Groundwater Results for Risk Assessment

The contaminants were grouped based on their mobility as represented by K_ds in the vadose zone and underlying unconfined aquifer. The contaminant groups were used rather than the individual mobility of each contaminant primarily because of the uncertainty involved in determining the mobility of individual contaminants. Where there was ambiguity, contaminants were placed within the more mobile group.

This approach required post-processing to determine contaminant concentrations for each constituent in the group, perform other adjustments as appropriate, and combine the results of each source area. The approach is conservative in that it will result in a somewhat higher overall estimation of concentration and mobility compared to an approach that uses each contaminant's estimated K_d values.

In summary, post-processing was performed in two phases. The first phase entailed reducing the data from multiple files (generally eight) at a 250-m (820-ft) grid spacing, into one file representing the desired 1-km (0.62-mi) grid spacing, for each time step of interest and K_d group. One file for each time of interest was input into the ARC/INFO geographic information system (GIS). An INFO program was written to enable GIS to perform the second phase of post-processing.

The second phase of post-processing for each of these values included adjusting the eight raw concentration data values for aquifer thickness, initial calculated concentration for each constituent, and radioactive decay. The eight adjusted values were then added to predict a single concentration value for each constituent within the K_d group at each 1-km (0.62-mi) grid node. The results of the ARC/INFO post-processing program were exported into Surfer format files for each constituent at each time of interest. Additional details for each phase are provided in the following subsections.

F.2.4.2.1 Reducing Data Results to 1-km (0.62-mi) Grid

The VAM2D model stores all predicted contaminant concentrations for each grid node for each time period of interest consecutively in one file. Thus, each output file would contain up to six data arrays, each representing one of the specified time periods of interest (e.g., 300, 500, 1,000, 2,500, 5,000, and 10,000 years from the model initiation time). Each data array contained 32,768 lines, 1 for each node of the groundwater model. Each line contained the x-coordinate, y-coordinate, and calculated concentration value. The output file for each source area was split into separate data files, each representing a concentration data array for one time period of interest. These matrix files were given a name representing the appropriate source area and time.

For each time period of interest, the eight data matrix files (one for each source area, which include 1WSS, 2WSS, 3WDS, 1ESS, 2ESS, 3EDS, 4ESS, and 5EDS) were combined into one file containing

the x-coordinate, y-coordinate, and eight consecutive concentration values. Additionally, the data were reduced from the 250-m (820-ft) model grid spacing to the desired (1-km [0.62-mi]) grid spacing. This reduced the number of concentration values representing each source area from 32,768 to 2,173.

A FORTRAN program was written to address combining the eight files (one for each source area) into one file. The program performed the following tasks:

- First, the program read in the x-coordinate and y-coordinate and calculated concentration value for the first site (1WSS) and stored these into three data arrays. Next, the program read the remaining seven files and stored only the concentration values into data arrays.
- Once all of the data were stored into arrays, the program determined if there were any negative concentration values at 1-km (0.62-mi) node points. (Negative concentration values are caused by numeric dispersion within the model. This usually only occurs early in time and at the leading edge of the contaminant plume where concentration values are low.) Negative concentration values were adjusted as follows: The program looked for two nodes on either side of the negative node that were both positive concentration values and adjusted the negative value to be the average of the two. The program looked at orthogonal values (i.e., east to west, or north to south), followed by diagonal values. If the negative value could not be resolved in this manner, it was changed to its absolute value.
- Next, values reported in the model below 1.0E-12 were changed to zero values. The VAM2D model numerically estimates concentrations at all node points for each timestep; consequently, even at the beginning timesteps of the model, nodes tens of kilometers away show minuscule numbers such as 1.23E-370. These numbers obviously are not valid predictions of contaminant concentrations; therefore, a determination was made as to where the concentration should be considered "zero." The value 1.0E-12 was chosen because it was more than 20 orders of magnitude less than the initial concentration.
- Finally, the program wrote an output file for import into the GIS. Every fourth node on the finer grid corresponded directly to the 1-km grid spacing. Therefore, only every fourth grid point and corresponding concentration was output to the GIS file. This output file contained 2,173 lines of data, each representing a 1-km (0.62-mi) node. Each line contained the x-coordinate, y-coordinate, and eight consecutive calculated concentration values corresponding to the eight sites, respectively.

F.2.4.2.2 Adjusting Raw Data to Constituent Concentrations

Once the data were reduced to a more manageable number of values, the resulting file was imported as a raw data table into ARC/INFO for additional post-processing. Each raw data table generally contained eight values (one for each tank source area) for each 1-km (0.62-mi) grid node. The steps used for this process are described in the following text.

Step One - Adjust Raw Data for Aquifer Thickness for Each Site
Two-dimensional contaminant transport modeling results in predictions of contaminants distributed uniformly throughout the thickness of the aquifer. However, Hanford Site data indicated that the majority of contaminants are concentrated within the upper portion (approximately 6 m [20 ft]) of the aquifer. The unadjusted results from the 2-D model effectively diluted concentration predictions.

To compensate for the dilution of calculated contaminant concentrations throughout the aquifer, the model code was modified by HydroGeoLogic to track cumulative mass per unit thickness (meter) as well as the cumulative mass retained within the aquifer. From this information, the average thickness of the aquifer within the area of the contaminant plume was determined and a corresponding concentration factor was calculated. The raw value at each 1-km (0.62-mi) grid node was multiplied by the concentration factor to re-distribute the contaminant into the upper 6 m (20 ft) of the aquifer.

Step Two - Adjust Results for the Initial Concentration of Each Constituent in the K_d Group
Within any one of the K_d groups, the calculated concentration of each waste constituent at any location and time within the aquifer is scalable from the concentration used in the transport simulation.

A linear relationship exists between the unit concentration used in the transport simulation and the resulting calculated concentration in groundwater for all other constituents within any K_d group. For example, if an initial concentration of 100 g/L at the source results in a concentration of 25 g/L at a given node and time, then a contaminant with an initial concentration of 10 g/L will result in a concentration of 2.5 g/L at that node and time. This relationship allows the model results for one contaminant to be post-processed for all of the other contaminants within the K_d group.

Step two entailed adjusting the raw data values at each node by the ratio of the concentration of the contaminant of interest to the concentration modeled. This step resulted in a matrix of concentration values for each constituent for the particular K_d group. For example, the concentration simulated for the No Action alternative for the K_d one group ($K_d = 0$) was based on nitrate and set at 400 g/L. For this alternative, the initial concentration of uranium-238 (U-238) was 70.036 g/L. Initial concentration values for each of the constituents for the various alternatives are provided in Section F.2.2.3. To predict the concentration values of U-238 (also in K_d group one) at site 1WSS, the result at each node was adjusted by multiplying the calculated concentration by 70.036/400 = 0.17509.

Step Three - Adjust Radionuclide Constituents for Decay at the Time of Interest
The concentration of each radioisotope was then adjusted for decay for each time of interest. The relationship used for this adjustment is $A(t) = A(0)e^{-kt}$, where k = ln 2/ half-life of the radioisotope of interest in days, and t = the time of interest (days), A(t) is the decayed concentration value at time t, and A(0) is raw data concentration value prior to decay.

For example, the half-life of U-238 is 2.34E+07 years, or 8.55E+09 days. To determine the adjustment factor for decay at 27.4 years (10,000 days) the following calculations were performed:

- $k = \ln 2 / 8.55E+09 \text{ days} = 8.11E-11/\text{day}$
- $kt = 8.11E-11/\text{day} \cdot 10{,}000 \text{ days} = 8.11E-7$
- $e^{-kt} = e^{-8.11E-07} = 9.999E-01$

To determine the concentration at each node, the raw data concentration would then be multiplied by 9.999E-01 to determine the final result at each node as follows, assuming an initial concentration value of 5.500 mg/L.

- A(t) = 5.500 mg/L (9.999E-01)
- A(t) = 5.499 mg/L

Ingrowth of daughter products was not calculated.

Step Four - Combine Results for Each Constituent

The first three steps determined calculated concentrations in groundwater for discrete source areas at each 1-km (0.62-mi) node for each constituent at each time of interest. Once this information was obtained, the eight concentration values at each node (associated with each tank source) were added to provide a single calculated concentration in groundwater from all sources. This information was stored in the INFO database and exported to an ASCII text file for final processing. Each file was then run through a program to change the format of the file so that it could be read directly into Surfer for the risk assessment task. The ASCII file contained a list of the concentration values sorted by grid location. The Surfer file was required to be in the following format:

Line 1: id (4 characters)
Line 2: nx,ny (where nx=number of grid lines along X axis, ny=number of grid lines along Y axis)
Line 3: xlo,xhi (where xlo=minimum x-coordinate of grid, xhi=maximum x-coordinate of grid)
Line 4: ylo,yhi (where ylo=minimum y-coordinate of grid, yhi=maximum y-coordinate of grid)
Line 5: grid row 1 (concentration values organized in row order)
Line 6: grid row 2
Line 7: grid row 3
.
.
.
Line 57: grid row 53

F.3.0 PREDICTED CONTAMINANT CONCENTRATIONS

This section describes the potential impacts to the groundwater aquifer from the TWRS alternatives. The discussion includes the calculated movement of contaminants through the vadose zone and unconfined aquifer. Results are presented for five time periods; 300, 500, 2,500, 5,000, and

10,000 years from the present for the primary contributor to human health risk, C14, I-129, Tc-99, U-238, and nitrate.

F.3.1 NO ACTION ALTERNATIVE (TANK WASTE)

The No Action alternative would result in the release of the total waste inventory from the 177 tanks into the vadose zone. The contaminants in K_d groups one and two, modeled as K_d equals zero and one, respectively, ultimately pass through the vadose zone and reach groundwater in the underlying unconfined aquifer, within the 10,000-year period of interest. Once in the aquifer, the contaminants in K_d group 1 move relatively quickly through the aquifer and discharge to the Columbia River.
The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.1.1 Vadose Zone

The scenario for this alterative includes the following major assumptions:

- Infiltration is 5.0 cm/year initially and throughout the period of interest;
- Contaminant release for the five SST source areas and the three DST source areas is assumed to begin at the end of institutional control in the year 2095; and
- The initial unit concentration assumed in modeling for K_d groups one and two (K_d equals zero and one) is 400,000 mg/L.

For K_d equals zero, the vadose modeling results predict contaminant first arrival at the vadose zone/groundwater interface at approximately 130 to 150 years (Figure F.3.1.1). (Note: All figures and tables follow the text.) Peak concentration at the vadose zone/groundwater interface is reached at times varying from approximately 210 to 260 years.

Contaminant concentrations from four of the five SST source areas (1WSS, 2WSS, 1ESS, and 4ESS) reach or nearly reach steady-state and the maximum possible (400,000 mg/L) concentration.
The vadose zone in the 200 West Area is generally thinner by 5 to 20 m (16 to 65 ft), compared to that in the 200 East Area. The flatter shape of the peak of the time/concentration curves for the 200 West Area sites compared to the 200 East Area sites indicates that peak concentrations calculated at the groundwater-vadose zone interface are relatively sensitive to vadose zone thickness. The fifth SST source area, 2ESS, is located in 200 East. First arrival of contaminants at the water table from this source area is similar to that from the other SST sources but the peak concentration is much lower, at approximately 28,000 mg/L. This occurs because the contaminant mass and corresponding release period (Table F.2.2.10) for the 2ESS source area is generally one or more orders of magnitude less than the other source areas.

For K_d equals one, contaminant first arrival at the groundwater varies from approximately 1,020 to 1,380 years (Figure F.3.1.2).

For contaminant groups 3 and 4 (K_d equals 10 and 50), first arrival occurs very late (i.e., beyond the 10,000 period of interest). For this reason, modeling results are not reported for these K_d groups.

F.3.1.2 Groundwater

Contaminants in K_d groups 1 and 2, modeled as K_d equals zero and one, respectively, are calculated to reach the groundwater of the unconfined aquifer within the period of interest. Two time frames were selected to illustrate the contaminant distribution in the unconfined aquifer. Figure F.3.1.3 presents the calculated nitrate distribution in the groundwater at 300 years from the present. Nitrate has assumed K_d equal to zero and thus moves at the velocity of groundwater. The time versus calculated concentration of nitrate at selected locations within the aquifer is provided in Figure F.3.1.4. Figure F.3.1.4 indicates that nitrate has moved completely through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 900 years from the present. The nitrate concentrations shown in Figures F.3.1.3 and F.3.1.4 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Figure F.3.1.5 provides the calculated distribution of bismuth in the groundwater at 5,000 years from the present. Bismuth is representative of elements in K_d group two (modeled as K_d equals one). Bismuth moves through the groundwater system at a much slower velocity than water, as illustrated in Figure F.3.1.6. This figure shows that for the selected observation nodes within the aquifer, it takes bismuth over 8,000 years from first arrival until its concentration drops back to near zero. Time versus concentration for observation nodes 13767 and 23585 exhibit a bimodal pattern (Figure F.3.1.6). These two observation points are located along the Columbia River approximately due east of the 200 Areas, and southeast of the 200 Areas, respectively. Both of these locations receive contaminants from tank sources in both 200 East and 200 West Areas. The bimodal pattern is due to contaminants reaching the Columbia River from the 200 East Area sources first, followed by contaminants from 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originates only from 200 West Area sources. These two observation nodes are located between Gable Butte and Gable Mountain and along the Columbia River near the B Reactor, respectively. The bismuth concentrations shown in Figures F.3.1.5 and F.3.1.6 have been adjusted for their initial source concentrations shown in Table F.2.2.11, and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. Also provided in Table F.3.1.1 are the calculated maximum concentrations of the contaminants in K_d groups one and two in groundwater at five periods of interest ranging from 300 to 10,000 years from the present. The values presented in this table have been adjusted for their initial source concentration and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. Figures F.3.1.7 through F.3.1.20 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 300 through 2,500 years from the present. These figures represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

F.3.2 LONG-TERM MANAGEMENT ALTERNATIVE

The Long-Term Management alternative would result in the release of the total waste inventory from the 177 tanks into the vadose zone. The contaminants in K_d groups one and two, modeled as K_d equals zero and one, respectively, ultimately pass through the vadose zone and reach the groundwater in the underlying unconfined aquifer within the 10,000-year period of interest. Once in the aquifer, the

contaminants in K_d group one move relatively quickly through the aquifer and discharge to the Columbia River. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.2.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- Infiltration is 5.0 cm/year initially and throughout the period of interest;
- Contaminant release for the five SST source areas is assumed to begin at the end of institutional control in the year 2095;
- Contaminant releases from the three DST source areas are assumed to begin 100 years after the end of institutional control in the year 2195; and
- The initial unit concentration assumed in modeling for K_d groups one and two (K_d equals zero and one) is 400,000 mg/L.

For K_d equals zero, the vadose modeling results predict contaminant first arrival at the vadose zone/groundwater interface at times varying from approximately 140 to 150 years for the SSTs and from approximately 230 to 250 years for the DSTs (Figure F.3.2.1). The difference between the first arrival times for the two tank types corresponds well to the release scenario assumed for SSTs and DSTs. Peak concentration at the vadose zone/groundwater interface is reached at times varying from approximately 210 to 350 years.

Contaminant concentrations from four of the five SST source areas (1WSS, 2WSS, 1ESS, and 4ESS) reach or nearly reach steady-state and the maximum possible (400,000 mg/L) concentration. The vadose zone in the 200 West Area is generally thinner by 5 to 20 m (16 to 66 ft), compared to that in the 200 East Area. The flatter shape of the peak of the time and concentration curves for the 200 West Area sites compared to the 200 East Area sites indicate that peak concentrations calculated at the groundwater-vadose zone interface are relatively sensitive to vadose-zone thickness. The fifth SST source area, 2ESS, is located in the 200 East Area. First arrival of contaminants at the water table from this source area is similar to that from the other SST sources, but the peak concentration is much lower at approximately 28,000 mg/L. This occurs because the contaminant mass and corresponding release period (Table F.2.2.12) for the 2ESS source area is generally one or more orders of magnitude less than the other source areas.

For K_d equals one, the vadose modeling results predict contaminant first arrival at the groundwater at times varying from approximately 1,020 to 1,470 years (Figure F.3.2.2). The time lag between first arrival of contaminants from SST source areas compared to DST source areas that was observed for K_d equals zero is not apparent for the K_d equals one simulations. This lack of contrast occurs because as the K_d increases, contaminant transport becomes increasingly more sensitive to the distance of travel (i.e., vadose zone thickness). This is illustrated by comparing the average time of first arrival at the groundwater between sources in the 200 Areas. The average time of first arrival to groundwater for the three source areas in the 200 West Area is approximately 1,290 years while the average time of first arrival for the five source areas in the 200 East Area is approximately 1,180 years. The longer

average time to first arrival to groundwater for source areas in the 200 West Area is consistent with the thicker vadose zone in the 200 West Area. Another observation apparent from the vadose modeling is that as the K_d increases, peak concentrations in groundwater decrease and duration increases for the period from first arrival until contaminant concentrations decrease back to zero. This is readily observed by comparing Figures F.3.2.1 and F.3.2.2.

For contaminant groups three and four (K_d equals 10 and 50), first arrival occurs beyond the 10,000-year period of interest. For this reason, modeling results are not reported for these K_d groups.

F.3.2.2 Groundwater

Contaminants in K_d groups one and two, modeled as K_d equals zero and one, respectively, are calculated to reach the groundwater in the unconfined aquifer within the period of interest. In the following discussion, nitrate representing a contaminant with a K_d equal to zero, and bismuth, representing a contaminant with a K_d equal to one, are used to illustrate general groundwater flow and contaminant transport in the unconfined aquifer. At the end of this subsection, additional isoconcentration maps are provided for Tc-99, I-129, C-14, U-238, and nitrate for 300 to 2,500 years from the present. These maps are provided because these contaminants exceed drinking water standards or human health advisories or have the potential to create substantial human health risk from groundwater use onsite.

Figure F.3.2.3 presents the calculated nitrate distribution in the groundwater at 300 years from the present. Nitrate has an assumed value of K_d equal to zero and thus moves at the velocity of groundwater. The time versus calculated concentration of nitrate at selected locations within the aquifer are provided in Figure F.3.2.4. Figure F.3.2.4 indicates that nitrate has moved through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 900 years from the present. The nitrate concentrations shown in Figures F.3.2.3 and F.3.2.4 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Figure F.3.2.5 provides the calculated distribution of bismuth in the groundwater at 5,000 years from present. Bismuth is in K_d group two (modeled at K_d equals one). Bismuth moves through the groundwater system at a much slower velocity than nitrate, as illustrated in Figure F.3.2.6. This figure shows that for the selected observation nodes within the aquifer, it takes bismuth approximately 7,500 years from first arrival until its concentration drops back to nearly zero. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.2.6 exhibit a bimodal pattern. Observation nodes 13767 and 23585 are located along the Columbia River approximately due east of the 200 Areas and southeast of the 200 Areas, respectively (Figure F.3.2.5). Both of these locations receive contaminants from tank sources in the 200 Areas. The bimodal pattern is due to contaminants first reaching the Columbia River from the 200 East Area sources and then followed by contaminants from the 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originates from the 200 West Area sources only. Observation nodes 25647 and 29076 are located between Gable Butte

and Gable Mountain and along the Columbia River near the 100 North Area, respectively. The bismuth concentrations shown in Figures F.3.2.5 and F.3.2.6 have been adjusted for their initial source concentrations shown on Table F.2.2.11 and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d groups one and two are provided in Table F.3.2.1 for 300, 500, 2,500, 5,000, and 10,000 years from 1995. The values presented in this table have been adjusted for their initial source concentration and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer. These selected times represent the times of concern for the risk assessment (Appendix D). Figures F.3.2.7 through F.3.2.20 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 300 through 2,500 years from the present.

F.3.3 IN SITU FILL AND CAP ALTERNATIVE

Under the In Situ Fill and Cap alternative, the complete inventory from the 177 tanks would be released into the vadose zone. Only the most mobile contaminants, those modeled as K_d equals zero, are calculated to reach the groundwater within the period of interest. The contaminant source is the same as for the No Action and Long-Term Management alternatives. The major difference between these alternatives is that a Hanford Barrier would be constructed over the tanks in the In Situ Fill and Cap alternative, which would result in a lower infiltration rate and mass flux to the vadose zone. Also, the tanks would be filled with sand and gravel to structurally stabilize the domes. Once in the aquifer, the contaminants move relatively quickly and then discharge to the Columbia River. Peak groundwater concentrations in the aquifer would be at least an order of magnitude lower than those calculated for the Long-Term Management alternative, primarily as a result of a lower infiltration rate due to the Hanford Barrier. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.3.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year;
- The infiltration rate is assumed to decrease to 0.5 cm/year in response to Hanford Site activities and decreases again to 0.05 cm/year after the Hanford Barrier is installed; the Hanford Barrier is assumed to lose integrity 1,000 years later, causing infiltration to increase to 0.1 cm/year throughout the remainder of the 10,000-year period of interest;
- Contaminant release for the eight tank source areas is assumed to begin 500 years after the Hanford Barrier is installed (NRC 1994);
- The initial unit concentration assumed in modeling is 400,000 mg/L; and
- The initial contaminant inventory and concentrations are the same as for the No Action alternative.

Contaminant first arrival at the vadose zone and groundwater interface is calculated to occur at times varying from approximately 2,330 to 3,380 years (Figure F.3.3.1). Peak concentration at the vadose

zone and groundwater interface is reached at times varying from approximately 4,080 to 6,300 years. This alternative, compared to the No Action and Long-Term Management alternatives, has a much longer calculated time to first arrival and peak concentration at the vadose zone and groundwater interface due to the lower infiltration rate through the Hanford Barrier. The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface is of a similar magnitude to that calculated for the Long-Term Management alternative. As with the No Action alternative, contaminant levels reach or nearly reach steady-state conditions with maximum concentrations of 400,000 mg/L for all source areas except site 2ESS.

F.3.3.2 Groundwater

Contaminants in K_d group one are calculated to reach the groundwater of the unconfined aquifer within the period of interest. In the following discussion, nitrate representing a contaminant with a K_d equal to zero is used to illustrate general groundwater flow and contaminant transport in the unconfined aquifer At the end of this subsection, addition isoconcentration maps are provided for Tc-99, I-129, C-14, U-238, and nitrate at 2,500 through 10,000 years from the present.

Figure F.3.3.2 presents the calculated nitrate distribution in the groundwater at 5,000 years from the present. Nitrate has an assumed value of K_d equal to zero and thus moves at the velocity of groundwater. The time versus concentration of nitrate at selected observation nodes is provided in Figure F.3.3.3. Figure F.3.3.3 indicates that nitrate concentrations reach peak concentration at approximately 5,500 years and continue at those concentration levels for approximately 1,500 years for nodes 13767 and 23585. For nodes 25647 and 29076, peak concentration is reached at about 5,000 years and continues for approximately 3,000 years. This is because nodes 25647 and 29076 would receive contaminants in groundwater from the 200 West Area sources only, and the average longevity of contaminant release into the vadose zone is approximately twice as long for the 200 West Area sites. Table F.2.2.13 provides release duration and mass for this alternative. The nitrate concentrations shown in Figures F.3.3.2 and F.3.3.3 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Contaminants have not yet reached groundwater from the sources from earlier time periods of interest (e.g., 300 and 500 years from the present). Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one are provided in Table F.3.3.1 for 2,500, 5,000, and 10,000 years from 1995. Figures F.3.3.4 through F.3.3.17 are provided to illustrate the distribution of Tc-99, I-129, C-14, U-238, and nitrate in the unconfined aquifer at time frames from 2,500 through 10,000 years from the present.

The sensitivity of the In Situ Fill and Cap alternative to changing the operating infiltration rate through the Hanford Barrier from 0.05 to 0.1 cm/year after 500 rather than 1,000 years was evaluated. This assumes that the Hanford Barrier degrades after 500 years. Results of this parameter sensitivity analysis suggest that peak concentrations of contaminants in groundwater remains the same but occur slightly earlier for the 500 year Hanford Barrier. Additional discussion of the parameter sensitivity is provided in Section F.4.3.5.

F.3.4 IN SITU VITRIFICATION ALTERNATIVE

The In Situ Vitrification alternative results in the partial release of the initial inventory from the 177 tanks into the vadose zone over the period of interest. Not all of the tank waste is released over the 10,000 year period of interest because of the low glass corrosion rate coupled with a cap over the tanks. Only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach the groundwater within the period of interest. Because the source is relatively large and the release rates are relatively low, contaminants are released at a constant concentration for thousands of years from each source area.

Once in the aquifer, the contaminants move relatively quickly and discharge to the Columbia River. Contaminant concentrations in the aquifer reach a constant level for much of the period of interest because of the long, constant concentration discharge of contaminants from the vadose zone.

F.3.4.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year;
- In response to Hanford Site activities, the infiltration rate is assumed to decrease to 0.5 cm/year and to 0.05 cm/year after the Hanford Barrier has been installed. The Hanford Barrier is assumed to lose some integrity 1,000 years later, which would cause infiltration to increase to 0.1 cm/year throughout the remainder of the 10,000-year period of interest;
- Contaminant release for the eight tank source areas is assumed to begin 500 years after the Hanford Barrier is installed; and
- The initial unit concentration assumed in modeling is 400 mg/L.

Contaminant first arrival at the vadose zone and groundwater interface is calculated to occur at times varying from approximately 2,350 to 3,410 years (Figure F.3.4.1). Peak concentration at the vadose zone and groundwater interface reach steady-state conditions with a concentration of 400 mg/L between approximately 6,250 to 7,500 years from the present and remain at that concentration for the remainder of the period of interest. This alternative, compared to the No Action and Long-Term Management alternatives, has a longer calculated time to first arrival and peak concentration at the vadose zone and groundwater interface primarily because of the lower infiltration rate through the Hanford Barrier. The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface would be lower. This is because the initial source concentrations are three orders of magnitude less than the source concentrations for the No Action and Long-Term Management alternatives.

F.3.4.2 Groundwater

Contaminants in K_d group one are calculated to reach the groundwater of the unconfined aquifer within the period of interest. The distribution of two contaminants, Tc-99 and U-238, in groundwater at selected time frames are provided to illustrate the impact of this alternative. Figures F.3.4.2 and F.3.4.3 provide the predicted distribution of Tc-99 and U-238 respectively for 5,000 years from the

present. Variations in the distribution are due to variations in the inventory of each contaminant at the eight source areas. The time versus concentration of U-238 in the unconfined aquifer at selected locations is provided in Figure F.3.4.4 where U-238 can be observed to reach steady-state conditions at approximately 6,000 years. The U-238 concentrations actually drop slightly after approximately 6,000 years because of radioactive decay. A stable contaminant such as sodium would continue at its peak or steady-state concentrations beyond the 10,000 year period of interest.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one ($K_d = 0$) are provided in Table F.3.4.1 for 5,000 and 10,000 years from 1995. Contaminants for earlier time periods (e.g., 300, 500, and 2,500 years) are not presented because they would not have reached groundwater within this time period. The predicted distribution of U-238 in the unconfined aquifer 10,000 years from the present is provided in Figure F.3.4.5. The U-238 and Tc-99 concentrations shown in Figures F.3.4.2 through F.3.4.5 have been adjusted for their assumed initial source concentration and represent the calculated concentrations in the upper 6 m (20 ft) of the unconfined aquifer.

F.3.5 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE

The Ex Situ Intermediate Separations alternative would release contaminants to the vadose zone from the 177 tanks associated with retrieval operations (from SSTs only), residual waste left in the tanks (for all tanks), and releases from the LAW disposal facility. Only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach the groundwater within the period of interest. Compared to the No Action and Long-Term Management alternatives, the mass of contaminants released from the tanks would be relatively small.

Once in the aquifer, the contaminants would move relatively quickly and discharge to the Columbia River. Contaminant concentrations from the tank source areas have a relatively sharp peak. Contaminant concentrations from the LAW disposal facility would reach peak concentrations in the groundwater approximately 6,610 years from the present and remain at their peak concentration for the remainder of the period of interest. The peak concentrations in the groundwater from the LAW facility are over two orders of magnitude less than the peaks associated with contaminants from the tank sources.

F.3.5.1 Vadose Zone

The scenario for this alternative includes the following major assumptions:

- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year for tank source areas and the LAW source area;
- In response to remediation activities, the infiltration rate is assumed to decrease to 0.5 cm/year when retrieval activities start and to 0.05 cm/year after the Hanford Barrier is installed at tank source areas and the LAW source area. The Hanford Barrier is assumed to lose some integrity 1,000 years later, which would cause infiltration to increase to 0.1 cm/year throughout the remainder of the 10,000-year period of interest for tank sources, and the LAW disposal facility.

- Contaminant release for the five SST source areas is assumed to occur during two periods: first during retrieval when the infiltration rate is 0.5 cm/yr and then from residual materials 500 years after Hanford Barrier construction when the infiltration rate is 0.05 cm/yr (NRC 1994).
- Contaminant release for the three DST source areas is assumed to result from releases from residual material 500 years after barrier construction.
- Contaminant release for the LAW facility is assumed to begin 500 years after the Hanford Barrier is constructed over the vaults (NRC 1994).
- For the tank source areas the initial unit concentration calculated is 400,000 mg/L.
- For the LAW source area the initial unit concentration calculated is 100,000 mg/L.
- For the tank source areas the initial contaminant concentrations would be the same as for the No Action and Long-Term Management alternatives. For the LAW disposal facility the initial concentrations are provided in Table F.2.2.17.

Contaminant first arrival at the groundwater is calculated to occur at times varying from approximately 1,070 to 3,420 years from the tank source areas and 3,320 years from the LAW facility. The comparatively early arrival time of over 1,000 years is related to vadose zone migration of contaminants released during retrieval when the infiltration rate is relatively high (0.5 cm/yr). Concentration versus time at the vadose zone and groundwater interface for the unit contaminant releases from the eight source areas and the LAW facility are illustrated in Figure F.3.5.1. The initial source concentration for the eight source areas and the LAW facility are 400,000 and 100,000 mg/L, respectively. It was necessary to use a different constituent to represent vadose zone concentrations for the LAW disposal facility because nitrate is not present in the vitrified waste source.

Peak contaminant concentrations at the vadose zone and groundwater interface for the tank source areas would be reached at times varying from 3,630 to 5,110 years. Peak contaminant concentrations at the vadose zone and groundwater interface for the LAW facility would be reached at approximately 6,610 years and remain at that concentration for the remainder of the period of interest. Compared to the Long-Term Management alternative, this alternative has a much longer time to first arrival and peak contaminant concentrations at the vadose zone and groundwater interface primarily because of the lower infiltration rate through the Hanford Barrier and the low corrosion rate of the vitrified waste in the LAW facility.

The calculated peak concentration for each of the eight source areas at the vadose zone and groundwater interface is lower that for the No Action and Long-Term Management alternatives for K_d equals zero by approximately an order of magnitude. Contaminants in K_d groups two through four, modeled as K_d equals 1.0, 10.0, and 50.0 mL/g, did not reach the groundwater within the period of interest.

F.3.5.2 Groundwater

Contaminants in K_d group one are calculated to reach the groundwater of the unconfined aquifer within the period of interest. Figure F.3.5.2 presents the calculated nitrate distribution in the groundwater

from the tank sources 5,000 years from the present. Nitrate has an assumed K_d equal to zero and thus moves at the velocity of groundwater.

The time versus concentration of nitrate from the tank sources at selected observation nodes are provided in Figure F.3.5.3. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.5.3 exhibit a bimodal pattern. Both of these locations receive contaminants from tank sources in the 200 Areas. The bimodal pattern is due to contaminants reaching the Columbia River first from the 200 East Area sources followed by contaminants from the 200 West Area sources. The other two observation nodes (25647 and 29076) do not exhibit the bimodal pattern because the primary source of contaminants to these points originate only from the 200 West Area sources. Figure F.3.5.3 indicates that nitrate has moved completely through the groundwater system (i.e., nitrate concentrations in groundwater have fallen to approximately zero) prior to approximately 7,000 years from the present. The nitrate concentrations shown in Figures F.3.5.2 and F.3.5.3 have been adjusted for an assumed initial source concentration of 360,000 mg/L of nitrate and represent calculated concentrations in the upper 6 m (20 feet) of the aquifer.

The calculated concentrations of U-238 versus time in the unconfined aquifer for tank sources only and the LAW vault source at selected observation nodes are provided in Figures F.3.5.4 and F.3.5.5, respectively. Time versus concentration for observation nodes 13767 and 23585 on Figure F.3.5.5 indicates that U-238 concentrations reach steady-state conditions at approximately 7,000 years and continue at those concentration levels throughout the remainder of the time period of interest. Because the LAW burial facility is located in the 200 East Area, observation nodes 25647 and 29076 remain at a concentration of zero throughout the time period of interest. This is because groundwater does not flow from the 200 East Area towards these nodes. Figure F.3.5.6 provides the predicted distribution of U-238 in the unconfined aquifer at 5,000 years from the present from both tank and LAW vault sources combined. The distribution of this contaminant is much the same as calculated for nitrate at the same time frame. The contaminant concentrations have been adjusted for their assumed initial source concentrations, radioactive decay where applicable, and represent calculated concentrations in the upper 6 m (20 ft) of the aquifer.

Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one from the tank sources are provided in Table F.3.5.1 for 2,500, 5,000, and 10,000 years from the present. Contaminants have not yet reached groundwater from the tank sources at earlier time periods of interest (e.g., 300, 500, and 2,500 years from the present). Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one from the LAW disposal site are provided in Table F.3.5.2 for 5,000 and 10,000 years from the present. Contaminants have not yet reached groundwater from the LAW disposal sources at earlier time periods of interest.

F.3.6 EX SITU NO SEPARATIONS ALTERNATIVE

Under this alternative, waste would be retrieved from the tanks, vitrified or calcined, and shipped to the potential geologic repository for disposal. A Hanford Barrier would be placed over the tanks. Groundwater impacts would result from potential releases to the groundwater system associated with

releases 1) during retrieval from the waste tanks; and 2) from residuals remaining in the tanks. The vitrified or calcined waste would not have a potential groundwater impact because they would be shipped offsite for disposal. The groundwater impacts for this alternative would be the same as those estimated for the retrieval and residual releases for Ex Situ Intermediate Separations alternative. The calculated distribution of nitrate in the unconfined aquifer 5,000 years from the present is illustrated in Figure F.3.5.2. The calculated U-238 concentrations in groundwater from the tank sources at 5,000 years is illustrated in Figure F.3.6.1.

F.3.7 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE

This alternative is similar to the Ex Situ Intermediate Separations alternative, with the only difference being that a more extensive separations process would be used. Under this alternative, waste would be retrieved from the tanks, HLW would be separated from the LAW, and both HLW and LAW would be vitrified. The extensive separations process would result in a smaller amount of contaminant source associated with the LAW vaults. A Hanford Barrier would be placed over the tanks and LAW vaults. Potential groundwater impacts would result from contaminant releases to the groundwater system 1) during tank waste retrieval; 2) from residuals in the tanks; and 3) from the LAW vaults. Groundwater impacts associated with retrieval and residual releases would be the same as for the Ex Situ Intermediate Separations alternative. This alternative would include extensive waste separation processes, but there would still be some contribution of U-238 from releases associated with the LAW vaults. Figure F.3.7.1 shows the calculated U-238 concentrations in groundwater 5,000 years from the present for both tank and vault sources.

F.3.8 EX SITU/IN SITU COMBINATION ALTERNATIVE

The tank waste Ex Situ/In Situ Combination alternative would remediate 107 tanks in situ by filling and capping the tanks using the methods described under the In Situ Fill and Cap alternative. The waste in the remaining 70 tanks (60 SSTs and 10 DSTs) would be retrieved and treated using methods described under the Ex Situ Intermediate Separations alternative. The LAW from these tanks would be disposed of in a LAW vault. The HLW would be shipped to a potential geologic repository. As with both the In Situ Fill and Cap and Ex Situ Intermediate Separations alternatives, only the most mobile contaminants, those modeled as K_d equal to zero, are calculated to reach groundwater within the period of interest.

Once in the aquifer, the contaminants move relatively quickly through the aquifer and discharge to the Columbia River. Peak groundwater concentrations in the aquifer would be at least an order of magnitude lower than those calculated for the No Action alternative, primarily as a result of a lower infiltration rate due to the Hanford Barrier, which is constructed over the tanks remediated in situ and the LAW vault. The results of contaminant transport modeling through the vadose zone and groundwater are discussed in the following sections.

F.3.8.1 Vadose Zone

The two major components resulting in releases to the vadose zone are 1) tank sources from retrieval releases and releases from tanks remediated in situ; and 2) releases from the LAW vault. The scenarios

for these components include all of the assumptions stated for the In Situ Fill and Cap and Ex Situ Intermediate Separations alternatives. For purposed of analysis, the residual that may be left in the tanks after retrieval (assumed to be 1 percent of the initial inventory from the retrieved tanks) is assumed to be additive to the inventory of tanks that are remediated in situ.

F.3.8.2 Groundwater

One of the objectives of this alterative is to reduce the number of tanks in which the waste is processed ex situ and yet achieve low calculated groundwater concentrations of the high-risk contaminants Tc-99, C-14, I-129, and uranium. These contaminants are all mobile and are in K_d group one. They, along with several other contaminants in K_d group one, are calculated to reach the groundwater in the unconfined aquifer within the period of interest. The distributions of Tc-99, C-14, I-129, and U-238 in the unconfined aquifer (U-238 being the most abundant of the tank waste uranium isotopes) are presented in this section for 5,000 and 10,000 years from the present. Although contaminant first arrival for tank sources occurs before 2,500 years, concentrations are approximately one order of magnitude lower than those predicted at 5,000 years. Therefore, contaminant distribution maps were not prepared for the 2,500-year period of interest.

Figures F.3.8.1 through F.3.8.3 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 5,000 years from the present from the tank sources remediated in situ. These calculated concentrations are from approximately 5 to 10 times lower than the concentrations calculated for the In Situ Fill and Cap alternatives. Concentrations of Tc-99 and U-238 for the LAW vault source at 5,000 years from the present are shown on Figures F.3.8.4 and F.3.8.5, respectively. Contaminant concentrations from the LAW vault source are 100 to 1,000 times lower than from tank sources. I-129 is not shown for the LAW vaults because it is not in the vault inventory.

Figures F.3.8.6 through F.3.8.8 present the calculated distributions of Tc-99, I-129, and U-238 in the groundwater at 10,000 years from the present for the tank sources remediated in situ. These calculated concentrations are from approximately 5 to 1,000 times lower than the concentrations calculated for the In Situ Fill and Cap alternative. Concentrations of Tc-99 and U-238 for the LAW vault source at 10,000 years from the present are shown on Figures F.3.8.9 and F.3.8.10, respectively. As with the 5,000 year time frame, contaminant concentrations from the LAW vault source are 100 to 1,000 times lower than from the tank sources. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d group one are provided in Tables F.3.8.1 through F.3.8.3 for the tank retrieval, in situ tank remediation, and LAW vaults contributions, respectively. The maximums calculated in these tables are not additive on a one-to-one basis because the maximums for the three components of the alternative occur at a different location within the unconfined aquifer.

F.3.9 PHASED IMPLEMENTATION ALTERNATIVE

Phase 1

There are no groundwater impacts associated with the first phase of this alternative. Waste retrieval only occurs in the DSTs, and there are no releases assumed to come from these tanks. The retrieved waste is vitrified and shipped to an onsite repository.

Total Alternative

The contaminant concentrations for this alternative would be the same as those for the Ex Situ Intermediate Separations alternative, discussed in Section F.3.5. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d Group One from the tank sources are provided in Table F.3.9.1 for 2,500, 5,000, and 10,000 years from the present. Contaminants have not yet reached groundwater from the tank sources at earlier time periods. Maximum contaminant concentrations in the groundwater for each of the contaminants in K_d Group One from the LAW disposal site are provided in Table F.3.9.2 for 5,000 and 10,000 years from the present. Contaminants have not yet reached groundwater from the LAW sources at earlier time periods.

F.3.10 EFFLUENT TREATMENT FACILITY

The effects of disposal on groundwater were simulated as entering the uppermost aquifer beneath the SALDS at a projected rate of 568 L/min (150 gal/min) over an area of 8,350 m^2 (90,000 ft^2) for 125 years. Tritium concentrations in the treated effluent entering the groundwater system were assumed to be 2.1E-05 Ci/L (21μCi/L) with a half-life of 12.3 years. The simulation results indicated that disposal of treated effluent would have little effect on the local direction for groundwater movement beneath the SALDS. Groundwater flow directions resume their northeasterly regional flow direction at a point approximately 300 m (980 ft) downgradient of the disposal site. A residence time of 100 years for tritium in the uppermost aquifer was obtained as the travel time for tritium between the disposal site and the Columbia River. Maximum tritium concentrations at the riverbank prior to dilution in the Columbia River are calculated to be 1.4E-08 Ci/L, which is below the Federal drinking water standard of 2.0E-08 Ci/L (20,000 pCi/L) (Jacobs 1996).

F.3.11 SUMMARY OF RESULTS

F.3.11.1 Observed Contamination Concentrations

Currently, hazardous chemicals and radionuclides at levels that exceed Federal drinking water standards are present in groundwater beneath the 200 Areas and in plumes emanating from the 200 Areas that are moving toward the Columbia River. Hazardous chemical contaminants observed to exceed drinking water standards include nitrates, cyanide, fluoride, chromium, chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene (Dresel et al. 1994). Radiological contaminants include I-129, tritium, Cs-137, Pu-239 and 240, Tc-99, and Sr-90. Generally, the groundwater beneath the 200 Areas is severely contaminated at levels that substantially exceed drinking water standards. For example, I-129 is present at levels that exceed standards by up to 20 times (Dresel et al. 1994). Groundwater-use restrictions have been implemented to prevent current and future uses of contaminated groundwater. Implementing any of the TWRS alternatives would add contaminants to the groundwater. However, peak concentrations from the alternatives would result in less risk than that derived from existing contaminant distributions in groundwater.

F.3.11.2 Calculated Contaminant Concentrations

Table F.3.11.1 compares the maximum calculated contaminant concentration in the groundwater for the alternatives. These calculated contaminant concentrations are for five representative contaminants at five selected times within the unconfined aquifer beneath the Hanford Site. Federal drinking water

standards are provided as a basis of comparison. The contaminants shown on Table F.3.11.1 were selected as indicators, based on the criteria of 1) mobility in the environment; 2) persistence (e.g., long half-life); and 3) high human toxicity. Many other contaminants are calculated to be released for each alternative and this information is carried forward to the human health risk assessment (Section 5.11). The following observations are based on data presented in Table F.3.11.1.

Calculated contaminant concentrations would be highest at 300 and 500 years for the No Action and Long-Term Management alternatives compared to other alternatives. The tank inventory would be released faster than any of the other alternatives because there would be no engineered barriers such as the Hanford Barrier to reduce infiltration, nor would there be any effort to stabilize the waste. For the these two alternatives, the maximum calculated contaminant concentrations would drop several orders of magnitude by 2,500 years because all $K_d=0$ contaminants would have passed through the groundwater system. The contaminant concentrations would be lowest for these two alternatives at 5,000- and 10,000-years because most of the mass released from the tanks would have currently passed through the groundwater system and discharged into the Columbia River prior to 5,000 years from the present.

At 2,500 years from the present, contaminants in the groundwater associated with the all of the alternatives, except the Phased Implementation alternative, would be evident but at lower maximum calculated concentration (e.g., by at least by a factor of 100 for nitrate) compared to the No Action alternative and Long-Term Management alternative. At this point in time, the concentration of all of the contaminants in the $K_d=1$ group for the No Action and Long-Term Management alternatives would have peaked in groundwater, and contaminant concentrations would be dropping. Conversely, source concentrations from the In Situ Fill and Cap and the Ex Situ Intermediate Separations alternatives would still be increasing and would peak between 2,500 and 5,000 years from the present.

The earliest arrival of contaminants in the groundwater associated with the In Situ Vitrification alternative would be 2,500 years from the present, and would peak between 2,500 and 5,000 years from the present.

The levels of contaminant concentrations for all of the Ex Situ alternatives would be low at all times. There would be only slight exceedances of drinking water standards.

Under all of the alternatives that include placing waste in onsite LAW vaults, the concentrations of contaminants in the groundwater would be within drinking water standards for the contaminants of concern.

F.4.0 FLOW AND TRANSPORT MODEL

The vadose zone and groundwater modeling effort used VAM2D to predict contaminant migration through the vadose zone and groundwater. VAM2D has been previously used for flow and transport assessments at the Hanford Site. The model formulation used in the code is a descendant of that used

in the SATURN code presented by Huyakorn et al. (Huyakorn et al. 1984, 1985) and was developed by HydroGeoLogic Inc. (Huyakorn et al. 1991).

The approach used for this modeling effort relies as much as possible on extensive previous work completed at the Hanford Site (e.g., hydrogeological investigations and modeling studies). Understanding and being able to predict changes in the hydraulic head of the unconfined aquifer is in an advanced stage at the Hanford Site. However, contaminant transport in the unconfined aquifer and flow and contaminant transport in the vadose zone are still in relatively early stages of understanding and development. The modeling approach was as follows:

- A combined groundwater flow and transport code (VAM2D) was used.
- Hydrogeologic and contaminant transport parameters from previous studies, including Wood et al. (Wood et al. 1995), Kincaid et al. (Kincaid et al. 1993), and Wurstner and Devary (Wurstner-Devary 1993) were used in this modeling effort.
- The VAM2D flow model of the unconfined aquifer at the Hanford Site was developed based on a previously published Sitewide calibrated groundwater flow model developed with the CFEST code (Wurstner-Devary 1993). The VAM2D flow model of the unconfined aquifer was then benchmarked against these results.

Details of the approach used to test the model are provided in the following sections.

F.4.1 FEATURES OF THE VAM2D FLOW AND TRANSPORT CODE

VAM2D is a 2-D, finite element model developed for simulating saturated and unsaturated flow and transport. Using a single model code for both vadose zone and groundwater modeling simplified the combined modeling effort. VAM2D is capable of performing flow and transport simulations in vertical cross-sections as well as horizontal orientations.

The capabilities of VAM2D applicable to the TWRS EIS modeling effort include the following:

- Simulates flow and transport in saturated and unsaturated zones;
- Solves flow and transport simultaneously or sequentially;
- Accommodates a wide range of field conditions;
- Computes hysteretic effects on flow because of wetting and drying cycles; and
- Computes the effects of variable anisotropic hydraulic conductivities on flow in stratified media.

F.4.2 LIMITATIONS OF THE TRANSPORT MODEL

Limitations of VAM2D specified in the user's manual (Huyakorn et al. 1991) include the following:

- Does not simulate three-dimensional flow. However, a two dimensional analysis is appropriate for the site in that there is a lower confirming bed in the Ringold Formation, and sufficient data to develop a three-dimensional flow and transport model may not be available;

- In performing variably saturated flow, the code handles only single-phase flow (i.e., water) and ignores the flow of a second phase (i.e., air or other nonaqueous phase). This is not a concern as aqueous phase liquids are not reported in site inventory;
- The code does not address kinetic sorption effects and/or reversible chemical reactions; and
- The groundwater flow portion of the model was executed for steady-state conditions. This did not allow simulation of the decay of the groundwater mounds associated with waste disposal activities.

F.4.3 RELIABILITY TESTING OF CALCULATED RESULTS

Several tests may be performed to demonstrate a model's ability to reasonably predict flow and contaminant transport. These include:

- Verification - Comparing the numerical solutions generated by the model with one or more analytical solution or with other solutions.
- Benchmarking - Testing the model solution against the solution of other models for the same problem.
- Calibration - Establishing that the model can reproduce field-measured conditions.
- Validation - Comparing model results with detailed field data.
- Parameter Sensitivity - Quantifying the uncertainty in the calibrated model caused by uncertainty in the estimates of the parameters used.

The following sections describe reliability testing performed on VAM2D for the Hanford Site.

F.4.3.1 Verification

A number of tests were performed to ensure reliability of the code on the computer platform used for the modeling effort (IBM RS/6000 workstation) and to compare results with known analytical solutions. These included the following:

- Initially verifying the model against sample problem 1 in the VAM2D User's Manual;
- Verifying results for saturated flow against an analytical solution (Dupuit solution) (Fetter 1994); and
- Verifying results for saturated transport against an analytical solution (Domenico solution [Domenico 1985]).

The sample problem results matched the results published in the VAM2D User's Manual for head, saturated value, and x-velocity. Y-velocity values differed slightly, however the differences were less than 2.0E-13. The results published in the user's manual were for VAM2D Version 5.2; Version 5.3 was used for this modeling effort.

For the flow problem to be solved with the Dupuit solution, a simple model was constructed and solved for unconfined flow with fixed head boundaries at each end and fixed across a transect. The analytical solution was calculated for several points and compared to the model results. VAM2D model results

very closely matched the Dupuit solution. Results calculated by VAM2D compared to the analytical solution are provided as follows.

Distance from Left Boundary	Head Calculated by VAM2D	Head Calculated by Dupuit Solution
12.5 m	5.844 m	5.846 m
37.5 m	4.980 m	4.981 m

For the transport problem to be solved with the Domenico solution, a simple 2-D model was constructed and solved for transient transport. A contaminant was input at one grid node and a transient model run was performed to predict contaminant concentrations for several node points at a specified point in time (300,000 days). Concentrations based on the Domenico solution were calculated for several points and compared to the model results. VAM2D model results very closely matched the Domenico solution. Results calculated by VAM2D compared to the analytical solution are provided as follows.

Grid Location		Concentration Calculated	Concentration Calculated
Delta X	Delta Y	by VAM2D	by Domenico Solution
10 m	0 m	453.3 mg/L	455.71 mg/L
20 m	5 m	85.08 mg/L	83.15 mg/L
30 m	0 m	270.5 mg/L	273.71 mg/L
40 m	10 m	14.60 mg/L	13.73 mg/L

F.4.3.2 Benchmarking

The groundwater flow model effort was developed and benchmarked as follows:

- Unconfined aquifer flow parameters and boundary conditions used to set up the VAM2D model were developed from published groundwater flow modeling work using CFEST (Wurstner-Devary 1993). This effort has undergone verification, calibration, and quasi-validation efforts, which were initiated in the mid-1960's.
- VAM2D predictions of hydraulic head were compared to these published CFEST results (Wurstner-Devary 1993). Basic differences in the model input requirements and the grid used required minor adjustments, primarily to boundary discretization, to obtain a closer match.

Figure F.4.3.1 shows both the published results from prior model development and the hydraulic heads calculated with the VAM2D model. As expected, this figure indicates good agreement between the VAM2D results and the previously published results.

F.4.3.3 Calibration

Calibration of a groundwater model consists of comparing its results to an independent standard. Changing flow conditions at the Hanford Site make an absolute calibration infeasible. However, a qualitative calibration can be performed. This qualitative calibration begins by examining the

geometry of a tritium plume that is present on the Hanford Site and estimating tritium travel times from the 200 East Area to the Columbia River. Contaminants originating from the 200 East Area are estimated to take approximately 20 to 25 years to reach the Columbia River. The estimated travel time is based on site operations beginning in the 1940's and detection of contaminants in springs and groundwater in the 1970's.

In this qualitative calibration effort, the VAM2D model was used to simulate a contaminant concentration of 200,000 mg/L source originating from B Pond in the 200 East Area. Discharge fluid fluxes were based on 1979 data, and the transient transport simulation was based on the steady-state field (also based on 1979 data). Figure F.4.3.2 provides estimates of tritium levels observed in groundwater based on 1977 environmental monitoring (Meyers 1978). Figure F.4.3.3 provides the 300 mg/L isoconcentration lines for tritium at 10, 20, and 30 years, assuming this constant discharge rate. Figure F.4.3.3 demonstrates that the travel times calculated by VAM2D correspond well with the assumed 20- to 25-year travel time. Additionally, the plume geometry for the tritium plume originating from the 200 East Area (Figure F.4.3.2) is similar to the predicted plume geometry (Figure F.4.3.3). An exact match between these two plumes should be not expected because discharge amounts varied substantially over time, and the observed tritium plume (Figure F.4.3.2) was created by multiple sources. However, similarities between the two plume geometries indicate that the VAM2D results are reasonable.

F.4.3.4 Validation

Validating a groundwater model consists of comparing model results with detailed field data. However, rigorous validation requires accurate historic data on effluent discharges as a function of time.

Although data are available on flow and transport within the unconfined aquifer, the data set is not sufficient to perform a detailed model validation. Flow conditions have changed dramatically since the early 1940's, primarily as the result of changes in wastewater discharges. Historic records of effluent amounts and water quality have not been maintained since that time in sufficient detail to perform a rigorous validation of flow and transport in the unconfined aquifer.

F.4.3.5 Parameter Sensitivity

Parameter sensitivity was investigated for the following areas:

- The effect of higher glass surface areas for the In Situ Vitrification alternative;
- The effect of changing the performance period of the Hanford Barrier from 1,000 to 500 years;
- The effect of the decay of the potentiometric head resulting from groundwater mounding due to discharge to the Hanford Site ponds;
- The effect of variations in filtration rate; and
- The effect of variations in distribution coefficient (K_d).

In Situ Vitrification Surface Area

As part of parameter sensitivity analysis, the vitrified glass surface area was assumed to have doubled to represent the case where extensive cracking of the waste form occurred. This higher surface area resulted in doubling the corrosion rate. The predicted U-238 concentrations in groundwater at 5,000 and 10,000 years, respectively, at the higher corrosion rate are provided in Figures F.4.3.4 and F.4.3.5. Comparing these figures with Figures F.3.4.3 and F.3.4.5, which are based on the original corrosion rate shows that the calculated contaminant concentrations in groundwater at the higher surface area are almost indistinguishable from those calculated for the base case analysis.

500-Year versus 1,000-Year Hanford Barrier

There is some uncertainty concerning the long-term performance of the Hanford Barrier that would be placed over the tanks and the LAW vaults. Using the In Situ Fill and Cap alternative as a basis for comparison, this uncertainty was investigated. The Hanford Barrier that would be placed over the tanks is assumed to degrade 500 years after placement instead of 1,000 years as is assumed in Section F.3.3. At 500 years the water flux through the Hanford Barrier is assumed to double from 0.05 cm/year to 0.1 cm/year. The calculated nitrate concentration at selected locations within the unconfined aquifer is provided in Figure F.4.3.6. Comparing this figure with Figure F.3.3.3 demonstrates that there is no significant difference in peak concentrations of nitrate, the most abundant and mobile contaminant. The time of arrival of contaminants (using nitrate as an example) is slightly earlier for the 500-year Hanford Barrier. A comparison of Figures F.4.3.7 and F.3.3.16 for calculated U-238 concentrations in groundwater at 10,000 years from the present indicates that U-238 concentrations are low for both cases and, for the 500-year Hanford Barrier, calculated U-238 concentrations are lower by approximately a factor 5 to 10. This occurs because the higher water flux through the 500-year Hanford Barrier allows U-238 to travel faster through the vadose zone and the groundwater system.

Groundwater Mounding

Because the VAM2D model used a steady-state flow field to simulate the transport of contaminants in the unconfined aquifer, it was not possible to quantify the effects of the dissipation of the groundwater mounds caused by discharge to the Hanford Site ponds.

Groundwater gradients in the unconfined aquifer are expected to take on a more easterly direction, much like that calculated in the hindcast of the water table for the Hanford Site (Figure F.4.3.8). The hindcast predicts water levels in the unconfined aquifer before the impacts of waste disposal and associated mounding from the ponds.

Similar water levels are also predicted by a forecast groundwater flow model recently completed by Dresel (Dresel et al. 1995). The predicted water level contours for the year 2040 (Figure 2.11 from Dresel et al. 1995) illustrate the response following dissipation of the groundwater mounds. The forecast predicts water level elevations very similar to present conditions with the exception of a more pronounced easterly direction of flow. Overall elevations are very similar to present conditions and elevations predicted by the hindcast are also similar to present conditions.

The dissipation of the mounds is expected to cause contaminants in the vicinity of the 200 East Area to flow in a more easterly direction. However, because the overall gradient in the aquifer would remain relatively unchanged, travel times to the Columbia River and expected concentrations and the risk associated with those concentrations is expected to be approximately the same. The possible difference might be shifting the area where the risk occurs slightly to the north.

During calibration of the model, it was decided that sufficiently accurate predictions would result from calibration based on presently observed conditions of potentiometric head. Predictions of contaminant migration based on assumed changes from existing conditions until 10,000 years in the future would not provide increased certainty.

Variations in Infiltration Rate

An infiltration rate of 5.0 cm/yr is assumed as the initial condition for all of the alternatives. For those alternatives involving active remediation such as the In Situ Vitrification and Ex Situ Intermediate Separations alternatives, the infiltration rate was assumed to be reduced to 0.5 cm/yr during the remediation period (e.g., during waste removal and cap construction).

The assumed infiltration rate of 5.0 cm/yr is an appropriate value that is within the range of reported values. Prior to site development in the early 1940's, the infiltration rate was likely much lower, on the order of a few millimeters per year, characteristic of the 200 Area Plateau under naturally vegetated conditions. As the tank farms were constructed, the natural vegetation was removed and the vicinity around the tanks was covered with sand and gravel. The current infiltration rate in the vicinity of the tanks is believed to be on the order of 10 cm/yr. This higher infiltration rate is temporal. It would be greatly reduced with the installation of a cap or return to natural shrub-steppe type ground cover.

To estimate the sensitivity of the overall results (e.g., concentration of tank wastes predicted in groundwater) to the initial infiltration rate of 5.0 cm/yr, an alternative infiltration scenario was developed for the In Situ Fill and Cap alternative as follows. For this alternative infiltration scenario, the initial infiltration rate is assumed to be 1.0 cm/yr for the 200 Area Plateau under natural vegetation. In the year 1955, it is assumed that the infiltration rate increased to 10 cm/yr and remains at this rate until after the cap construction is complete in the year 2023 for all source areas. At this time, the infiltration rate is reduced to 0.05 cm/yr and remains at this level for 1,000 years. All other aspects of the In Situ Fill and Cap alternative are as were assumed in the Section F.2.2.3.3. Contaminant flow and transport through the vadose zone for 3 of the 8 source areas was then simulated using this infiltration scenario. The source areas and their total vadose zone thicknesses (from the base of the tanks to the water table) are:

Source Area	Vadose Zone Thickness m (ft)
1WSS	51 (167.3)
2WSS	48 (157.4)
5EDS	68 (223.0)

These source areas were chosen because they bound the range of vadose zone thicknesses. When the results of this alternative infiltration scenario, in the form of time versus concentration, are compared to the nominal case (e.g., initial infiltration rate of 5.0 cm/yr) they are nearly identical with less than 1 percent difference between calculated concentrations.

Variations in Distribution Coefficients

As explained in earlier sections, the distribution coefficient (K_d) value for a specific contaminant is an indication of the mobility of the contaminant within the aquifer system. Contaminants with lower K_ds are more mobile and contaminants with higher K_ds are less mobile. Contaminants with K_ds of 0 and 1 mL/g have been calculated to arrive at the interface between the vadose zone and groundwater within the 10,000 period of interest for both the No Action and Long-Term Management alternatives. For the other alternatives, only contaminants in K_d Group 1 (K_d equal to 0) have been calculated to arrive at the interface between the vadose zone and groundwater within the 10,000 period of interest because the influx of precipitation into the waste is greatly reduced by the cap. Not all of the contaminants in K_d Group 1 have a K_d of zero. Uranium is an example of a contaminant that, while conservatively placed in K_d Group 1, likely has a K_d between zero and one. The Ex Situ Intermediate Separations alternative was selected as representative of alternatives that incorporate a cap and was used as the basis for estimating the sensitivity of contaminant transport for K_d values between zero and one.

Sensitivity of contaminant travel time through the vadose zone to various K_d values was evaluated by varying K_d for this alternative and for the 1WSS source area and then tabulating the arrival time at the vadose zone/groundwater interface for several K_d values. The range of K_d values selected for analysis and the times of first arrivals calculated by the model are as follows:

K_d Value (mL/g)	**First Arrival at Vadose Zone/Groundwater Interface** (years)
0.00	1,506
0.05	5,286
0.075	6,978
0.10	8,607
0.125	10,191

For K_d greater than 0.125 mL/g, first arrival did not occur until just beyond the 10,000-year period of interest. This is important for contaminants, such as uranium, that are reported to have K_d values of approximately 0.6 mL/g at the Hanford Site, as they would not reach the groundwater within the period of interest for alternatives that include a cap.

F.4.4 MODELING ASSUMPTIONS AND UNCERTAINTIES

Appendix F provides the basis of potential groundwater impacts associated with each of the TWRS alternatives. Developing the groundwater assessments provided in this appendix required several assumptions to uncertainties of some of the data. The major assumptions and uncertainties are related

to either the natural system (i.e., an understanding and ability to assign vadose zone and aquifer parameter values) or uncertainties inherent to the assessment approach.

The most important assumptions and uncertainties are as follows:

- The rates of infiltration into natural ground and through a cap;
- Distribution coefficient (K_d) of contaminants;
- Uncertainty in future groundwater flow direction due to decay of groundwater mounds onsite;
- Uncertainty in future groundwater flow direction and vadose zone thickness due to climate change;
- Uncertainty in vadose zone transport due to use of one-dimensional flow and transport simulation; and
- Uncertainty due to calculation of releases during retrieval.

Infiltration

The initial infiltration of precipitation into the vadose zone is assumed to occur at a rate of 5.0 cm/yr initially. Infiltration is one of the key diving forces for contaminant movement through the vadose zone. Infiltration affects the time of contaminant transport through the vadose zone: a higher rate results in a faster flow rate within the vadose zone and a shorter contaminant transport time.

Infiltration varies temporally and aerially. The temporal variation occurs seasonally with the change in temperature, plant activity, and precipitation. It also varies with climatic change. The spatial variation occurs with changes in vegetation type, surficial soil type, and man-made structures, such as paved parking lots. In response to infiltration rate changes, the vadose zone flow field varies temporally and spatially. However, it is not directly measurable with conventional techniques and is calculated by the model based on vadose zone parameters and the assumed infiltration rate. There is also a lag time between a change in infiltration rate at the surface and a change in the flow field in the vadose zone as the water percolates into the ground.

For each alternative, the initial infiltration rate (i.e., the rate before implementing remediation or no action) is assumed to be 5.0 cm/yr. This assumed initial infiltration rate is within the range of reported values for the Hanford Site and is appropriate given 1) the recent ground cover changes in the tank vicinity; 2) the uncertainties in future ground cover conditions; and 3) the one-dimensional vadose zone flow and transport model used for the simulations. Also, for alternatives that incorporate a cap, limited sensitivity analysis has shown that the contaminant transport through the vadose zone in not sensitive to the initial infiltration rate (Section 4.3.5).

From a temporal perspective, the higher infiltration in the vicinity of the tanks is a relatively recent occurrence, which is in response to the ground cover modifications that have occurred within the last 50 years. The relatively recent modifications in ground cover are not expected to have changed the flow field at depth within the vadose zone from that of predevelopment conditions. For alternatives involving a cap, conditions after the cap is installed are assumed to be representative of predevelopment

conditions in that the infiltration in the tank vicinity would be very low. Infiltration is assumed to remain at 5.0 cm/yr for the No Action and Long-Term Management alternatives.

Spatially, the rate would be expected to be lower away from the tanks where vegetation is present and surficial soils are of a finer texture. The one-dimensional model used for contaminant transport simulations through the vadose zone does not account for these infiltration changes with time and space. Thus, the assumed infiltration rate of 5.0 cm/yr was chosen as a conservative estimate.

Infiltration in the 200 Areas is reported to range from near 0 cm/yr where the ground cover is a shrub-steppe type characteristic of predevelopment conditions to 10 to 13 cm/yr, where the ground is unvegetated sand and gravel, characteristic of conditions around the tank farms since the mid-1940's or later (Gee et al. 1992).

The No Action and Long-Term Management alternatives are the only two alternatives that do not involve placement of a cap over the tanks. If a higher infiltration rate is used (i.e., greater than the assumed 5.0 cm/yr), this would result in earlier contaminant arrival in the groundwater with higher peak concentrations. Conversely, use of a lower infiltration rate would result in a delayed affect with somewhat lower peak contaminant concentrations.

Distribution Coefficients

An indication of a contaminants mobility in the vadose zone and groundwater aquifer is the distribution coefficient (K_d). A contaminant moves with the speed of water if its K_d is zero and progressively slower than water as the K_d values increases.

The tanks contain more than 100 radioactive and nonradioactive contaminants that potentially impact groundwater. Contaminants that are insoluble are assumed not to leach to groundwater. Values of K_d for the contaminants range from zero (in which the contaminant's movement in water is not retarded) to more than 100 (in which the contaminant moves much more slowly than water). Therefore, the contaminants were grouped as follows based on their mobility in the vadose zone and underlying unconfined aquifer:

- Group One - Nonsorbing (K_d = 0), K_d values in this group ranged from 0 to 0.99 mL/g.
- Group Two - Slightly sorbing (K_d = 1), K_d values ranged from 1 to 9.9 mL/g.
- Group Three - Moderately sorbing (K_d = 10), K_d values ranged from 10 to 49.9 mL/g.
- Group Four - Strongley sorbing (K_d = 50), K_d values are 50 mL/g or greater.

Contaminant transport simulations were then performed for each group based on the lowest value of the range. These results were then used to design a limited sensitively analysis (Section F.4.3.5).

The various contaminants in the tank waste each have their own chemical characteristic and would interact with the groundwater and geologic materials differently. This difference would result in

different rates of contaminant movement in the vadose zone and groundwater, ranging from that of groundwater to no measurable movement over a period of hundreds of years.

The distribution coefficient for a given contaminant not only depends on the chemical characteristics of the contaminant but also on the chemistry of the aquifer (or vadose zone) and the water within. For example, a contaminant with a K_d value of 0 in saturated sands might have a nonzero K_d value in a clay-rich zone. There is a large uncertainty with regard to contaminant mobility in all the different material and water types at the Hanford Site. For example, the K_d value of uranium has a reported experimental value that varies from a low estimate of 0 to a high estimate of 79.3 mL/g (best estimate value is 0.6 mL/g) in Hanford Site sediments with waters of neutral to high pH, low ionic strength, low organic, and oxic solutions. This same contaminant has a reported experimental value that varies from a low estimate of 100 to a high estimate of 1,000 mL/g (best estimate value is 100 mL/g) in Hanford Site sediments with waters of neutral to high pH levels, low ionic strength, low organic, and anoxic solutions (Kaplan et al. 1994).

Given the uncertainty about the mobility of uranium, it was initially assumed uranium has a zero K_d. Assuming a high K_d value would mean the contaminant did not reach groundwater within the 10,000-year period of interest.

Vadose zone simulations show that uranium with an assumed K_d value of zero does reach groundwater within the 10,000-year period of interest for all the alternatives and that drinking water standards are potentially exceeded. Based on these results, the sensitivity of the uranium mobility assumption can be better understood with additional simulations with slightly higher values of K_d. Vadose zone simulations indicate contaminants with a K_d value of 0.125 mL/g do not reach the groundwater within the 10,000 year period of interest, using the Ex Situ Intermediate Separations alternative as the base case.

Future Groundwater Flow Direction

In the modeling performed, future groundwater flow direction and gradient are not assumed to change from present conditions. The flow direction and gradient are primarily important to the time of contaminant transport from the source locations (i.e., the tanks and LAW vaults) to the Columbia River and where these contaminants enter the river. Likely changes in flow direction and gradient over the next few decades are assumed to be in response to the dissipation of existing groundwater mounds near disposal facilities, such as ponds or cribs, as discussed in Section F.4.3.5.

Climate Change

A climate change scenario was examined that included the return of an ice age. At present, the earth is in an interglacial phase. A transition to a glacial climate during the next few thousand years is highly unlikely. Such a transition during the next 10,000 years is more probable, but not assured. Over a million-year time scale, however, the global climate regime is virtually certain to pass through several glacial-interglacial cycles (National Research Council 1995).

Three potential changes associated with an ice age would likely impact onsite waste disposed. These include 1) an increase in infiltration through the waste causing a faster movement of contaminants from onsite disposal locations to the Columbia River, resulting from a cooler, wetter climate during early and late phases of the ice age; 2) a cold, dry climate causing reduced infiltration through the waste, slowing migration of waste to the Columbia River; and 3) a catastrophic flood that would reach the Central Plateau and dislodge and scatter waste from the disposal site. During previous ice ages, ice dams have formed on upper tributaries of the Columbia River. These dams, when broken through, have resulted in floods of up to 2,000 km^3 of water in a period of a few weeks compared to the present average flow of the Columbia River of about 100 km^3/year. Such floods would be likely to impact any waste disposed of near surface on the Hanford Site, scouring out waste sites to a depth of several meters and then redepositing waste from the tanks throughout the Pasco Basin.

Radioactive decay would have reduced the hazard from wastes disposed onsite under all of the alternatives by the time of the postulated glacial flood in the next 40,000 to 50,000 years. For all of the alternatives, peak impacts on groundwater beneath the 200 Areas would have occurred from 210 to 350 years from the present for the No Action and Long-Term Management alternatives for $K_d=0$ and from 3,630 to 8,870 years from the present for all other alternatives. Because of the low concentrations of plutonium and other radionuclides that would remain at the time of the postulated flood, the radiological consequences of a glacial flood would be small in comparison to the effects of the flood itself (DOE 1987).

One-Dimensional Flow

Two-dimensional or three-dimensional simulations of contaminant flow and transport in the vadose zone could provide more accurate estimates of contaminant arrival time, peak time, and peak concentrations (compared to one-dimensional simulations), provided that the spatial vadose zone hydraulic and transport properties were known. However, adequate knowledge of these parameter for two or three dimensional modeling is not currently available.

The one-dimensional simulations provided for this assessment are conservative and result in comparable estimates for each alternative. The one-dimensional simulations performed herein are conservative because they result in transport times that are at least as fast or faster compared to two-dimensional or three-dimensional simulations using the same vadose zone properties. Also, the peak contaminant concentrations at the vadose zone/groundwater interface for the one-dimensional simulations would be higher compared to peak concentration from two-dimensional or three-dimensional simulations.

Contaminants are assumed to move downward by advection with infiltration from precipitation and dissolution and leaching from tanks. The flow of water and transport of contaminants in the vadose zone is principally in the vertical direction because of the hydraulic gradient and geologic structure or layering in the vadose zone, which is assumed insufficient to result in extensive lateral spreading. Therefore, only one-dimensional modeling was performed in the vadose zone assuming a uniformly porous media and uniform hydraulic gradient.

The travel times are as fast or faster and the peak concentrations are higher for the one-dimensional simulations, because all transport and flow is in one direction only: downward within a uniformly porous media. Whereas, two- or three-dimensional flow and transport simulations can allow for lateral flow and transport.

Releases During Retrieval

The Ex Situ alternatives are all assumed to result in contaminant releases from SSTs during retrieval operations. Each SST was conservatively assumed to lose 15,140 L (4,000 gal) during retrieval for a total of 2,255,860 L (596,000 gal) from the 149 SSTs. This assumption is the upper bound and is the basis for the nominal case on which the potential groundwater impacts were calculated. The lower bound for retrieval losses (Section B.8) results in a total of approximately 436,000 L (115,000 gal) from all 149 SSTs.

Impacts to groundwater for the lower bounding retrieval losses assumption is accomplished qualitatively through a comparison of contaminant mass released during retrieval for the nominal case (upper bounding), the lower bounding retrieval scenario, and mass released as residual left in the tanks. Table F.4.4.1 provides this comparison for five selected contaminants.

All of the Ex Situ alternatives, based on the nominal retrieval scenario, have a contaminant first arrival time at the vadose zone/groundwater interface of approximately 1,070 years, which is because of losses during retrieval. The lower bounding retrieval scenario does not change the time of release and the contaminant first arrival time with this scenario would not be expected to change.

The rising limb of the concentration versus time curves at the vadose zone/groundwater interface (see Figure F.3.5.1 for characteristics of the Ex Situ alternatives) would shift to the right and calculated peak concentration would be lower and may be slightly later in time. Even though retrieval releases occur early compared to residual releases, the maximum peaks for the lower bounding scenario could be somewhat lower because total mass released is lower.

The following general alternative specific assumptions were made for the modeling effort.

General Assumptions

- For the radioactive contaminants, the mass was estimated for each isotope based on the decay of that isotope to December 31, 1995.
- Some contaminants in the tank inventory are of little importance and are not considered further in the groundwater assessment (Table F.2.2.3 provides a list of these contaminants).
- Contaminants are assumed to be released by their desorption and dissolution into pore fluids (this assumption holds for tank saltcake/sludge [No Action], grouted, and vitrified waste forms) and then moved by advection and diffusion from the waste source into the surrounding natural material or engineered barrier. Contaminants that are insoluble are assumed not the leach to groundwater.

- The LAW disposal facility is considered one source area even though 41 vaults are anticipated. The vaults would be covered with a continuous Hanford Barrier and the contents of each vault are assumed to be similar.
- The 177 tanks are divided into eight source areas based on tank contents (inventory), which may be different for different alternatives, tank proximity, and groundwater flow direction.
- Ingrowth of daughter products was not calculated.
- No preferential flow paths (e.g., macropore flow) exist in the vadose zone.

1) Tank waste No Action and Long-Term Management alternative assumptions include:
   - Releases to the groundwater system are associated with the complete inventory of contaminants in the waste tanks (Table F.2.2.2) except for contaminants that are insoluble.
   - Infiltration is 5.0 cm/year initially and throughout the period of interest.
   - Contaminant release for the five SST source areas is assumed to begin at the end of institutional control.
   - Contaminant releases from the three DST source areas are assumed to begin 100 years after the end of institutional control.
   - The duration of this release is based on a congruent dissolution model. In this model, all constituents in the waste inventory are assumed to be released in proportion to the most abundant material in the waste inventory, nitrate, and at the concentration of nitrate, which is 360 g/L (Serne-Wood 1990). The initial unit concentration assumed in modeling for K_d groups one and two (K_d equals zero and one) is 400,000 mg/L. The only difference between these alternatives is that under the Long-Term Management alternative, DSTs would be replaced during the institutional control period and assumed to begin leaking 100 years after the institutional control.

2) Tank waste In Situ Fill and Cap alternative assumptions include:
   - Releases to the groundwater system are associated with the complete inventory of contaminants in the waste tanks (Table F.2.2.2).
   - The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year.
   - In 1997 the infiltration rate is assumed to decrease to 0.5 cm/year in response to Hanford Site activities and decreases again to 0.05 cm/year after the Hanford Barrier is installed. The Hanford Barrier is assumed to have lost integrity 1,000 years after installation, which causes infiltration to increase to 0.1 cm/year throughout the remainder of the 10,000-year period of interest.
   - Five hundred years after the Hanford Barrier is installed, contaminant release for the eight tank source areas is assumed to begin (NRC 1994).
   - The principal constituent of the waste is nitrate and the congruent dissolution release model is used to estimate release from the waste, which is the same approach as described for the No Action and Long-Term Management alternatives. The dissolution concentration of nitrate is assumed to remain constant at 360 g/L (360,000 mg/L)

(Serne-Wood 1990), regardless of the water flux. The initial unit concentration assumed in modeling is 400,000 mg/L.

- The initial contaminant inventory and concentrations are the same as for the No Action and Long-Term Management alternatives.

3) Tank waste In Situ Vitrification alternative assumptions include:

- Releases to the groundwater system are associated with the contaminants in the waste tanks, but the vitrification process results in a different waste form (Table F.2.2.4).
- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year.
- The infiltration rate is assumed to decrease to 0.05 cm/year after the Hanford Barrier is installed. The Hanford Barrier is assumed to lose integrity 1,000 years after installation, which causes infiltration to increase to 0.1 cm/year throughout the remainder of the 10,000-year period of interest.
- Five hundred years after the Hanford Barrier is installed, contaminant release for the eight tank source areas is assumed to begin (NRC 1994).
- The release model for the vitrified mass was based on a constant total mass loss rate of 1E-03 $g/m^2 \cdot day$ (Shade et al. 1995). The mass loss rate is independent of the water flux from recharge. The composition of the vitrified mass was assumed to be identical to the soda-lime glass that is formed in the Ex Situ No Separations alternative (WHC 1995c). The release concentration of contaminants is then assumed to be proportional to their concentration in the soda-lime glass. Because the total mass loss rate is constant, the composition of the released solution is unaffected by the recharge rate. As the infiltration rate doubles after the barrier loses integrity, the mass flux increases proportionately. The low value of the total mass loss rate, combined with the very large quantity of vitrified mass results in a release time measured in millions of years.

4) Tank waste Ex Situ Intermediate Separations alternative assumptions include:

- Releases to the groundwater system are associated with 1) releases during retrieval from the SSTs; 2) releases from residuals that cannot be removed from the waste tanks; and 3) releases from the LAW disposal facility.
- The amount of liquid released from each SST during retrieval operations is 15,000 L (4,000 gal). The mass associated with retrieval operations at each source area is provided in Table F.2.2.5.
- The tank residual materials are assumed to be 1 percent of that for the No Action and Long-Term Management alternatives (Appendix A).
- The mass associated with the contaminants in the LAW vaults is based on the vitrified form of the retrieved waste (Table F.2.2.6).
- The initial vadose zone flow field is based on an infiltration rate of 5.0 cm/year for tank source areas and the LAW source area.
- In 1997 the infiltration rate is assumed to decrease to 0.5 cm/year in response to Site activities and decrease again to 0.05 cm/year after the Hanford Barrier is installed at

tank source areas and the LAW source area. The Hanford Barrier is assumed to lose integrity 1,000 years after installation, which causes infiltration to increase to 0.1-cm/year.

- Contaminant release for the five SST source areas is assumed to occur 1) during retrieval in 1997; and 2) from residual materials 500 years after Hanford Barrier construction.
- Contaminant release for the three DST source areas is assumed to result from releases from residual materials 500 years after Hanford Barrier construction.
- Contaminant release for the LAW facility is assumed to begin, 500 years after the Hanford Barrier is constructed over the vaults (NRC 1994).
- The solubility of each contaminant for retrieval releases and tank residuals is proportional to the solubility of (NO^-_3). For the tank source areas, the initial unit concentration assumed in modeling is 400,000 mg/L.
- The release model for the glass cullet was based on a constant corrosion rate of 3E-06 cm/year (Jacobs 19956). This corrosion rate is independent of the water flux from infiltration. The composition of the LAW glass is taken from the engineering data package for this alternative (WHC 1995j). The release concentration of the contaminants is assumed to be proportional to their concentration in the LAW glass. Because the total mass loss rate is constant, the composition of the released solution is unaffected by the infiltration rate. As the infiltration rate doubles after the barrier loses integrity, the mass flux increases proportionately. The low value of the corrosion rate, combined with the very large quantity of vitrified mass, results in a calculated release time of 170,000 years.
- For the tank source areas, the initial contaminant concentrations are the same as for the No Action and Long-Term Management alternatives. For the LAW disposal facility, the initial concentrations are provided in Table F.2.2.17.

5) Ex Situ No Separations

The assumptions for this alternative are the same as for the tank retrieval and tank residual components of the Ex Situ Intermediate Separations alternative (i.e., 1 percent of tank waste is assumed to remain as a residual in the tanks).

6) Ex Situ Extensive Separations

The assumptions for this alternative are the same as for the tank retrieval and tank residual components of the Ex Situ Intermediate Separations alternative (i.e., 1 percent of tank waste is assumed to remain as a residual in the tanks).

For this alternative, the contaminant inventory in the LAW vaults is smaller than estimated for the LAW vault component of the Ex Situ Intermediate Separations alternative (see Table F.2.2.7).

7) Tank Waste Ex Situ/In Situ Combinations

This alternative incorporates all of the assumptions listed for the Ex Situ Intermediate Separations alternative and the In Situ Fill and Cap alternative except as noted in the following. For the 70 tanks remediated ex situ:

- Releases to the groundwater system are due to losses during retrieval (Table F.2.2.8).
- Residual waste that may be left in a tank after retrieval is assumed to be 1 percent of the initial tank inventory.
- The 1 percent residual waste is added to the inventory of tanks remediated In Situ.

For the 107 tanks remediated in situ:

- Releases to the groundwater system are due to leaching from the waste form within the tanks (Table F.2.2.9). Table F.2.2.9 contains the initial waste inventory.

8) Phased Implementation alternative assumptions includes:

- There are no groundwater impacts associated with the first phase of this alternative because there are no contaminant releases from the tanks.
- The assumptions for the total alternative are the same as those for the Ex Situ Intermediate Separations alternative.

F.4.5 CONCEPTUAL GROUNDWATER CUMULATIVE IMPACTS

This section addresses potential cumulative groundwater impacts of other past and projected future waste disposal activities associated with the TWRS alternatives. The activities that may have a cumulative impact on the TWRS alternatives are as follows:

- Past practice waste disposed of to the ground as liquid;
- Past practice waste disposed of to the ground as solid;
- Solid low-level radioactive waste to be disposed of in the Environmental Restoration Disposal Facility (ERDF);
- Solid low-level radioactive waste to be disposed of in the 200 West Area burial grounds; and
- Solid low-level radioactive waste to be disposed of in the US Ecology burial grounds.

These activities result in two types of groundwater contamination plumes. The first type is in response to past practice liquid waste disposal to the ground. Large volumes, over 1,290 billion L (340 billion gal) in the 200 Areas, containing radionuclides and hazardous chemicals have been discharged to the ground surface or subsurface since 1944 (Wodrich 1991). The second type is long-term plumes associated with leaching of solid waste disposed of to the ground in the 200 Areas and on the Central Plateau (Wood et al. 1995). It is assumed that all of these disposal activities, except for the past practice liquid disposal, would have some cumulative impact with respect to the TWRS activities. Quantitative information, such as would be developed for a performance assessment, on the fate of current contaminant plumes resulting from past practice liquid waste disposal is not available; however, the following discussion suggests these contaminants will not interact with groundwater contaminant plumes associated with the TWRS alternatives.

Potential cumulative impacts with respect to contaminants C-14, I-129, Tc-99, and uranium are provided in the following sections for each of the solid waste disposal facilities. These contaminants were chosen for comparison because they have high mobility in the Hanford vadose zone and groundwater, have been routinely monitored in the groundwater, and have been identified as contributing much of the tank waste-related risk.

F.4.5.1 Past Practice Liquid Waste Disposal

Liquid waste disposal has resulted in extensive groundwater contamination in the 200 Areas as well as downgradient toward the Columbia River. Information on specific contaminants disposed of to ground surface or subsurface is limited to only a few key constituents including nitrate and radionuclides with half-lives greater than 10 years and in quantities large enough to be of concern in waste disposal and cleanup (Wodrich 1991). These radionuclides are Sr-90/Y-90, Cs-137, Tc-99, I-129, uranium, Am-241, and plutonium. Table F.4.5.1 provides a comparison of the inventories estimated for the past practice solid waste disposal and for TWRS tank waste. Quantitative estimates of contaminant concentration in groundwater with an acceptable degree of uncertainty from past practice liquid waste disposal activities are not possible using available information. Key information that is not available includes definition of the multiple source terms (e.g., waste volume, concentration, duration) and residual waste remaining in the vadose zone. A semi-quantitative approach coupled with some qualitative assumptions is used because of these limitations.

The approach is based on the assumption that present levels of groundwater contamination would be greatly reduced by the time any of the TWRS alternatives potentially impact groundwater. The major assumptions for this approach are as follows.

- Present groundwater contaminants, concentration levels, and distribution in the 200 Areas and downgradient are a result of the past practice liquid disposal in the 200 Areas.
- All liquid waste disposal to the ground at previously used waste disposal facilities (e.g., cribs, trenches, drains, and reverse wells) has been stopped or will be stopped by the year 2000.
- There will be no new ground disposal of radioactive or hazardous chemical-containing liquids, except for tritium.
- The remediation alternative for the past practice liquid waste disposal sites will be installation of caps by the year 2005.
- Less mobile contaminants such as Cs and Sr in the past practice liquid waste may contribute to the cumulative impact but are not considered at this time. As new information on this topic becomes available, it will be incorporated into the final version of the EIS.

Given these assumptions, the present concentrations of highly mobile contaminants in groundwater such as tritium, Tc-99, I-129, nitrate, and to a lesser extent, uranium currently would be experiencing a large reduction in concentration that would continue for less than 10 years, followed by many years where the contaminant concentration in groundwater diminishes at a much slower rate. Change in

uranium concentrations in well 299-W19-18 is an example of this process. This well is located in the 200 West Area adjacent to the inactive 216-U-1 and 216-U-2 cribs. The uranium concentration in this well has reduced at a uniform rate of approximately 3,000 μg/L for a 2 to 3-year period since remediation of the cribs in 1988 (Woodruff-Hanf 1993). By the end of 1992, the uranium concentration in this well was approximately 750 ug/L and the rate of reduction had dropped to approximately 80 ug/L/yr. The rate of concentration reduction is expected to continue to decline but at a very slow rate such that the uranium concentration at this well would appear to become constant at some low level. This level is not known and is assumed to be inconsequential by the time contaminants from the tanks arrive at the groundwater. This early reduction in concentration also is observed for tritium in observation well 699-24-33 (Woodruff-Hanf 1993).

In the performance assessment (PA) for the low-level waste burial grounds in the 200 West Area (Wood et al. 1995), it is concluded that mixing of the present day plume with that from the burial grounds is unlikely. These burial grounds include disposal sites with and without caps, thus times to peak groundwater contaminant concentrations range from approximately 125 to 1,000 years from present. The PA presents the following discussion to support this conclusion. First, the particle velocity in the unconfined aquifer, on the order of 10 m/yr, would result in the present plume migrating a few hundred meters over a few decades (Wood et al. 1995). Secondly, additional plume generation is unlikely because liquid discharge nearly has ceased, and it is likely that only very small quantities of the mobile radionuclides such as Tc-99, C-14, and I-129 remain in the present soil column. Other less mobile radionuclides are present in the soil column. They are believed to be short-lived (Wood et al. 1995) and would decay to inconsequential quantities before reaching the unconfined aquifer.

Of all the TWRS alternatives, the No Action and Long-Term Management alternatives have the earliest potential groundwater impact. First arrival of contaminants to the groundwater has been estimated to occur at about 140 years for these alternatives. Estimated first arrival of contaminants to groundwater for the other alternatives ranges from approximately 1,070 years for the ex situ alternatives to 2,330 years for the in situ alternatives. Cumulative impacts with respect to past practice liquid disposal likely would be very low for the ex situ and in situ alternatives and, with a larger degree of uncertainty, is assumed to be very low for the No Action and Long-Term Management alternatives.

F.4.5.2 Past Practice Solid Waste Disposal

Quantitative estimates of contaminant concentration in groundwater with an acceptable degree of uncertainty from past practice solid waste disposal activities is not possible with the present available information. As with past practice liquid waste disposal, key information not available includes definition of the multiple source terms (e.g., waste volume, concentration, duration). A semi-quantitative approach is used because of these limitations.

The approach is based on the premise that the potential impacts from the In Situ Fill and Cap alternative can be used as an analog for estimating impacts from past practice solid waste disposal. This estimate is conservative given the following major assumptions.

- The remediation alternative for the past practice solid waste disposal sites will be installation of caps by the year 2005.
- The inventory of past practice solid waste is in proportion to the distribution of waste in the tanks.

Contaminants from past practice solid waste disposal would be expected to reach the groundwater at approximately the same time as contaminants from the In Situ Fill and Cap alternative, given the previous assumptions. Based on the ratio of estimated past practice solid waste disposed to waste in tanks for C-14 and uranium (Table F.4.5.1), a factor of 1.2 is used to adjust the calculated groundwater concentrations upward from the In Situ Fill and Cap alternative. This is a semi-quantitative approximation of the potential impacts of the past practice solid waste disposal. Table F.4.5.2 provides the potential maximum groundwater concentrations for Tc-99, I-129, C-14, and uranium. Maximum groundwater impacts of the past practice solid waste disposal activities would occur at approximately 5,000 years based on the In Situ Fill and Cap alternative analog.

F.4.5.3 Solid Low-Level Radioactive Waste Disposal in the Environmental Restoration Disposal Facility

The proposed ERDF is a deep-lined trench disposal facility for the waste generated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 cleanup activities. The ERDF will be located adjacent to the southwest corner of the 200 West Area. The waste will be disposed of primarily in bulk noncontainerized form and is anticipated to consist primarily of contaminated soils and concrete rubble (Wood et al. 1995a). There are currently two principal documents that provide calculated groundwater dose information: the Remedial Investigation and Feasibility Report for the Environmental Restoration Disposal Facility (DOE 1994h) and the Environmental Restoration Disposal Facility Performance Assessment (Wood et al. 1995a). The PA was used herein as the basis for potential ERDF inventory and groundwater contaminant concentrations because the approach taken in the PA is similar to that used to calculate groundwater impacts from the TWRS waste tanks.

The projected ERDF inventory for Tc-99, I-129, C-14, and uranium is provided in Table F.4.5.1 (Wood et al. 1995a). The PA provides calculated groundwater drinking dose estimates for these radionuclides based on consumption of 730 L/yr (193 gal/yr). The maximum groundwater concentration for these radionuclides is calculated from the maximum dose using the drinking water consumption rate assumed in the PA and the DOE internal dose factor (Wood et al. 1995a).

Using Tc-99 as an example, the maximum groundwater concentration is calculated as follows. The reported maximum drinking water dose is 0.007 mrem/yr (Wood et al. 1995a) and the DOE internal dose factor for Tc-99 is 1.3E-06 mrem/pCi (Wood et al. 1995a). The maximum groundwater concentration of Tc-99 is calculated by dividing the reported maximum dose of 0.007 mrem/yr by the consumption rate of 730 L/yr (193 gal/yr) and the internal dose factor of 1.3E-06 mrem/pCi. This results in a maximum Tc-99 concentration in groundwater of 7.38 pCi/L. This maximum concentration would occur at approximately 1,500 years from present, assuming a K_d of zero and infiltration rate of

0.5 cm/yr (0.2 in./yr) (Wood et al. 1995a). Calculated maximum groundwater concentrations for Tc-99, I-129, C-14, and uranium are provided in Table F.4.5.2.

F.4.5.4 Solid Low-Level Radioactive Waste Disposal in the 200 West Burial Grounds

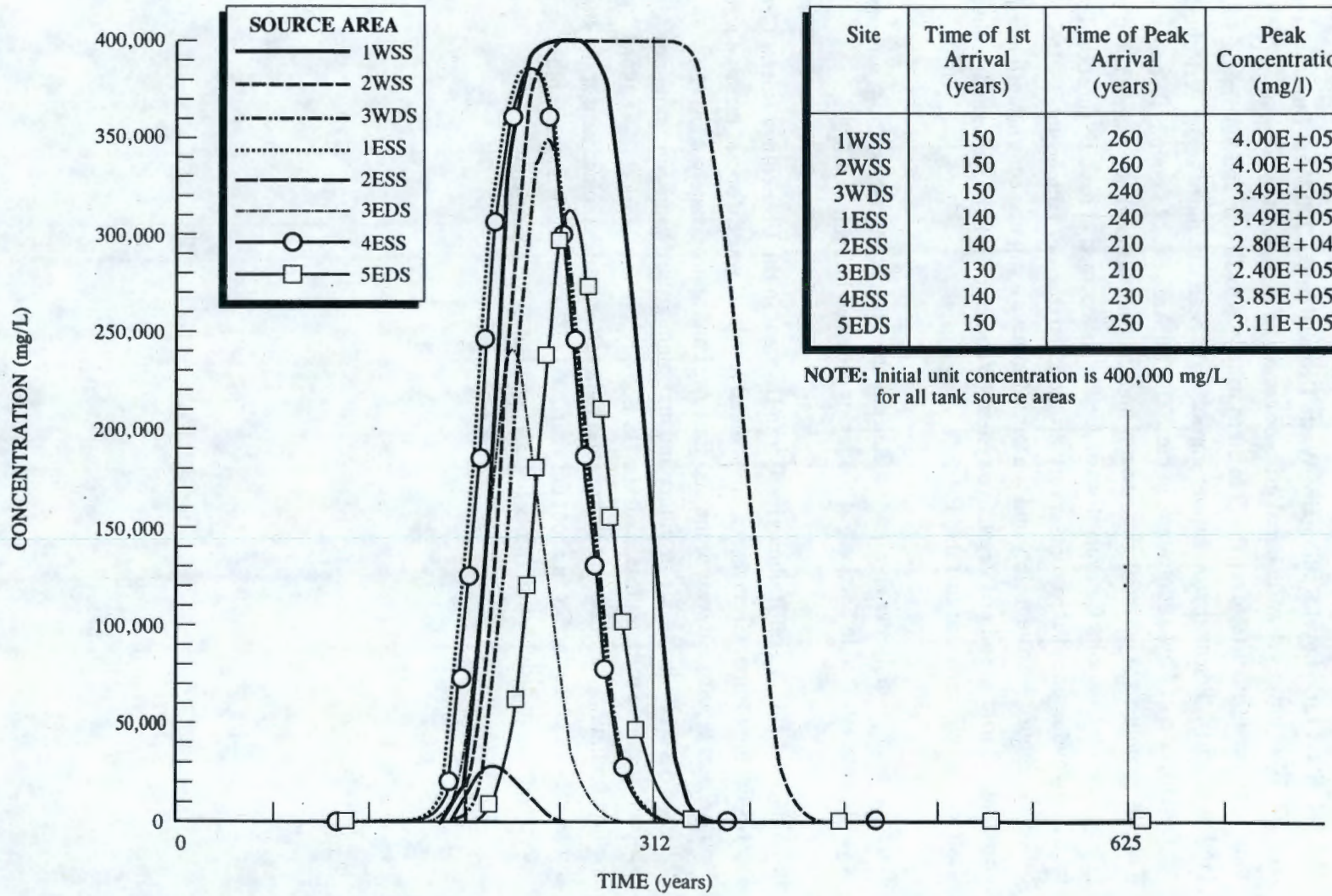
The 200 West low-level waste burial grounds consist of shallow (5 to 10 m deep [16.5 to 33 ft]), unlined trenches of variable widths (3 to 10 m wide [9.8 to 33 ft]), and lengths (50 to 100 m long [164 to 329 ft]). Potential groundwater impacts have been calculated in the Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds (Wood et al. 1995). This PA examines the potential groundwater impacts from disposal of waste in two different facility types. The first, called a Category 1 waste facility, is assumed to have no functional barriers (e.g., cap) and is intended to contain very low concentrations of radionuclides. The other facility is called a Category 3 waste facility and is assumed to have a cap that controls infiltration to the same degree as the natural soil and vegetative system (Wood et al. 1995). Radionuclide inventory for each waste category is provided in Table F.4.5.1.

The maximum groundwater contaminant concentration for Tc-99, I-129, C-14, and uranium was calculated as described in Section F.4.5.3 and is provided in Table F.4.5.2.

F.4.5.5 Solid Low-Level Radioactive Waste Disposal in the US Ecology Burial Grounds

The US Ecology Burial Grounds is a commercial low-level waste disposal facility located on the Central Plateau, just southwest of the 200 East Area and approximately 4 km (2.5 mi) east of the 200 West Area. Radionuclide inventory and maximum groundwater concentrations for Tc-99 I-129, C-14, and uranium were estimated for the US Ecology site at closure (Jacobs 1996). These values are based on preliminary estimates of future solid radioactive waste emplacement at the site. The estimates assume closure of the facility in about the year 2063. The inventory and maximum groundwater concentrations are provided in Tables F.4.5.1. and F.4.5.2, respectively.

Figure F.3.1.1 Predicted Contaminant Concentration for the No Action Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface

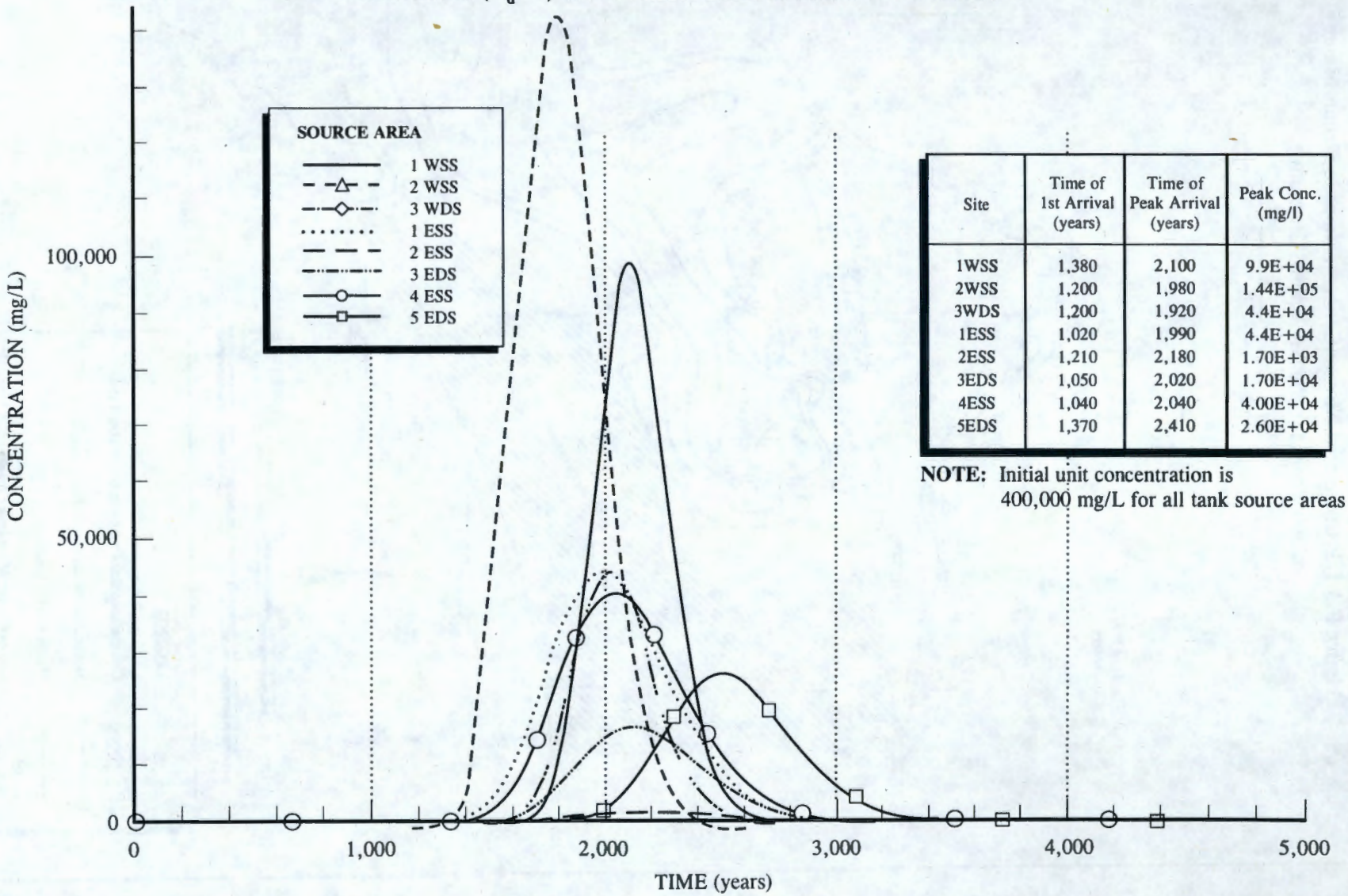


Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	150	260	4.00E+05
2WSS	150	260	4.00E+05
3WDS	150	240	3.49E+05
1ESS	140	240	3.49E+05
2ESS	140	210	2.80E+04
3EDS	130	210	2.40E+05
4ESS	140	230	3.85E+05
5EDS	150	250	3.11E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

9613409.1558

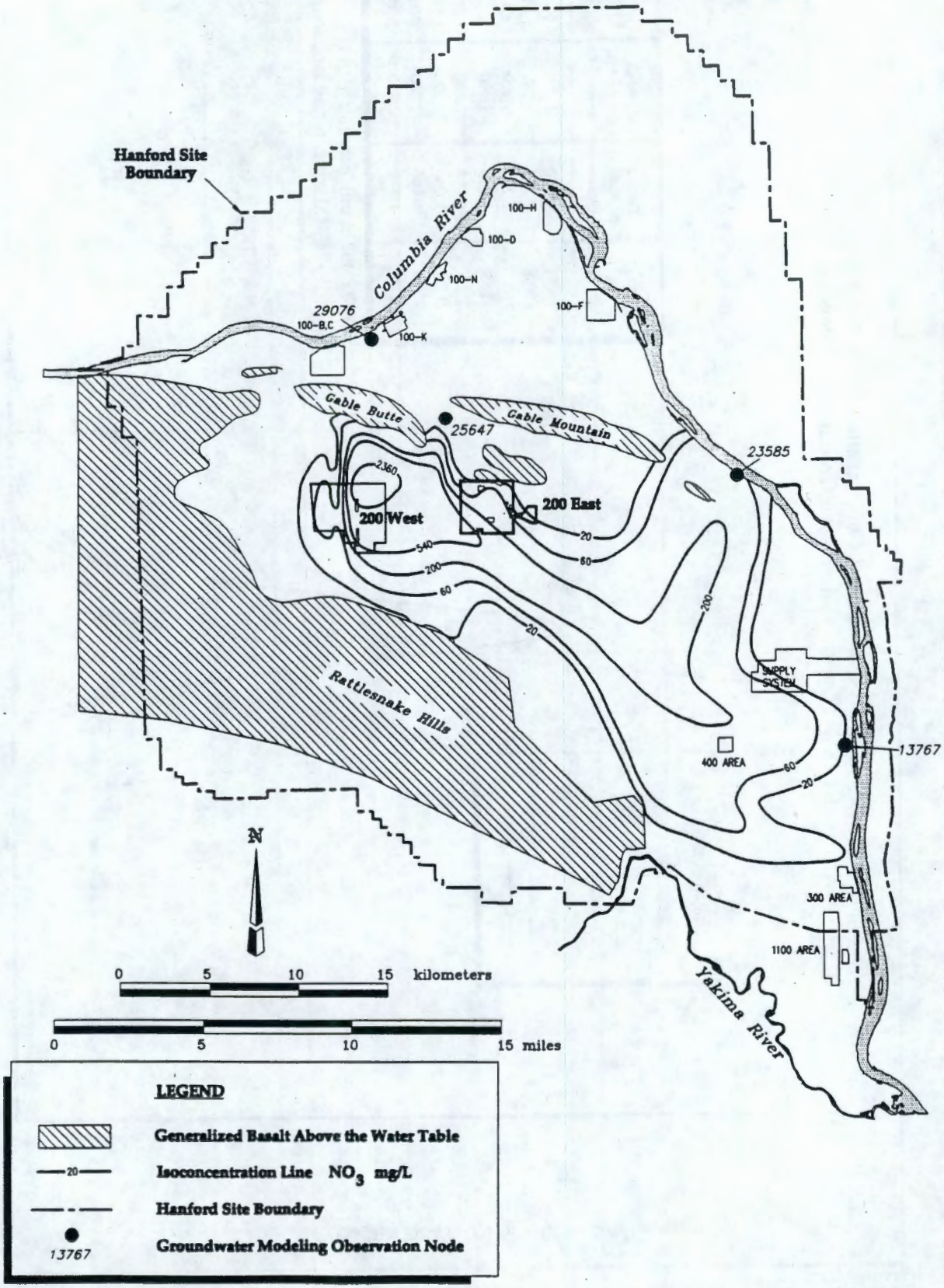
Figure F.3.1.2 Predicted Contaminant Concentration for the No Action Alternative (K_d=1) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	1,380	2,100	9.9E+04
2WSS	1,200	1,980	1.44E+05
3WDS	1,200	1,920	4.4E+04
1ESS	1,020	1,990	4.4E+04
2ESS	1,210	2,180	1.70E+03
3EDS	1,050	2,020	1.70E+04
4ESS	1,040	2,040	4.00E+04
5EDS	1,370	2,410	2.60E+04

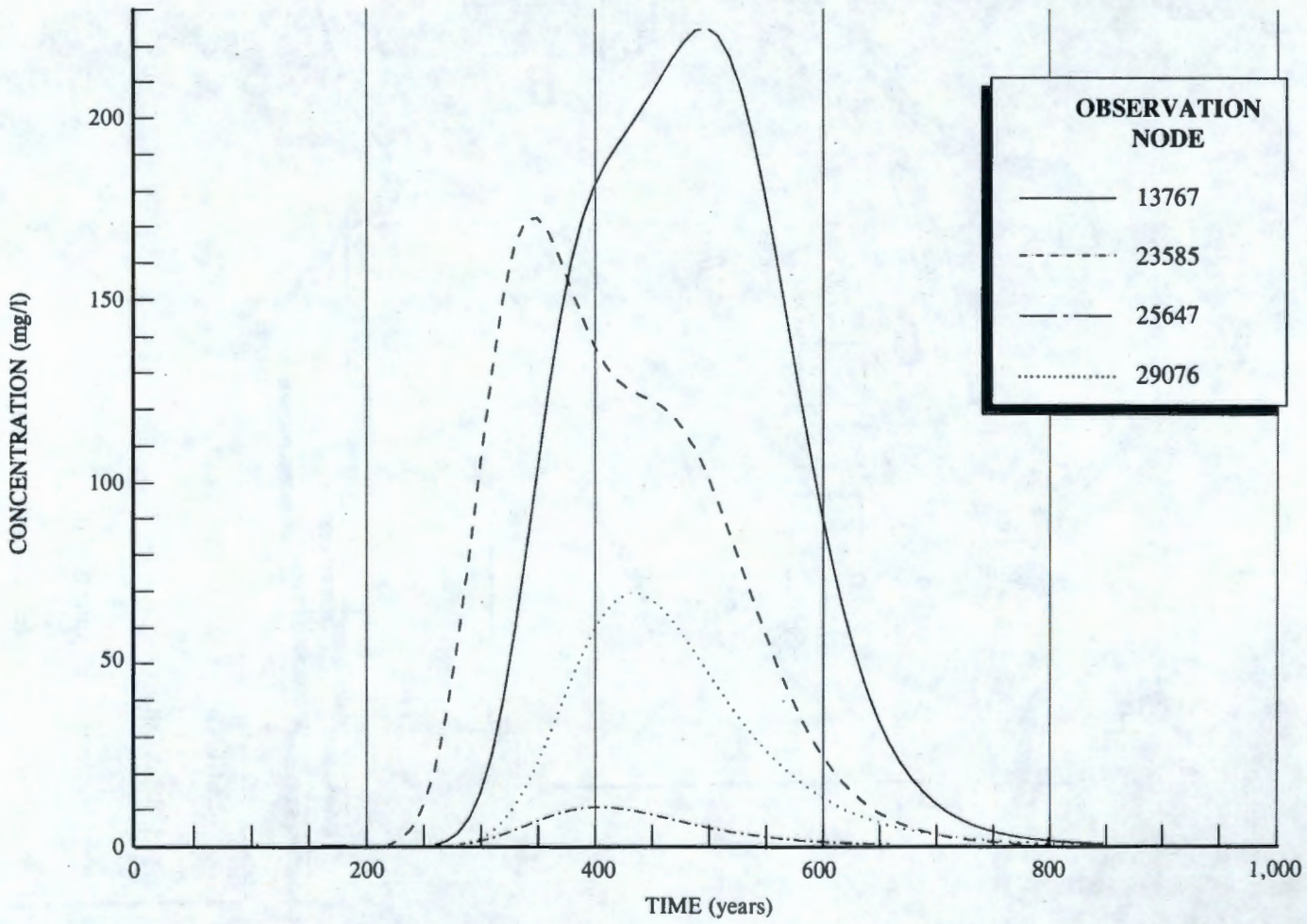
NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

Figure F.3.1.3 Calculated Nitrate Concentrations in Groundwater at 300 Years for the No Action Alternative



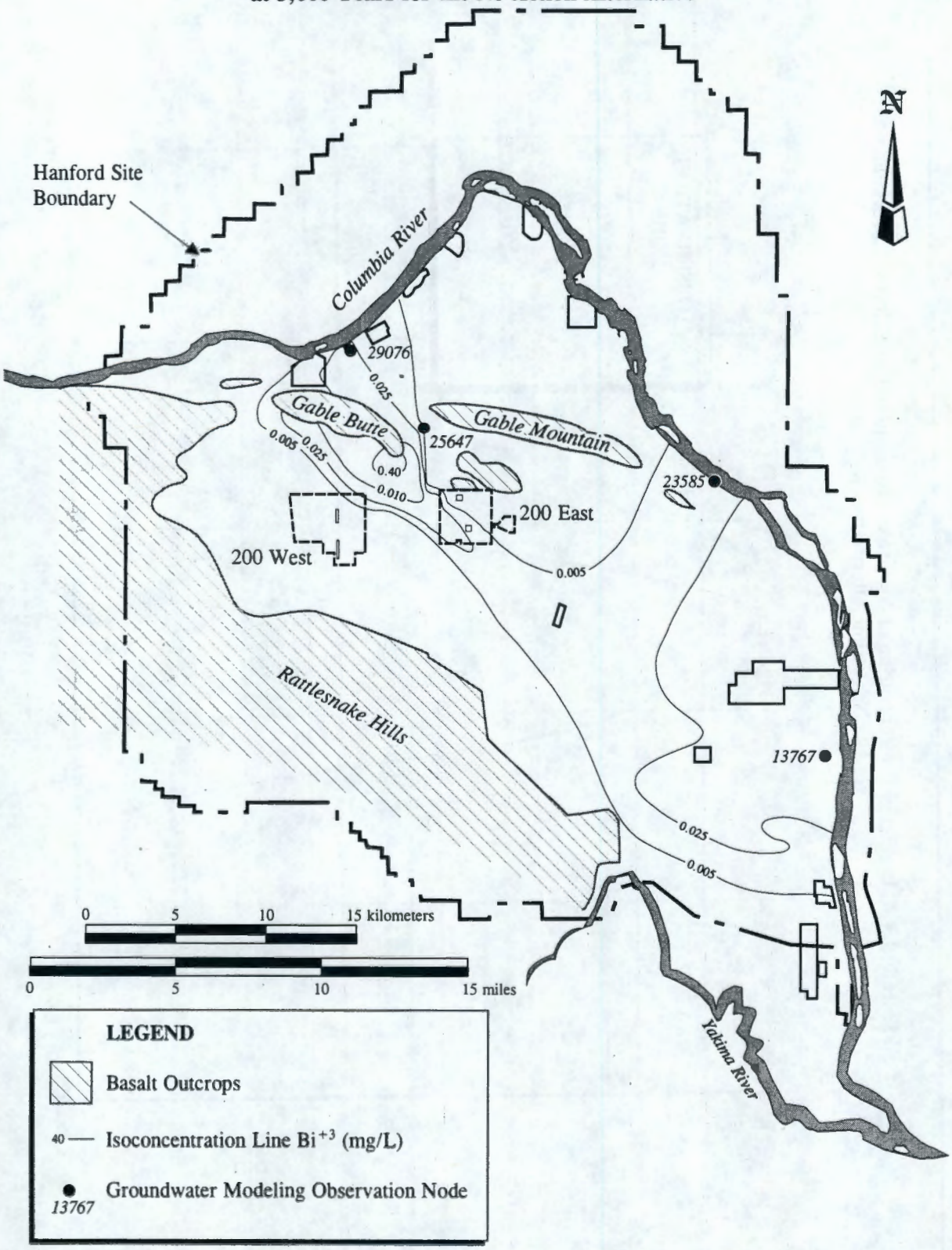
9613409.1559

Figure F.3.1.4 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the No Action Alternative (K_d = 0)



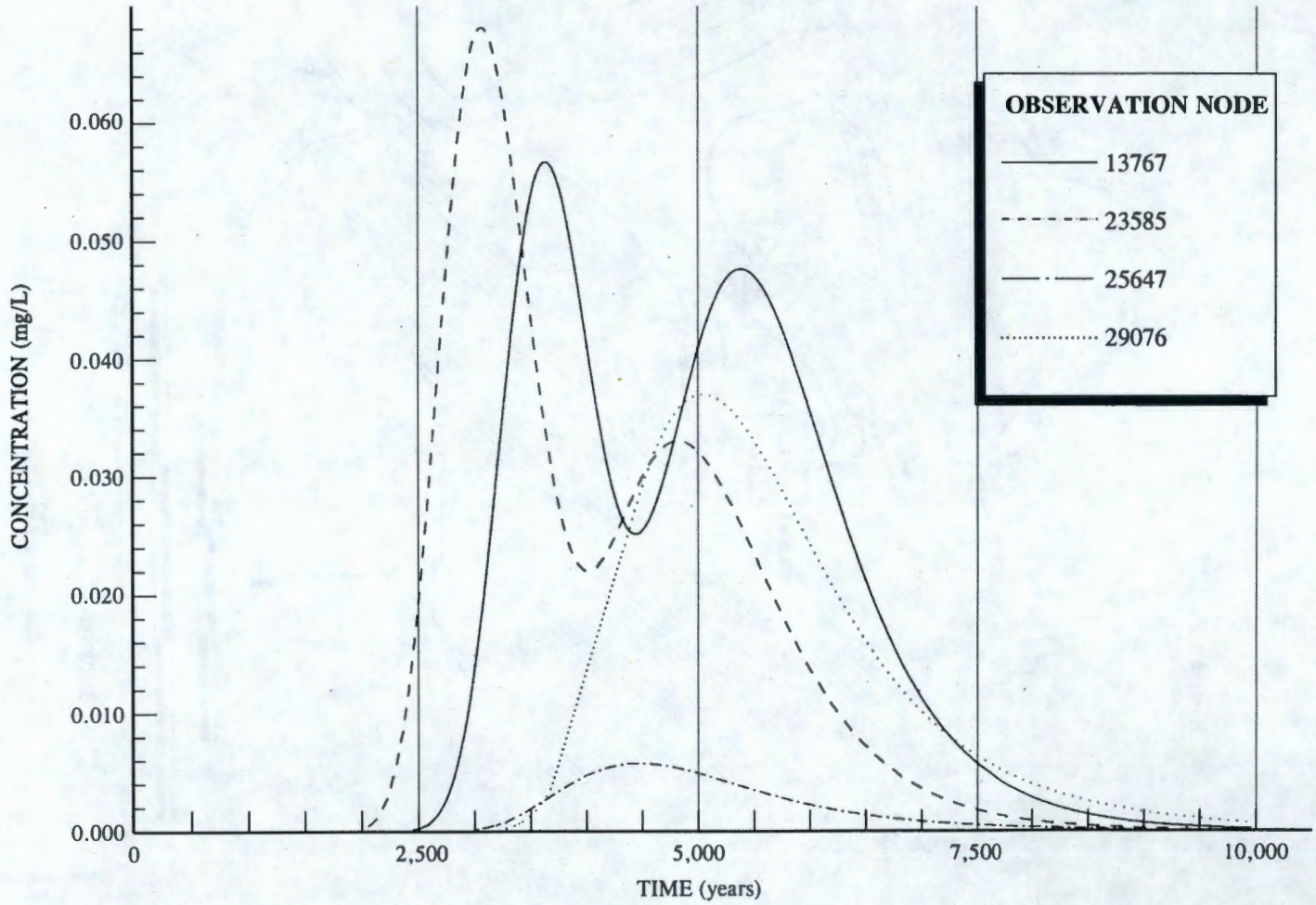
NOTE: See Figure F.3.1.3 for observation node locations

Figure F.3.1.5 Predicted Bismuth Concentrations in Groundwater at 5,000 Years for the No Action Alternative



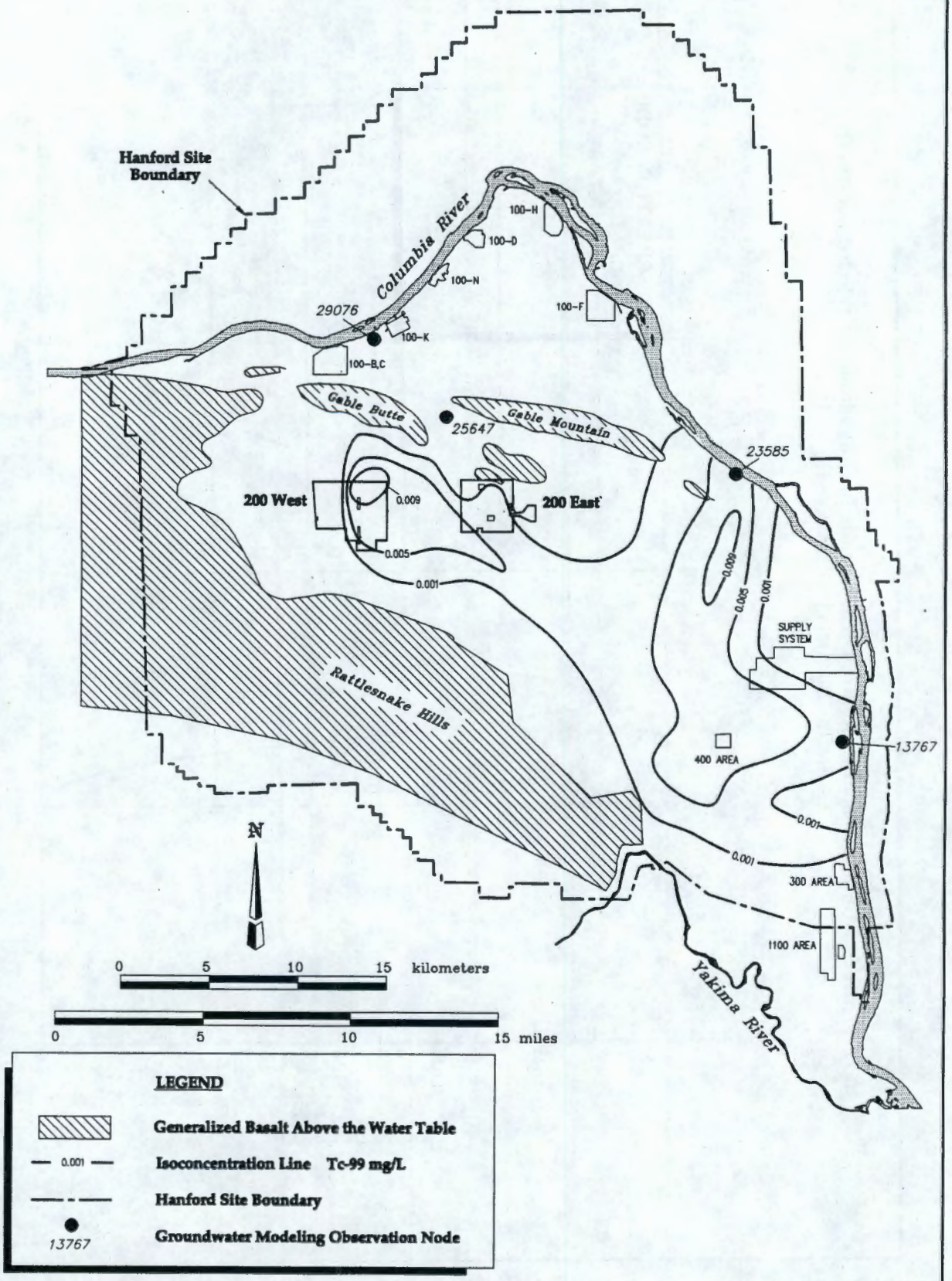
9613409.1560

Figure F.3.1.6 Calculated Concentration of Bismuth in Groundwater at Selected Locations for the No Action Alternative (K_d = 1)



NOTE: See Figure F.3.1.5 for observation node locations

Figure F.3.1.7 Predicted Technetium-99 Concentrations in Groundwater at 300 Years for the No Action Alternative



9613409.1561

Figure F.3.1.8 Predicted Iodine-129 Concentrations in Groundwater at 300 Years for the No Action Alternative

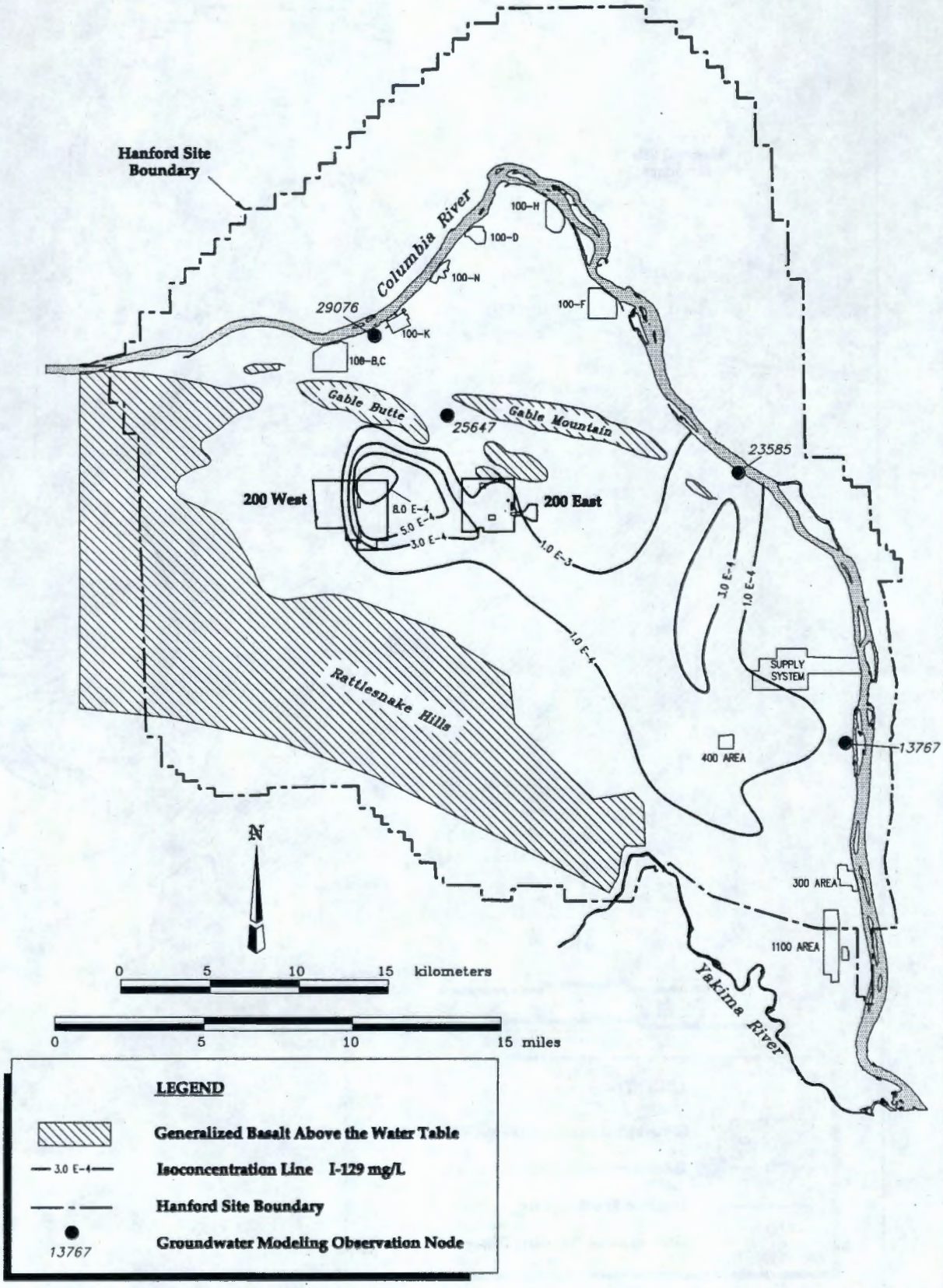
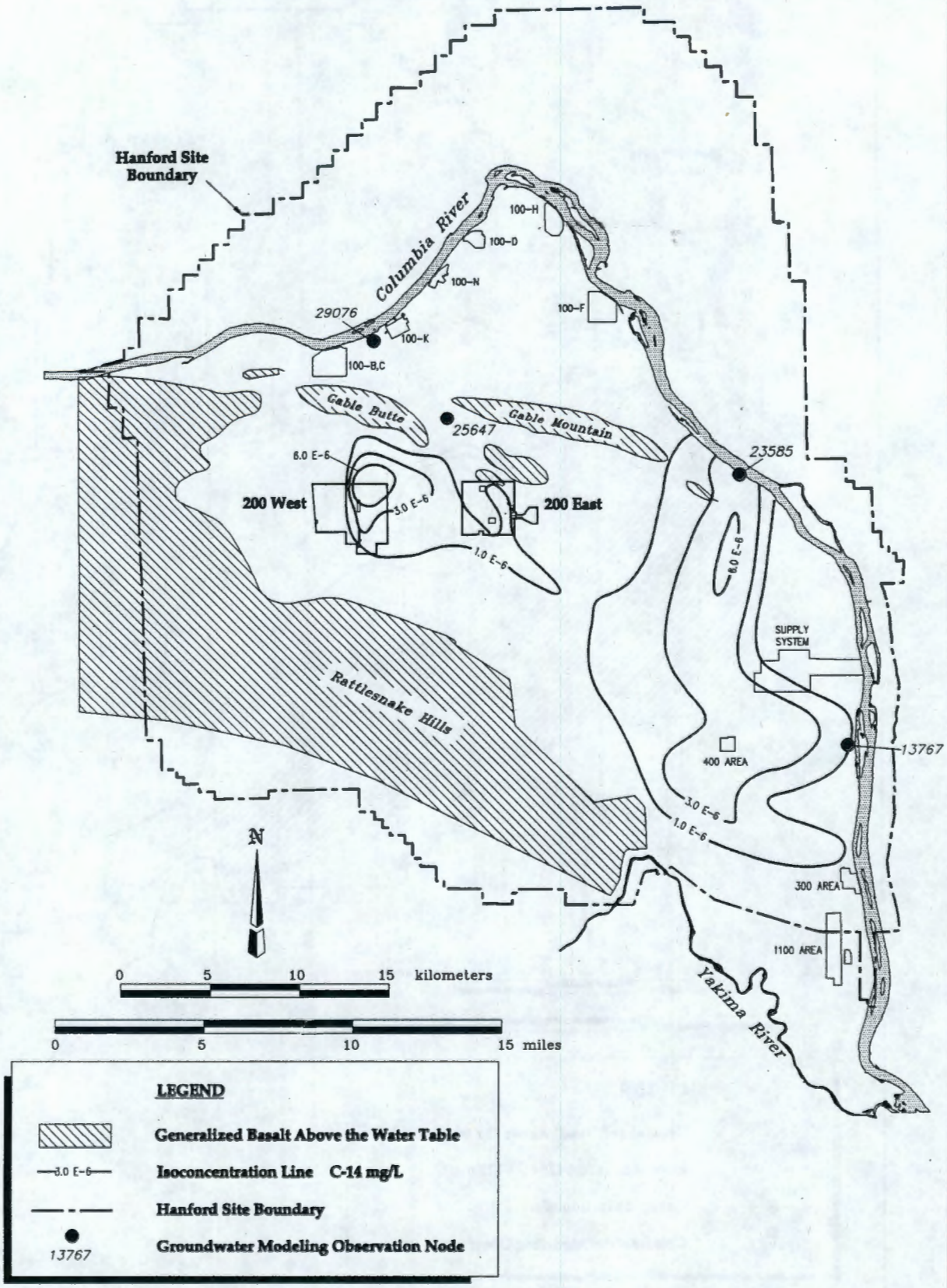


Figure F.3.1.9 Predicted Carbon-14 Concentrations in Groundwater at 300 Years for the No Action Alternative



9613409.1562

Figure F.3.1.10 Predicted Uranium-238 Concentrations in Groundwater at 300 Years for the No Action Alternative

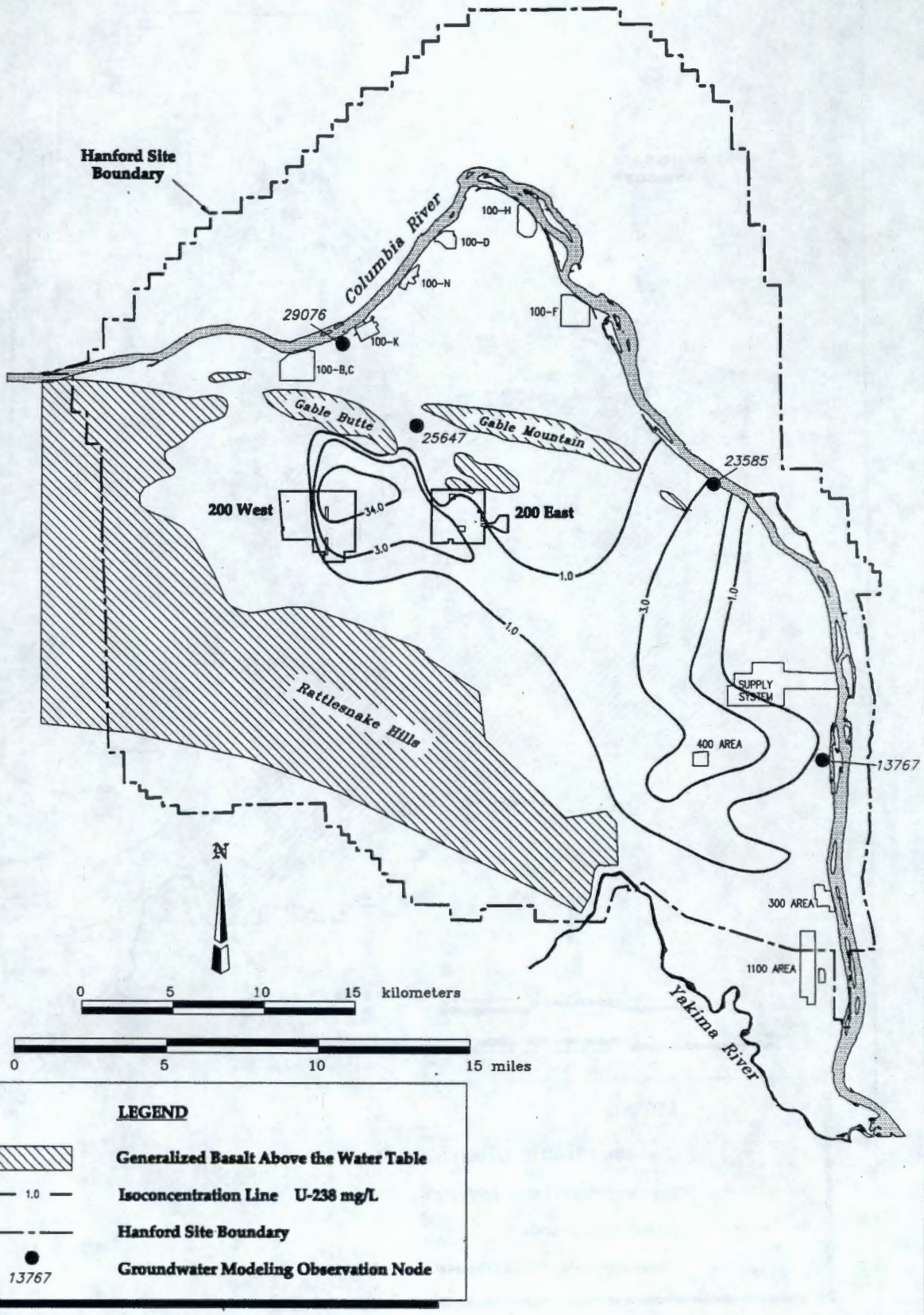
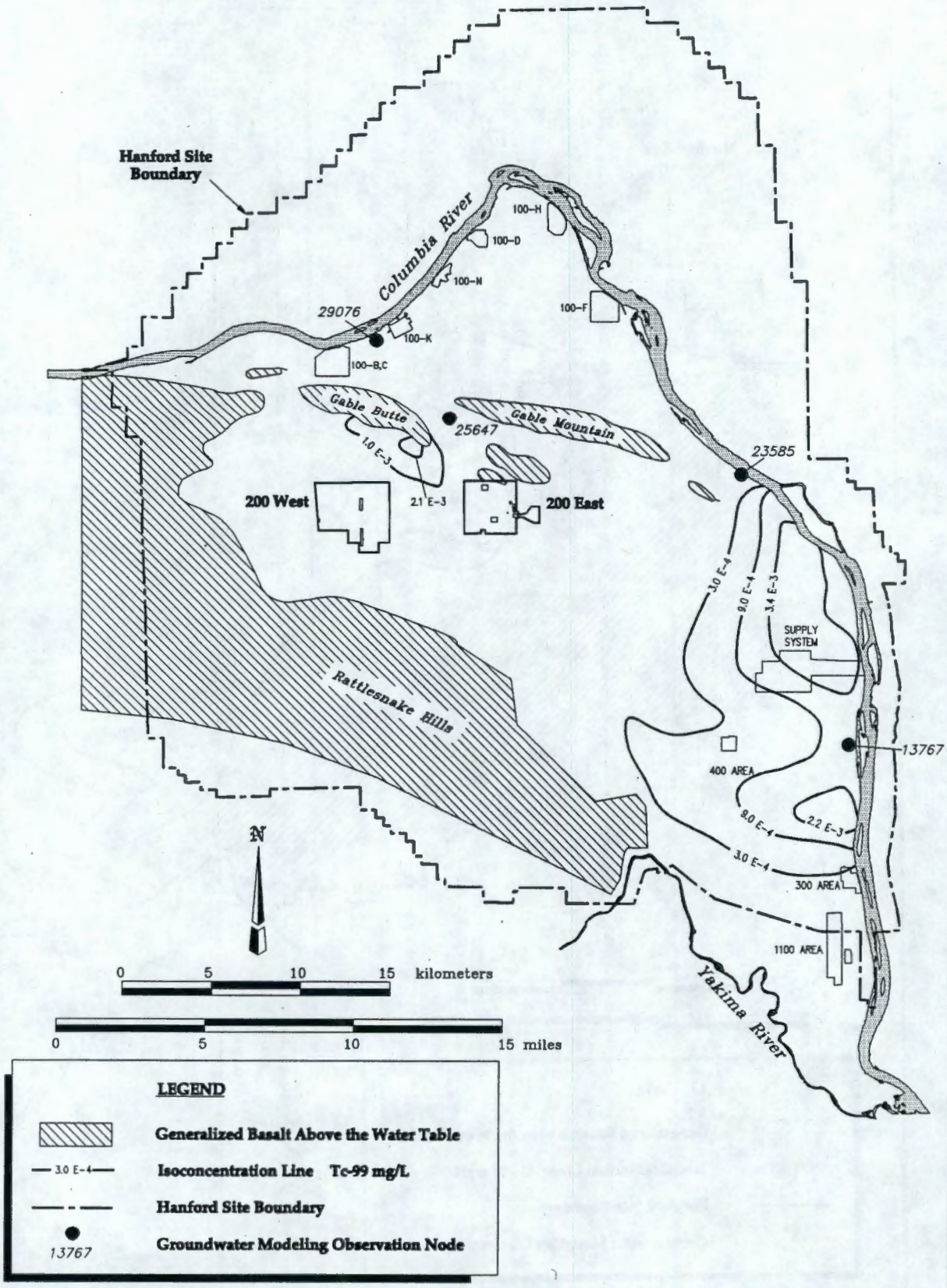


Figure F.3.1.11 Predicted Technetium-99 Concentrations in Groundwater at 500 Years for the No Action Alternative



9613409.1563

Figure F.3.1.12 Predicted Iodine-129 Concentrations in Groundwater at 500 Years for the No Action Alternative

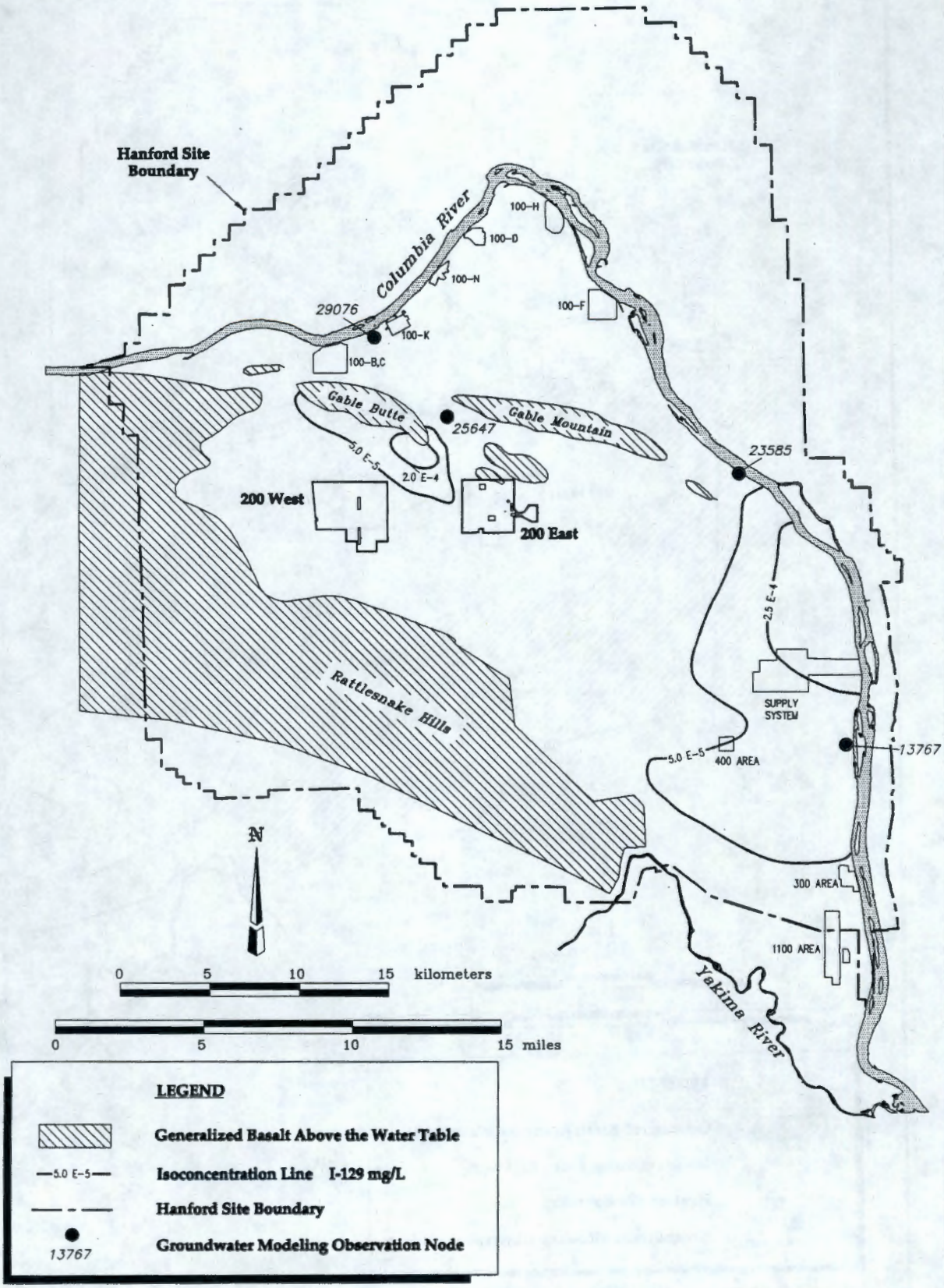
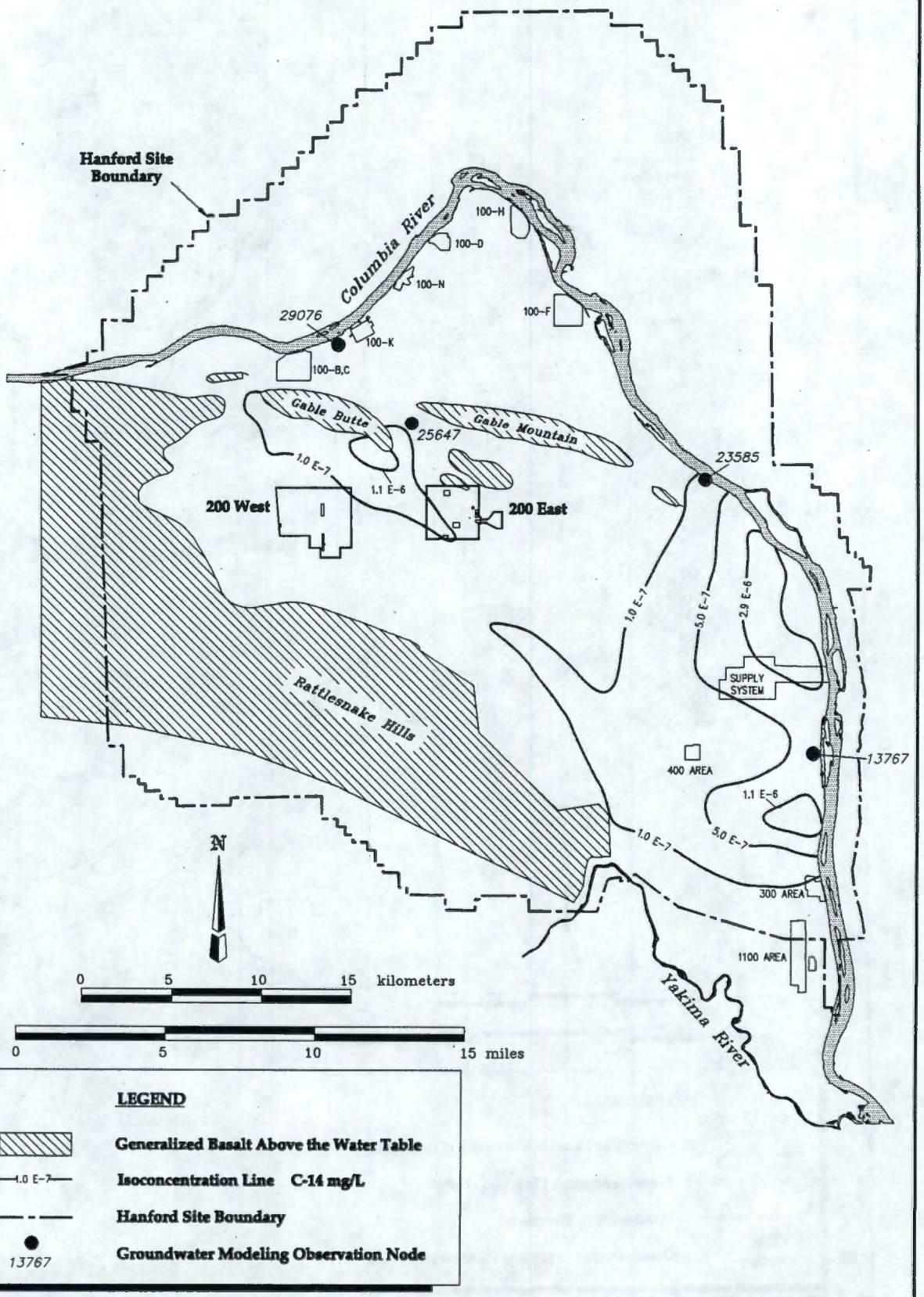


Figure F.3.1.13 Predicted Carbon-14 Concentrations in Groundwater at 500 Years for the No Action Alternative



9613409.1564

Figure F.3.1.14 Predicted Uranium-238 Concentrations in Groundwater at 500 Years for the No Action Alternative

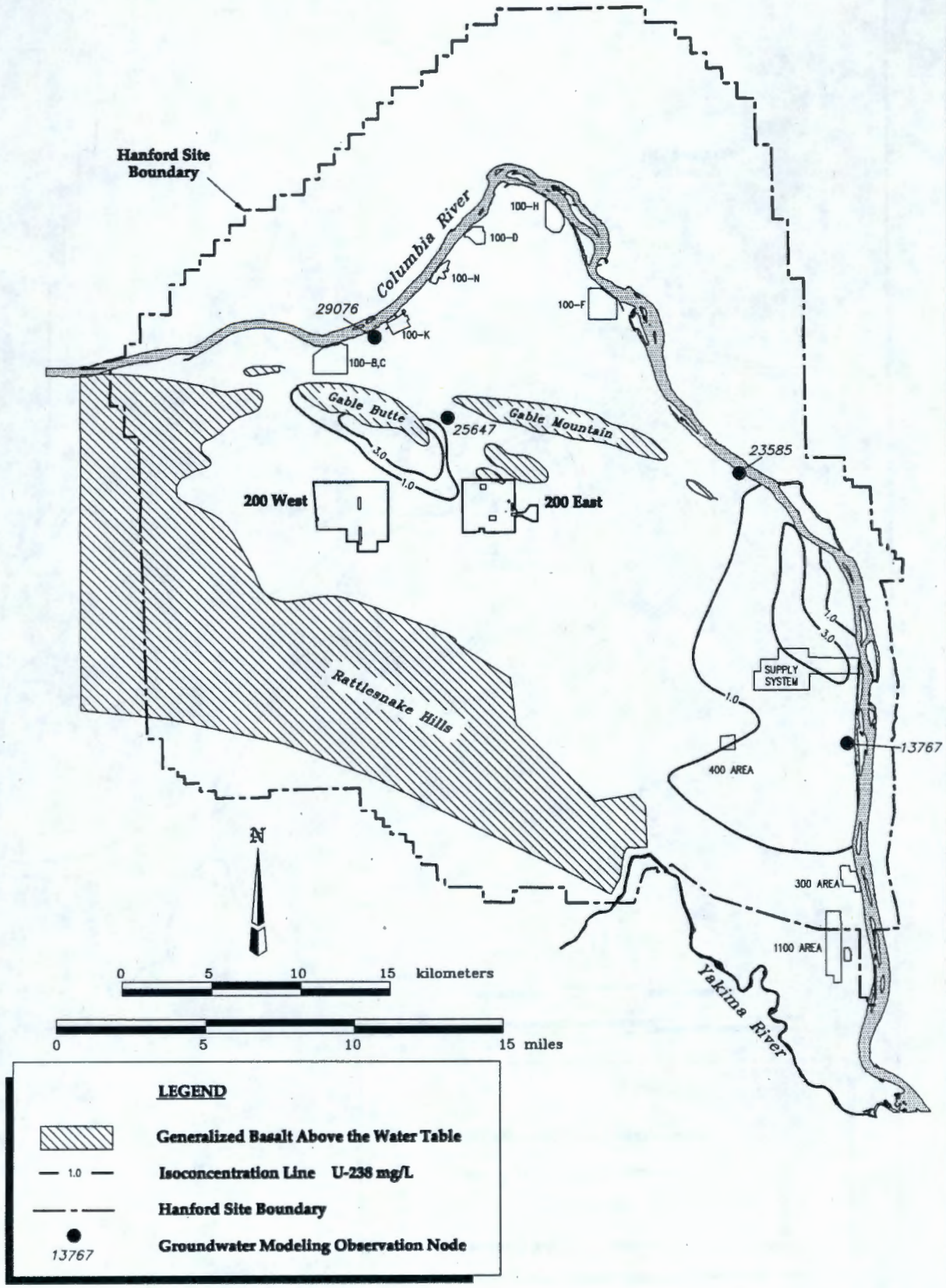
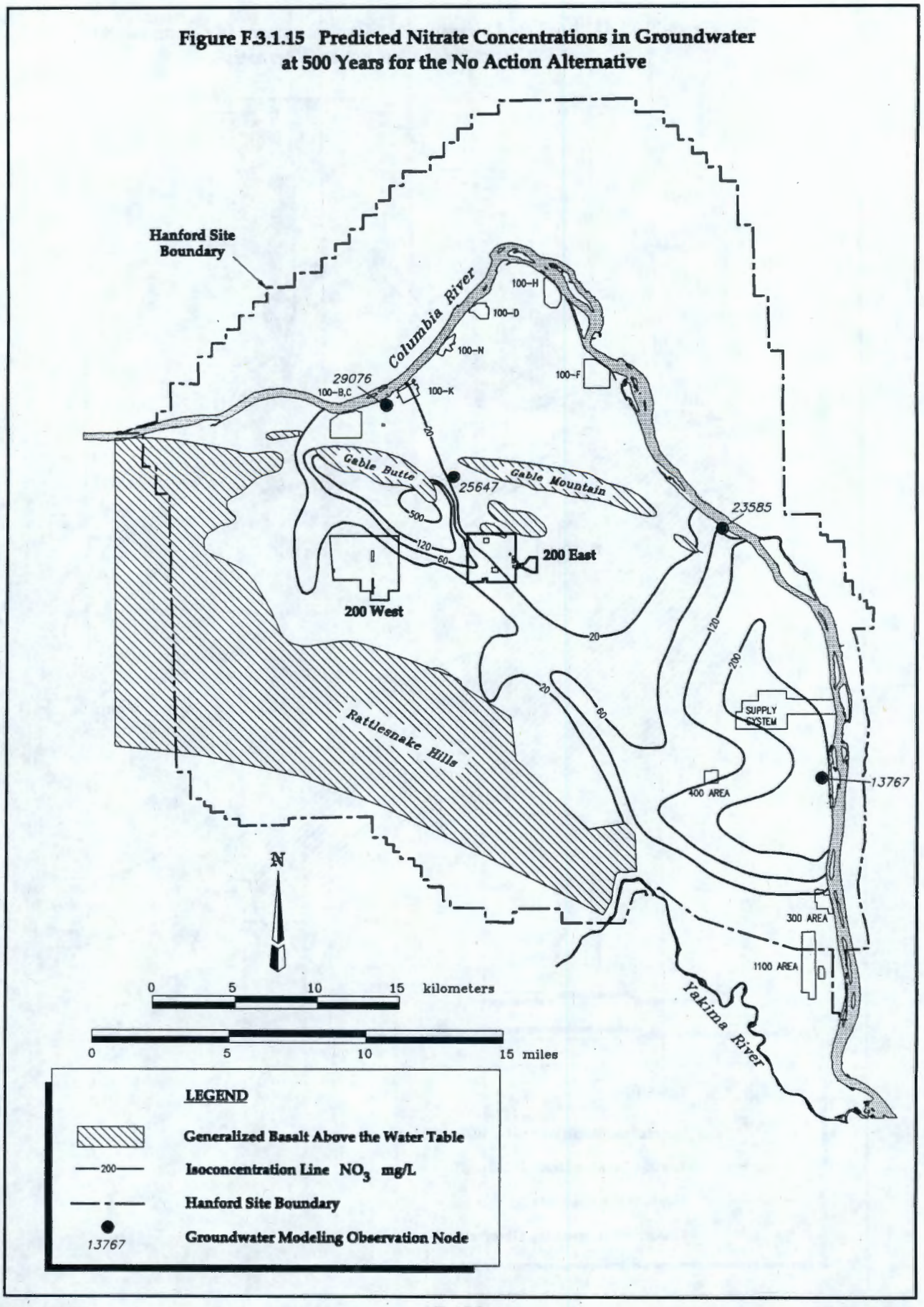


Figure F.3.1.15 Predicted Nitrate Concentrations in Groundwater at 500 Years for the No Action Alternative



9613409.1565

Figure F.3.1.16 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

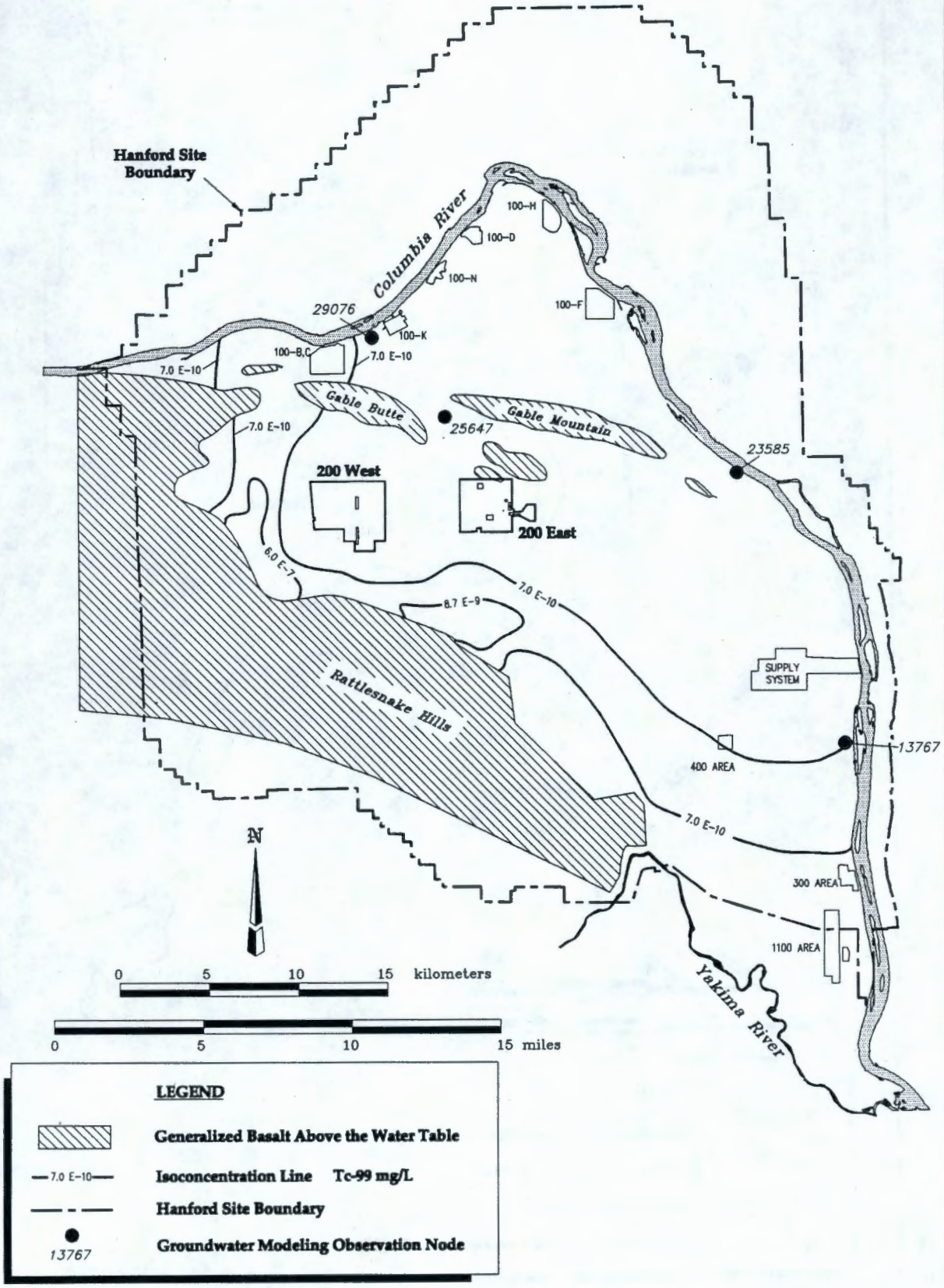
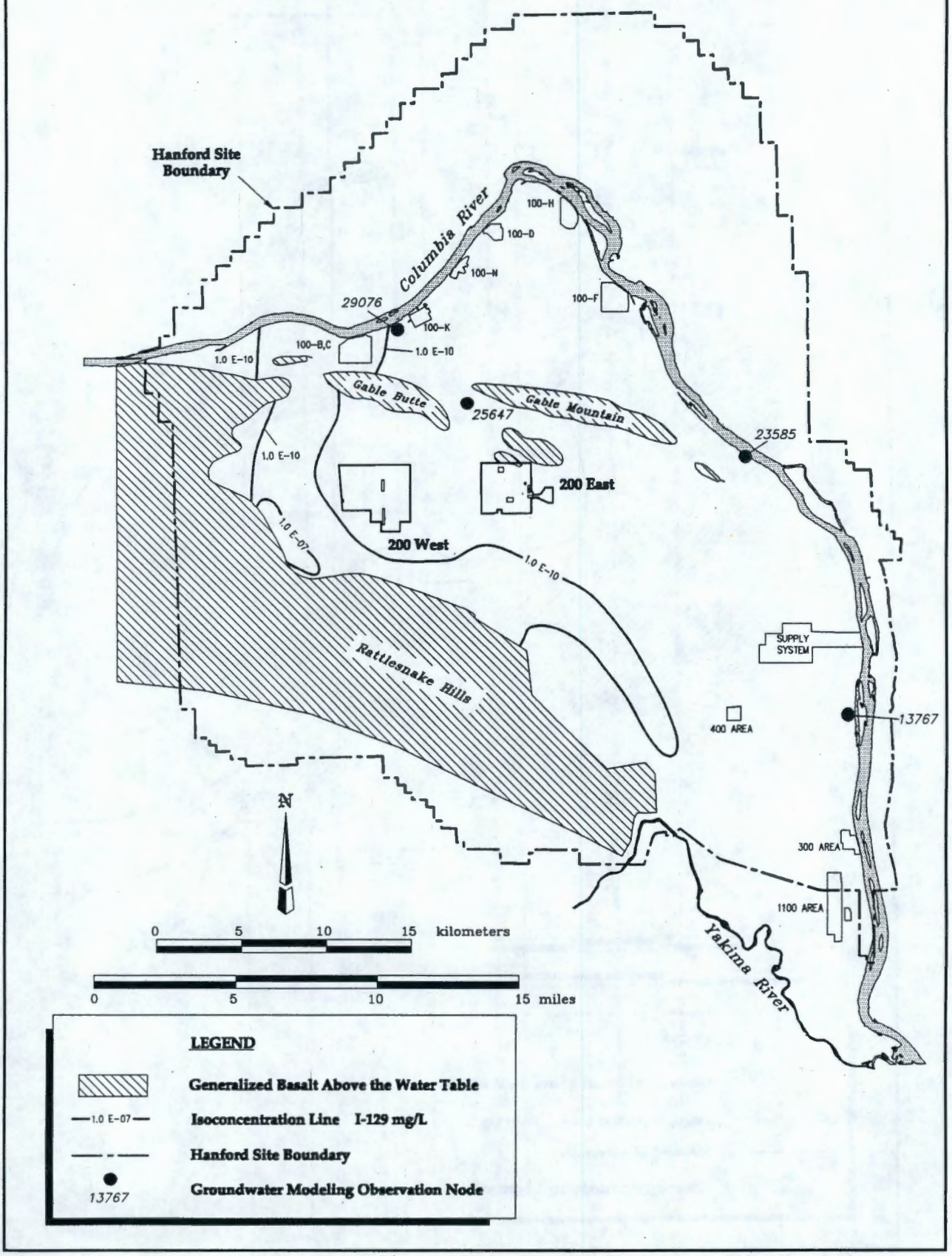


Figure F.3.1.17 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the No Action Alternative



9613409.1566

Figure F.3.1.18 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the No Action Alternative

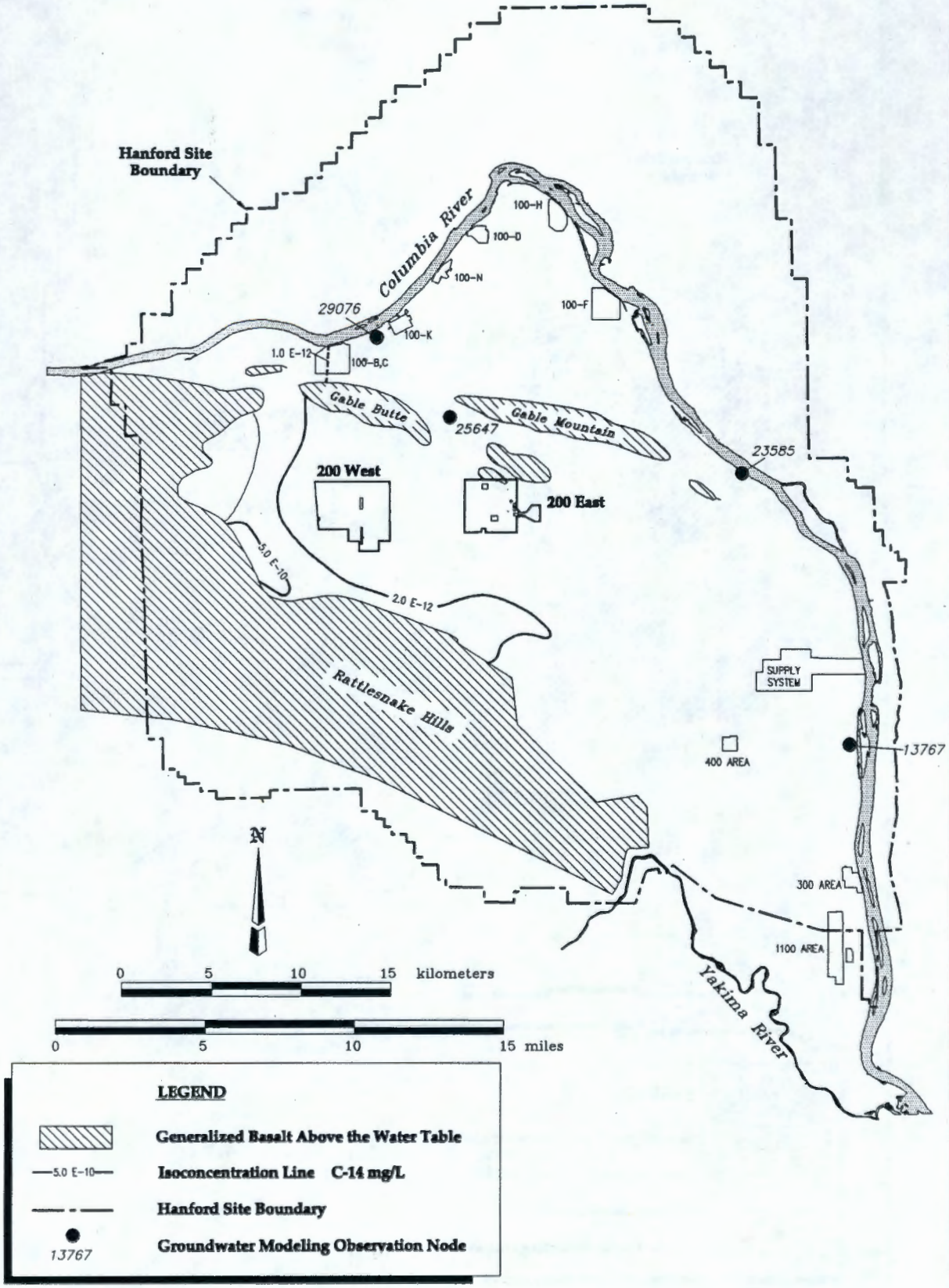
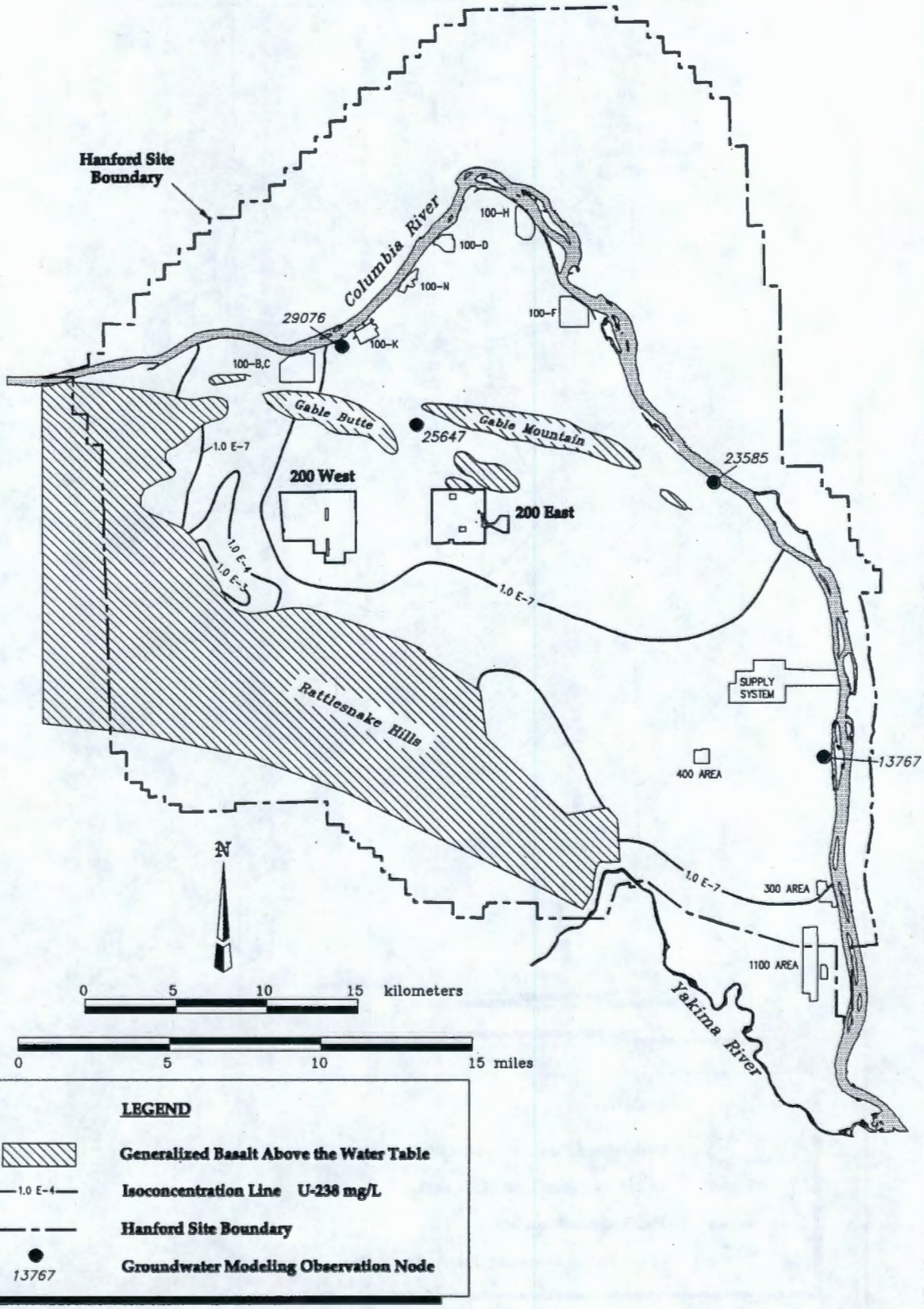


Figure F.3.1.19 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the No Action Alternative



9613409.1567

Figure F.3.1.20 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the No Action Alternative

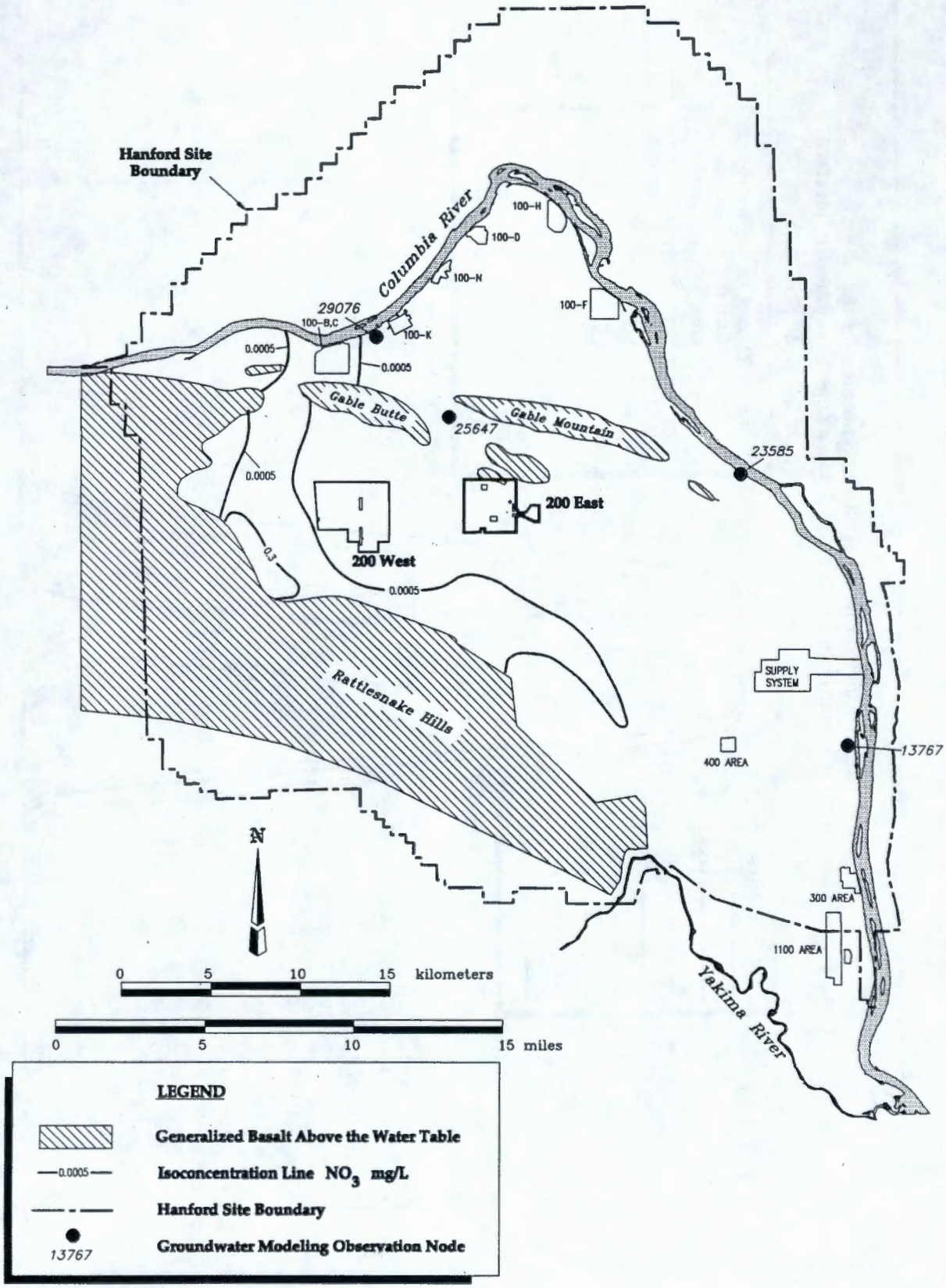
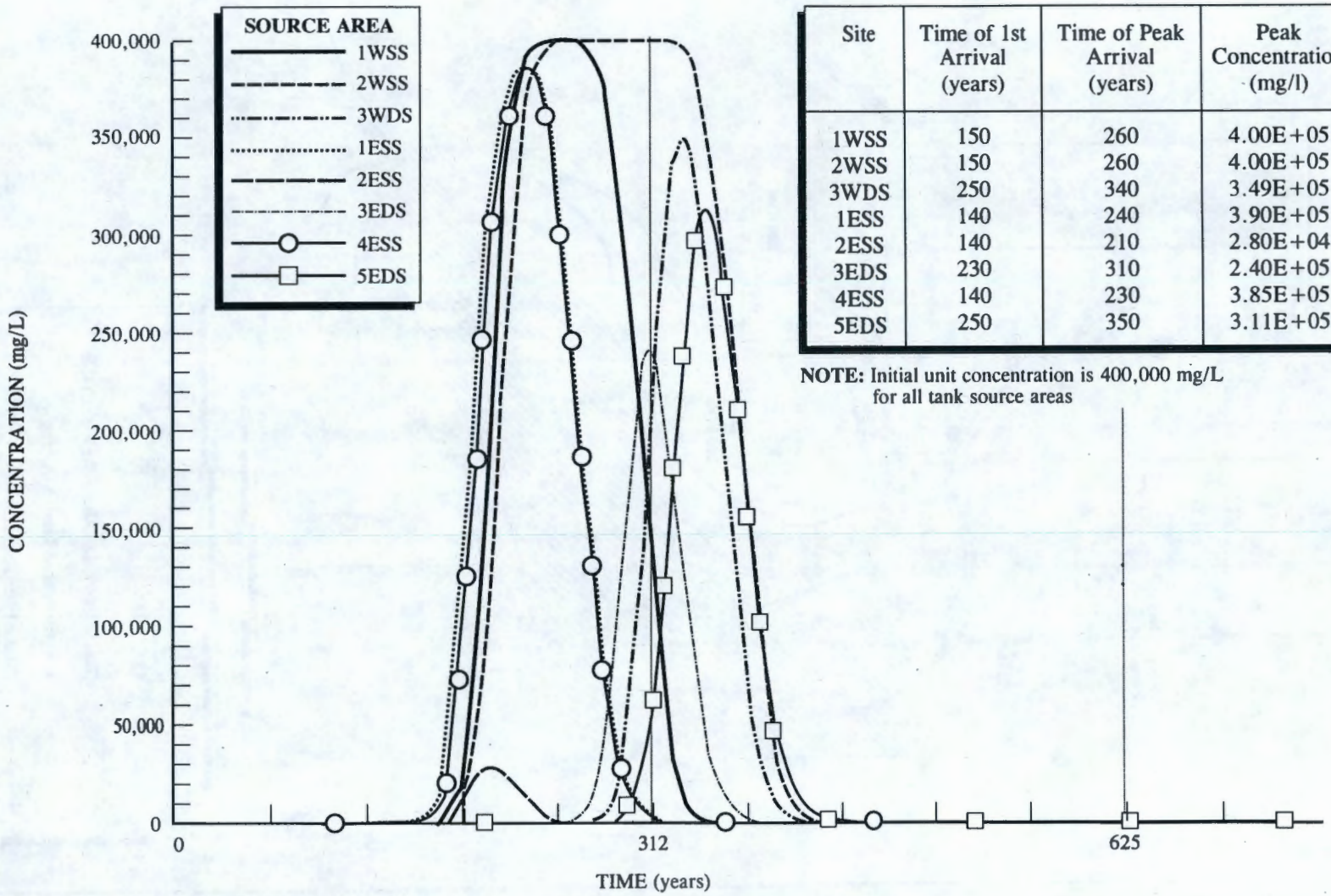


Figure F.3.2.1 Predicted Contaminant Concentration for the Long-Term Management Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface

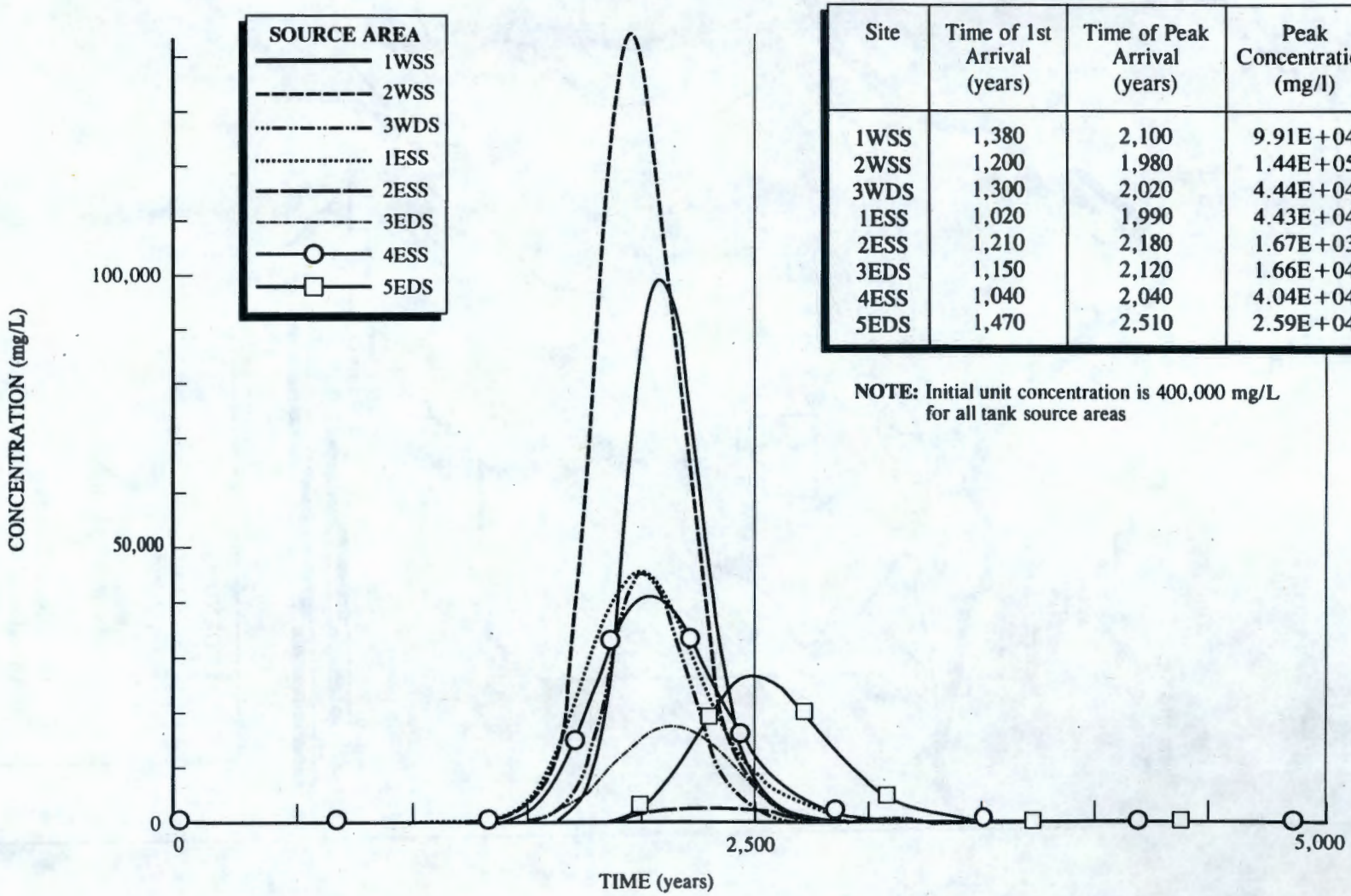


Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	150	260	4.00E+05
2WSS	150	260	4.00E+05
3WDS	250	340	3.49E+05
1ESS	140	240	3.90E+05
2ESS	140	210	2.80E+04
3EDS	230	310	2.40E+05
4ESS	140	230	3.85E+05
5EDS	250	350	3.11E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

9613409.1568

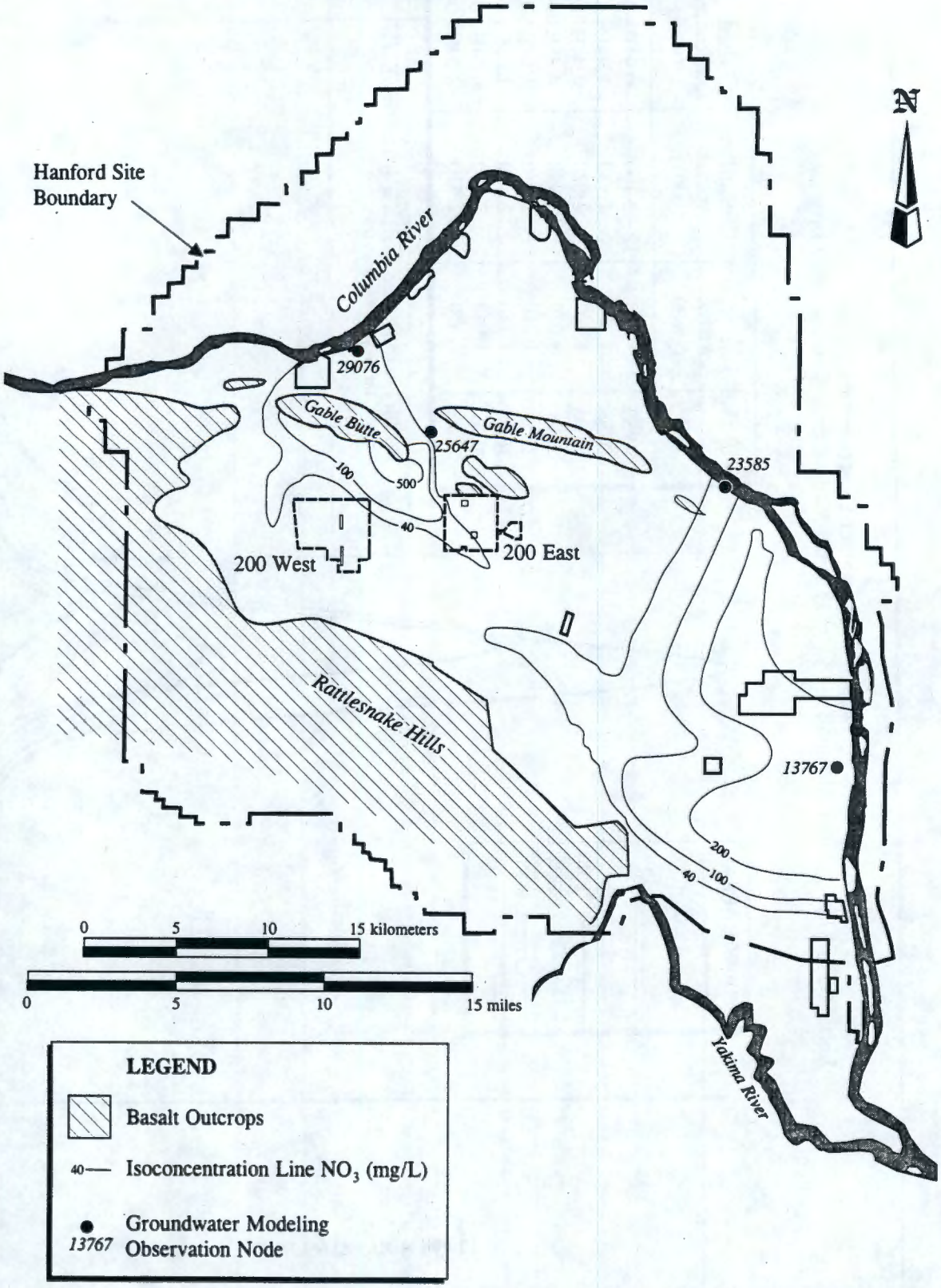
Figure F.3.2.2 Predicted Contaminant Concentration for the Long-Term Management Alternative (K_d = 1) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	1,380	2,100	9.91E+04
2WSS	1,200	1,980	1.44E+05
3WDS	1,300	2,020	4.44E+04
1ESS	1,020	1,990	4.43E+04
2ESS	1,210	2,180	1.67E+03
3EDS	1,150	2,120	1.66E+04
4ESS	1,040	2,040	4.04E+04
5EDS	1,470	2,510	2.59E+04

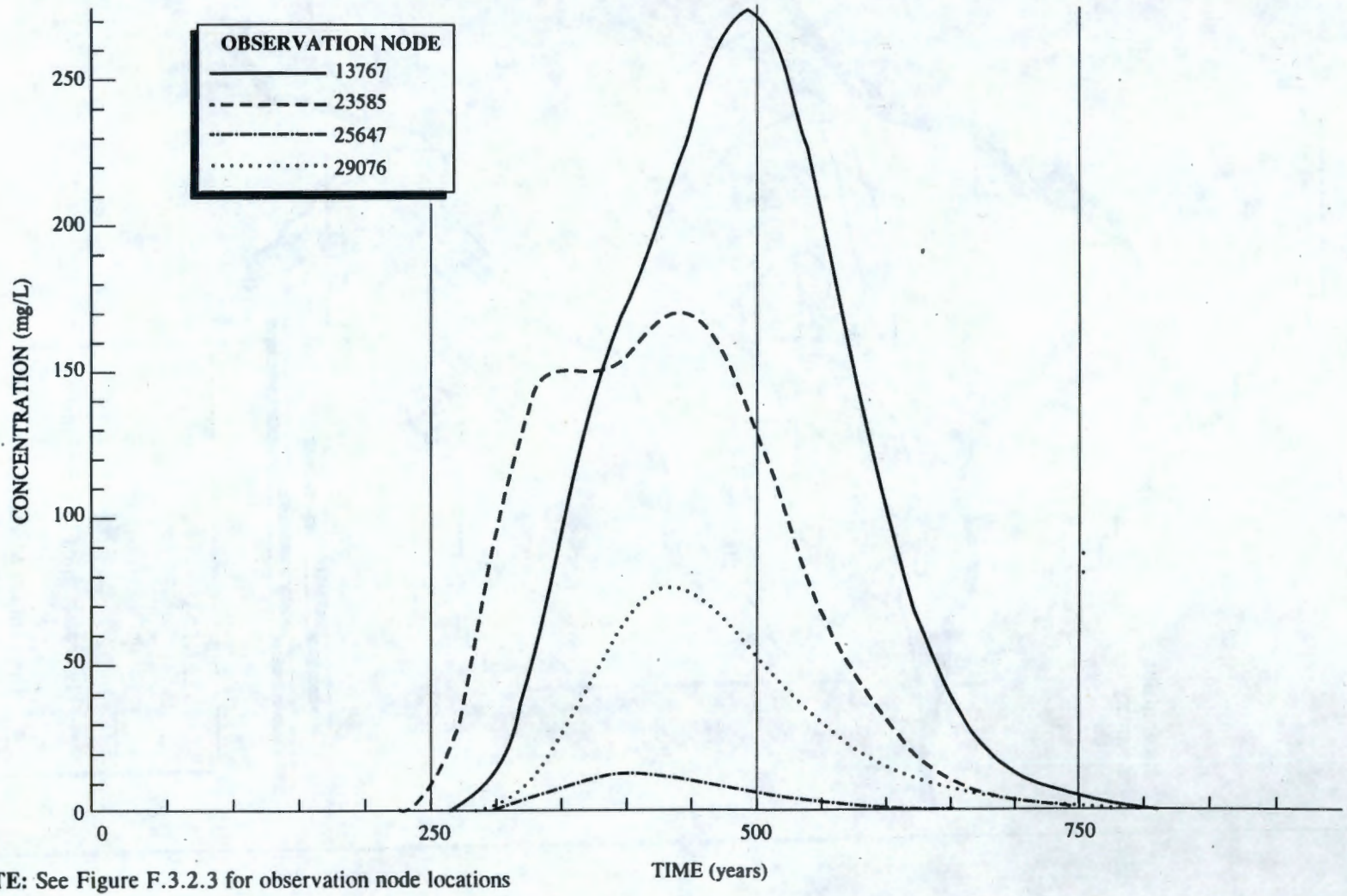
NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

Figure F.3.2.3 Predicted Nitrate Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative



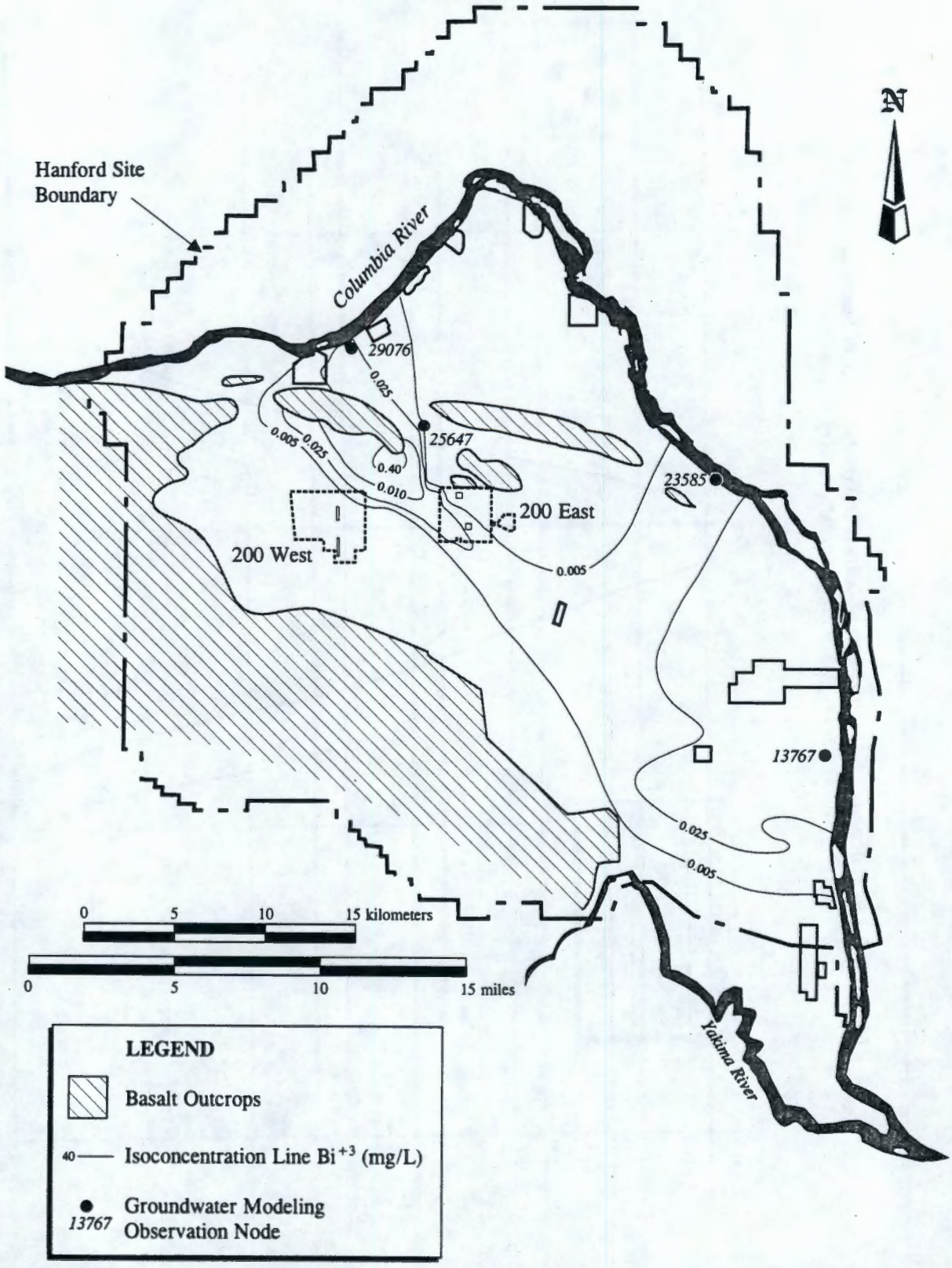
9613409.1569

Figure F.3.2.4 Calculated Concentration of Nitrate in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d = 0)



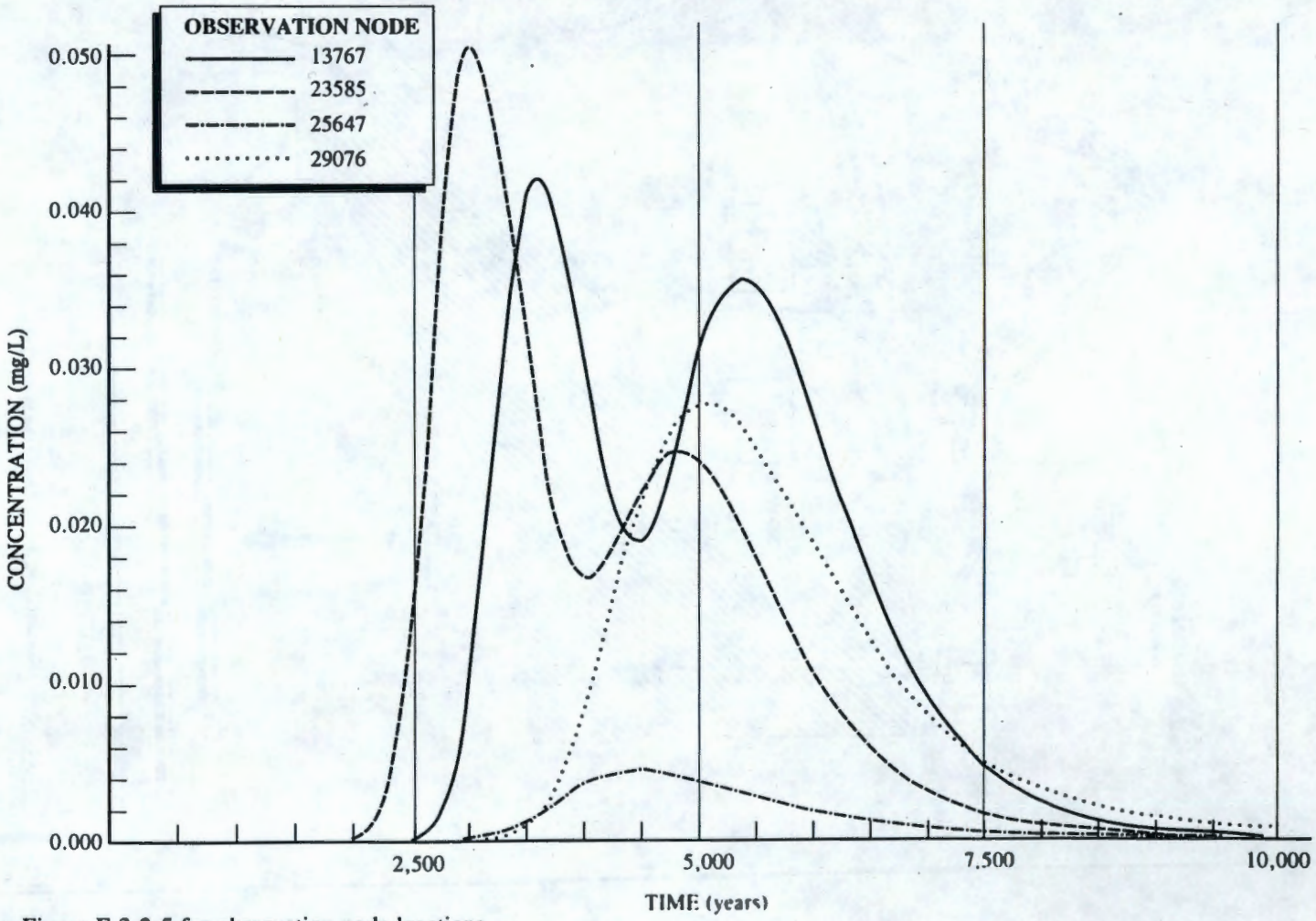
NOTE: See Figure F.3.2.3 for observation node locations

Figure F.3.2.5 Predicted Bismuth Distribution in Groundwater at 5,000 Years for the Long-Term Management Alternative



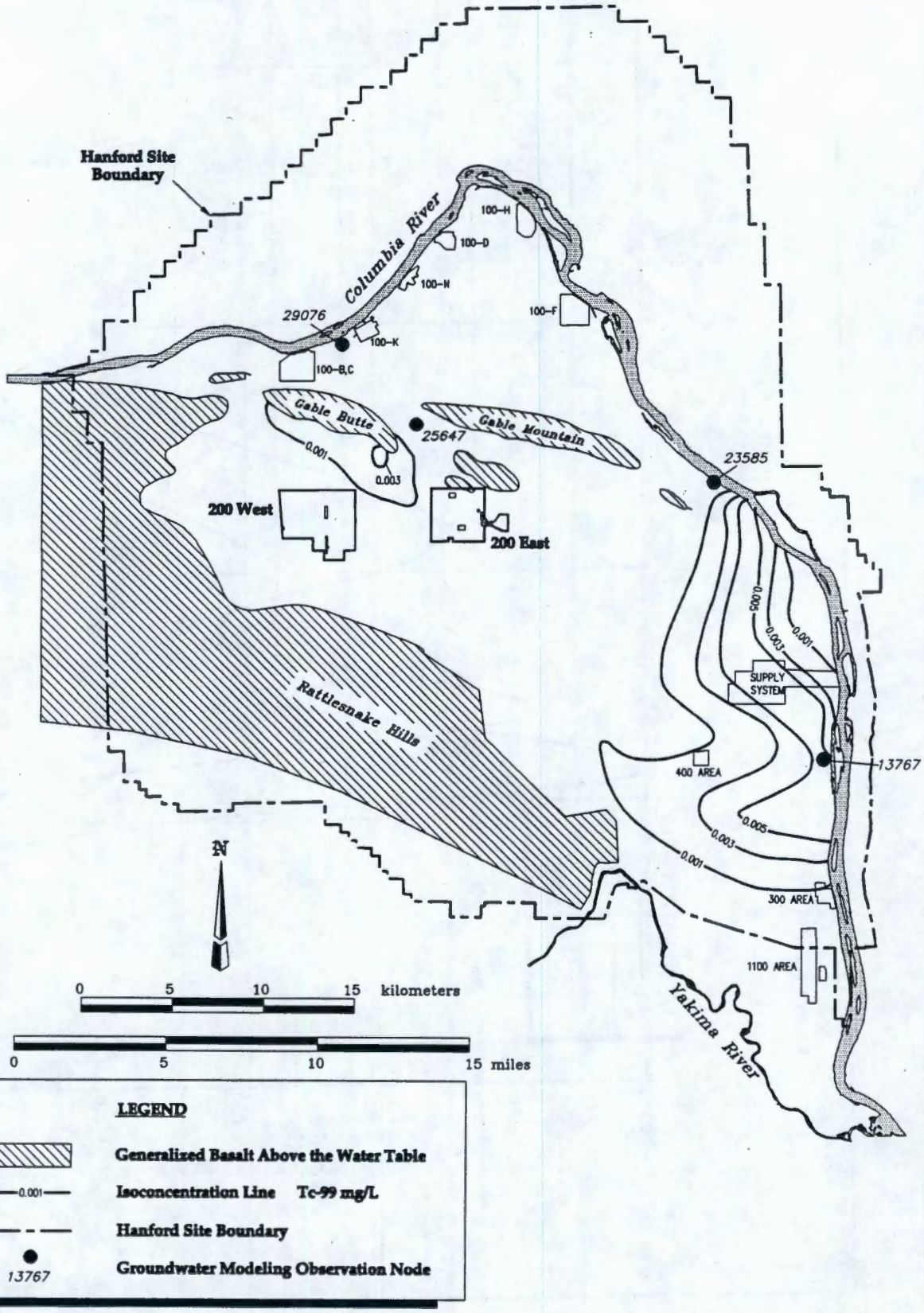
9613409.1570

Figure F.3.2.6 Predicted Concentration of Bismuth in Groundwater at Selected Locations for the Long-Term Management Alternative (K_d = 1)



NOTE: See Figure F.3.2.5 for observation node locations

Figure F.3.2.7 Predicted Technetium-99 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative



9613409.1571

Figure F.3.2.8 Predicted Iodine-129 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

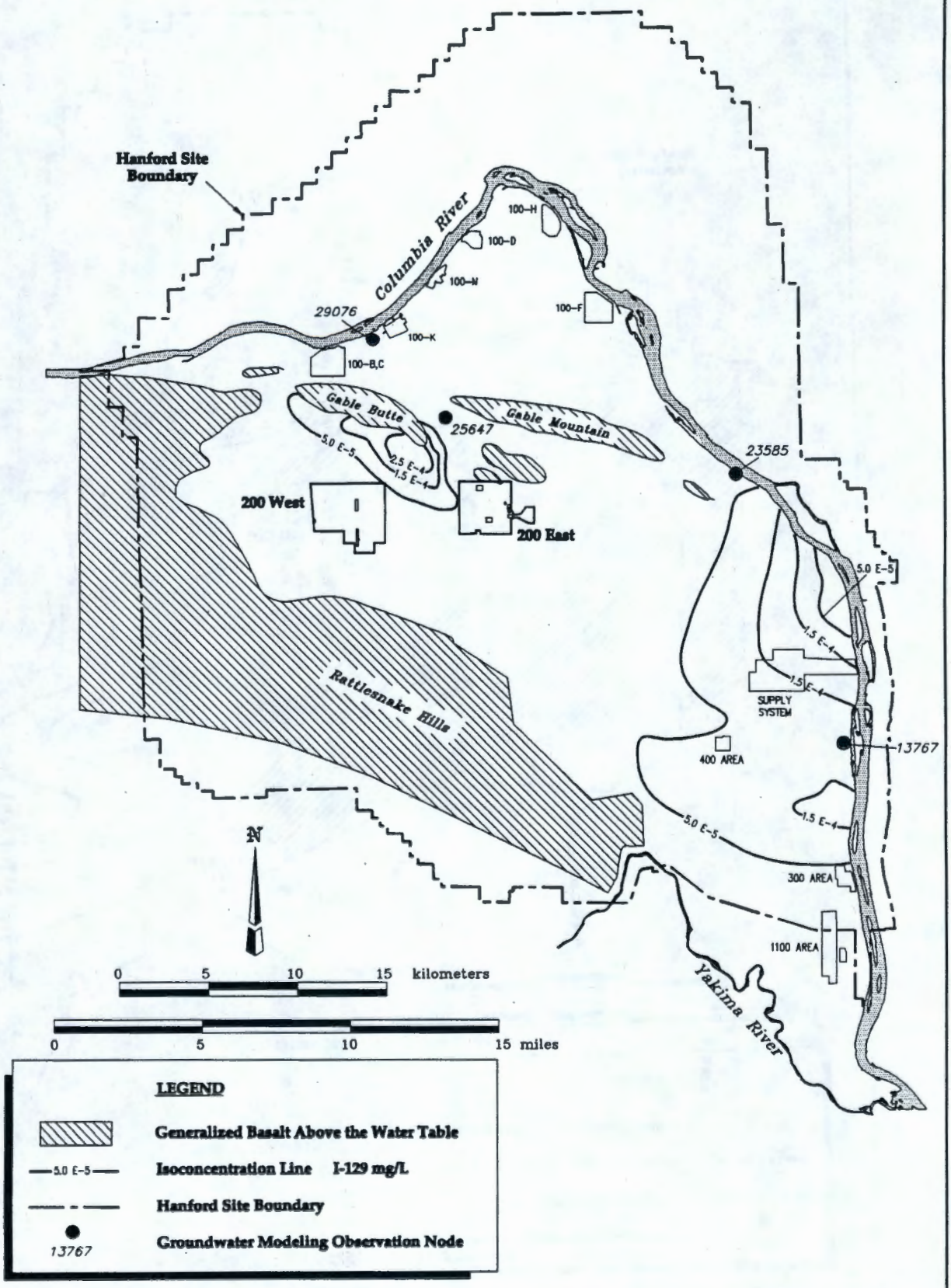
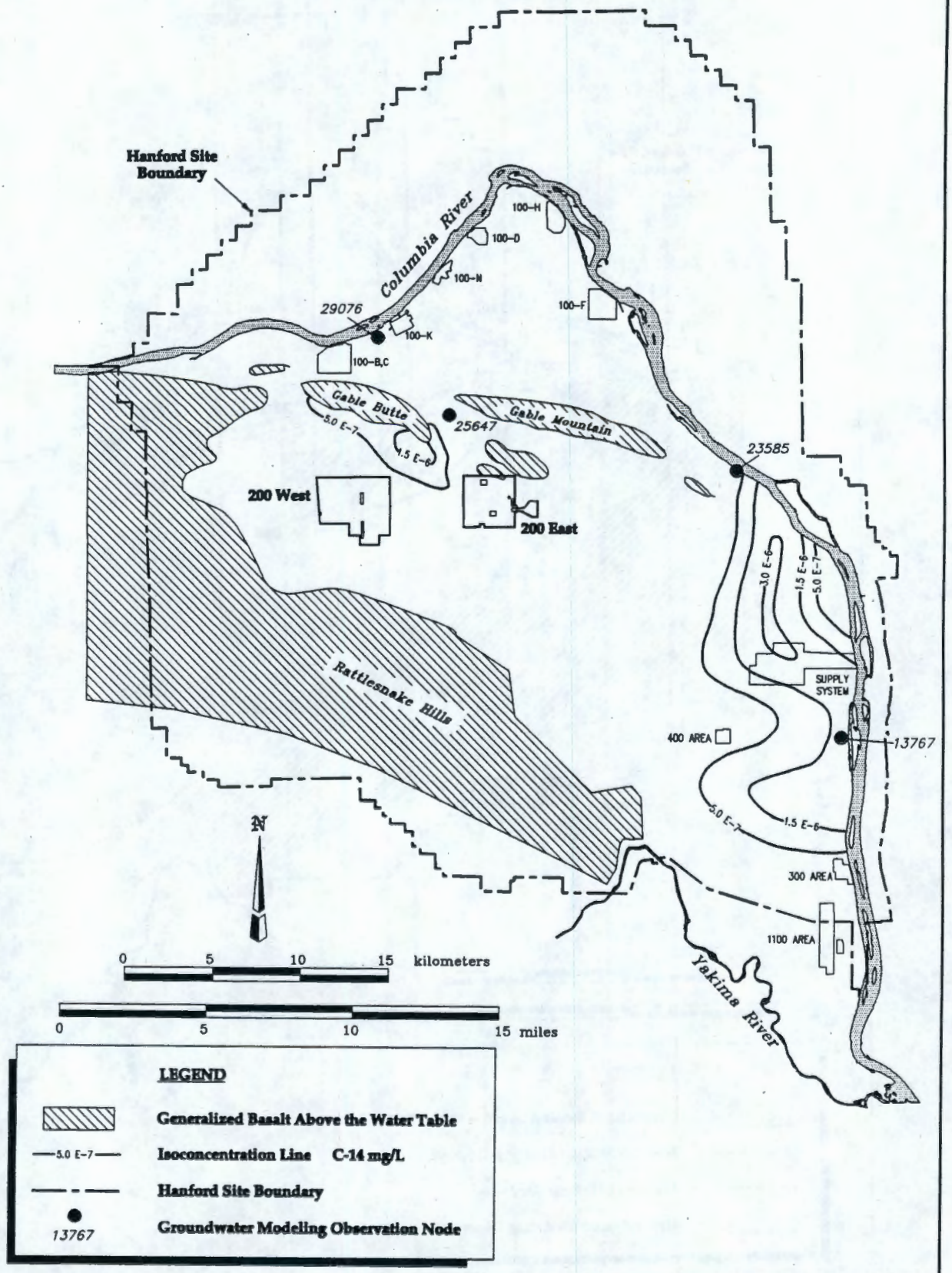


Figure F.3.2.9 Predicted Carbon-14 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative



9613409.1572

Figure F.3.2.10 Predicted Uranium-238 Concentrations in Groundwater at 300 Years for the Long-Term Management Alternative

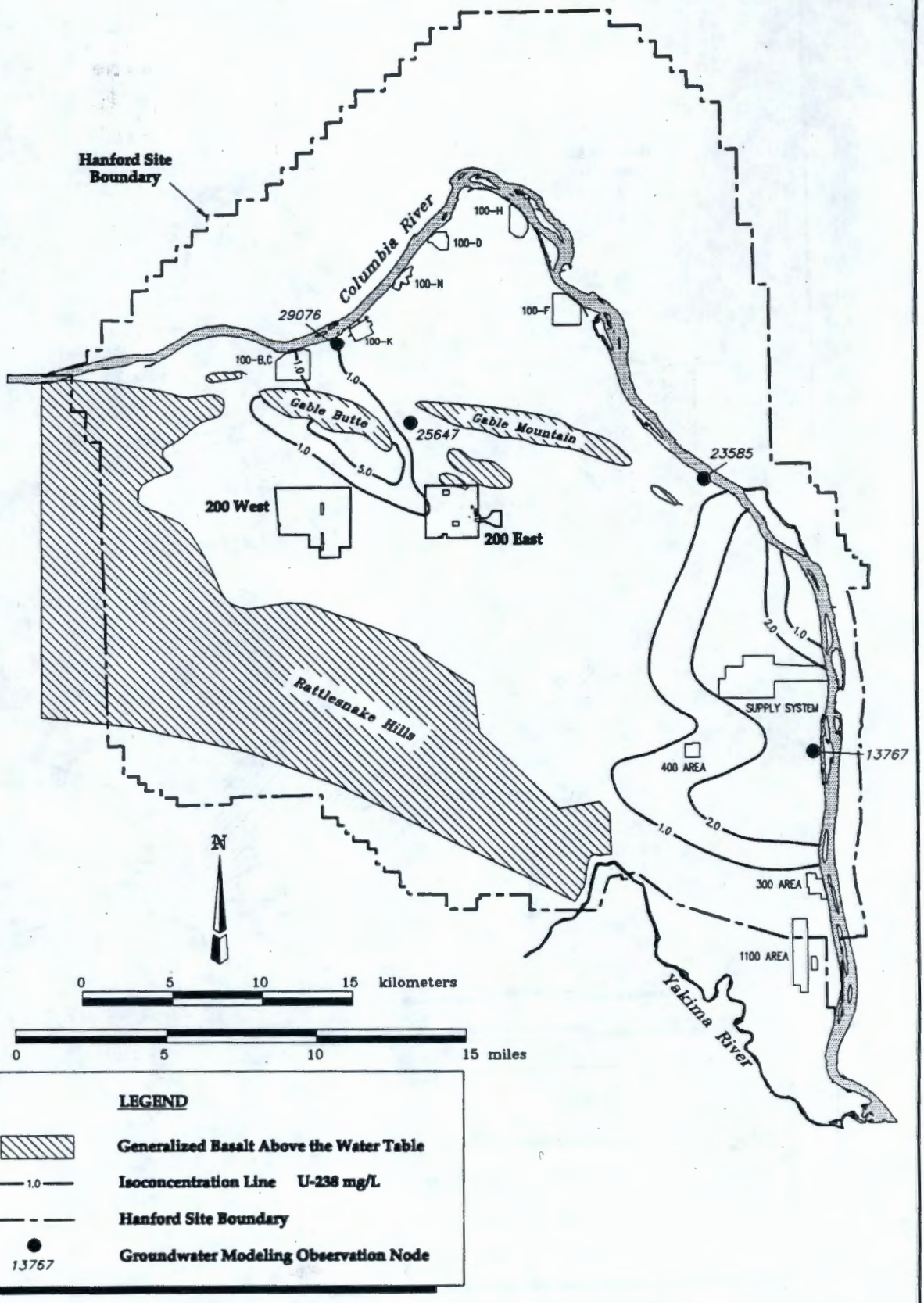
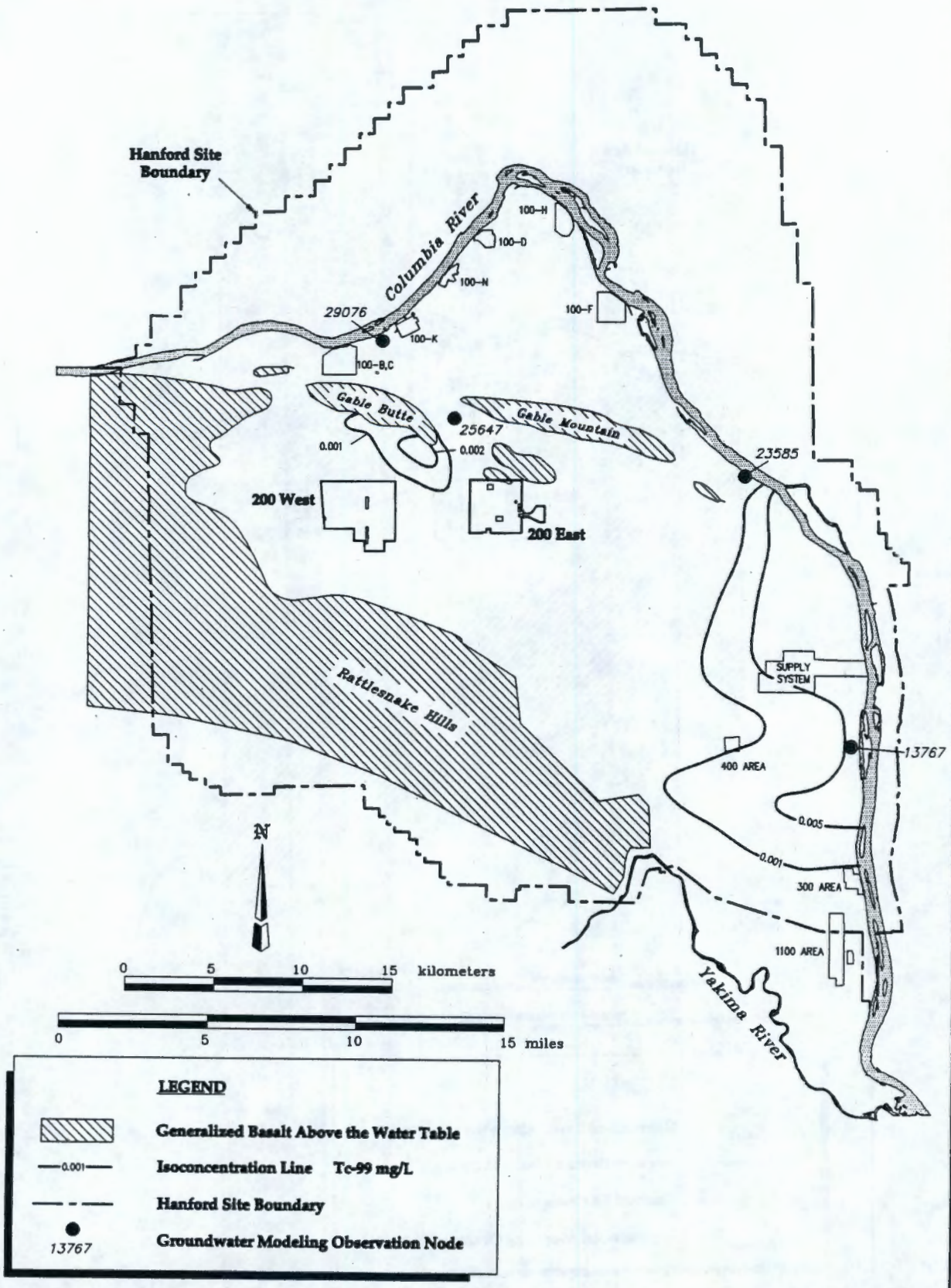


Figure F.3.2.11 Predicted Technetium-99 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative



9613409.1573

Figure F.3.2.12 Predicted Iodine-129 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative

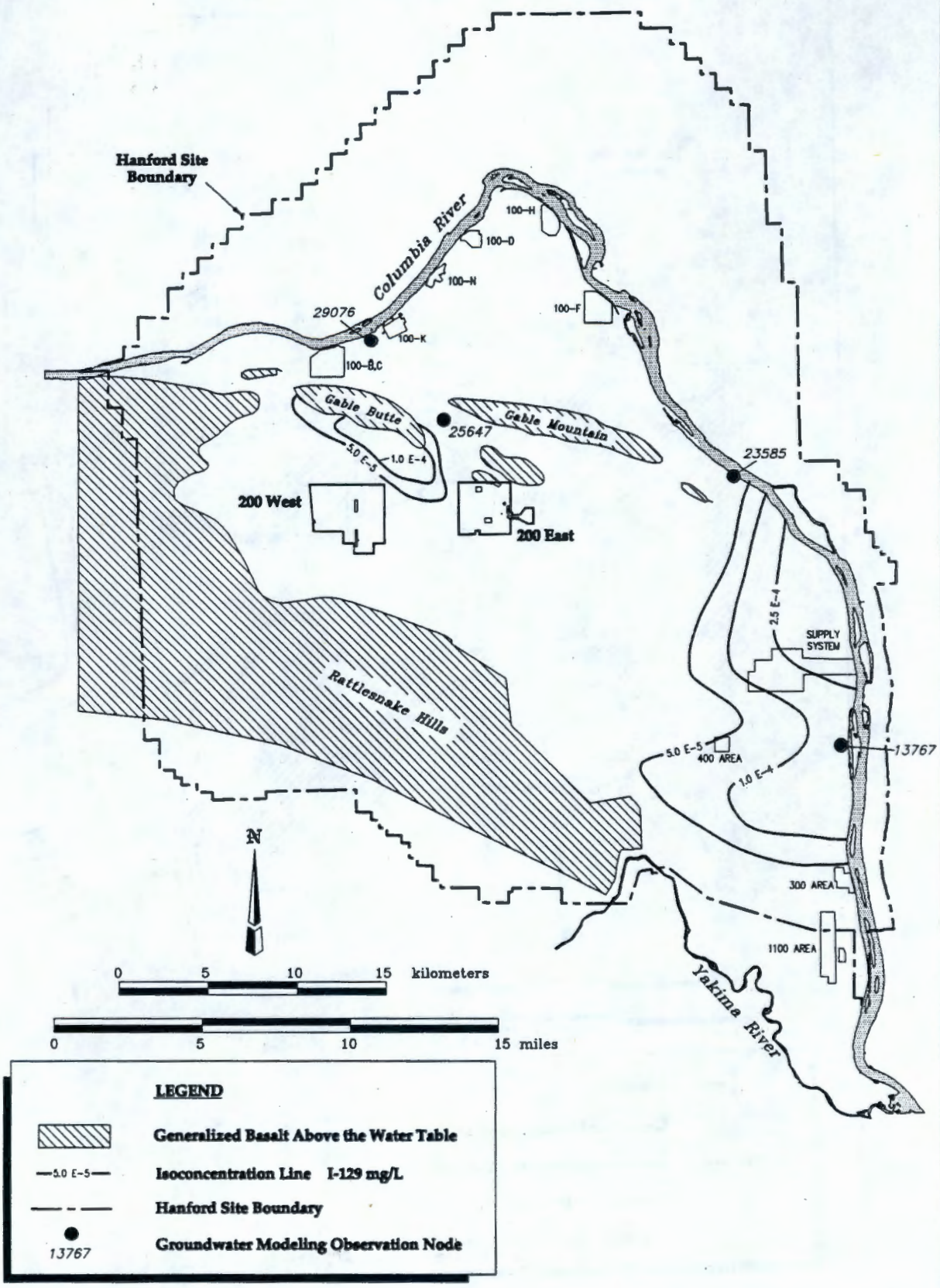
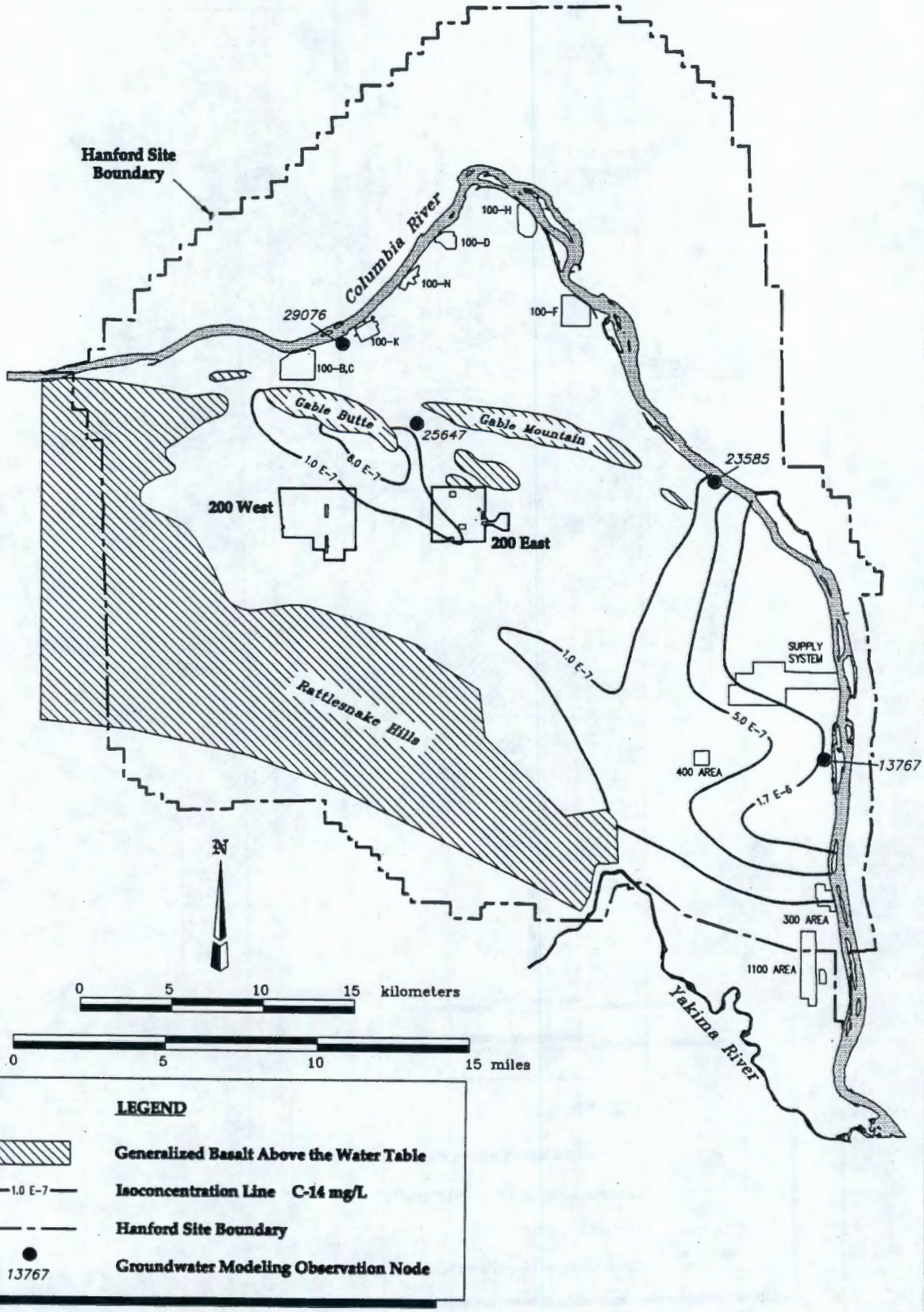


Figure F.3.2.13 Predicted Carbon-14 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative



9613409.1574

Figure F.3.2.14 Predicted Uranium-238 Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative

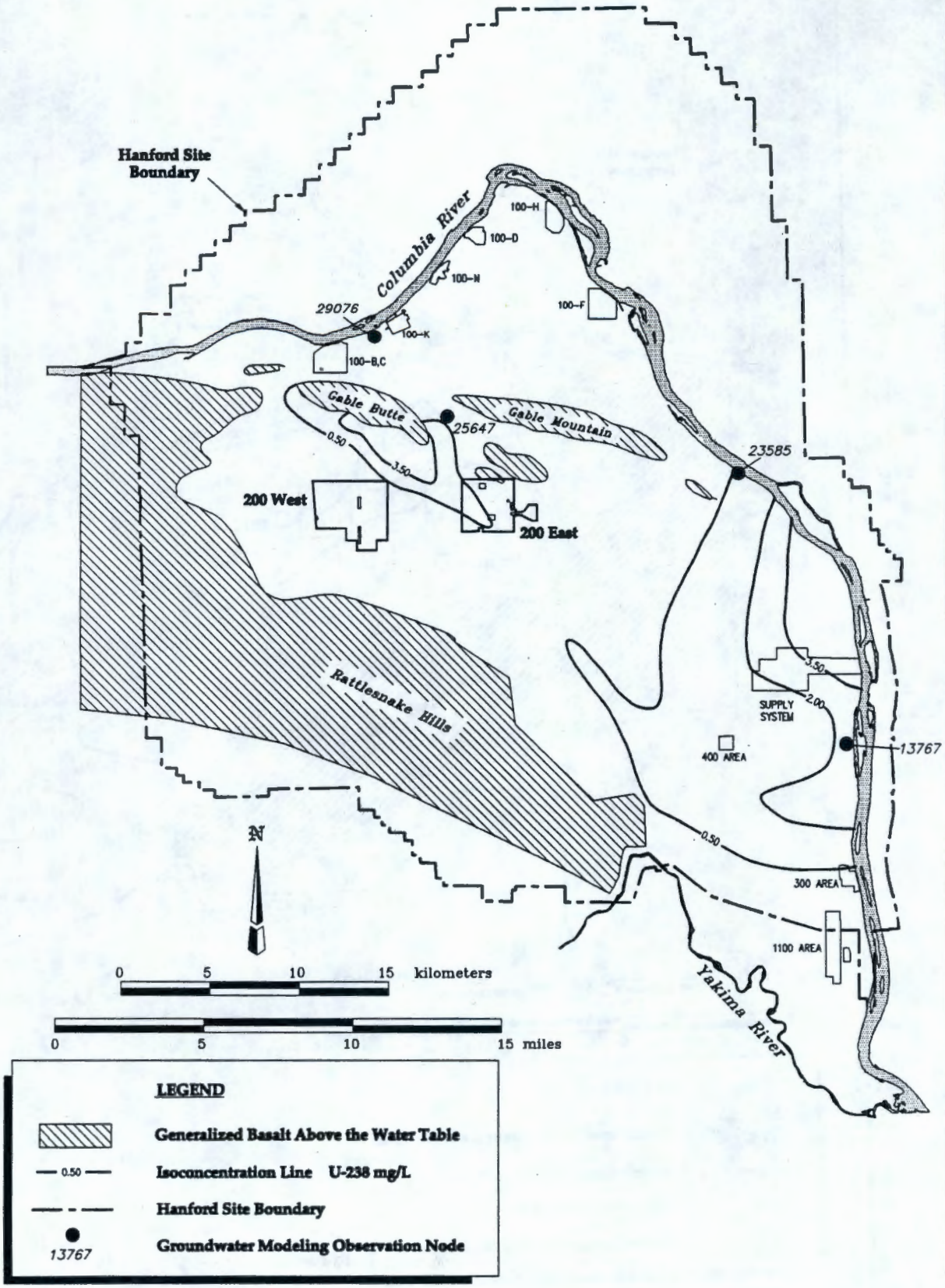
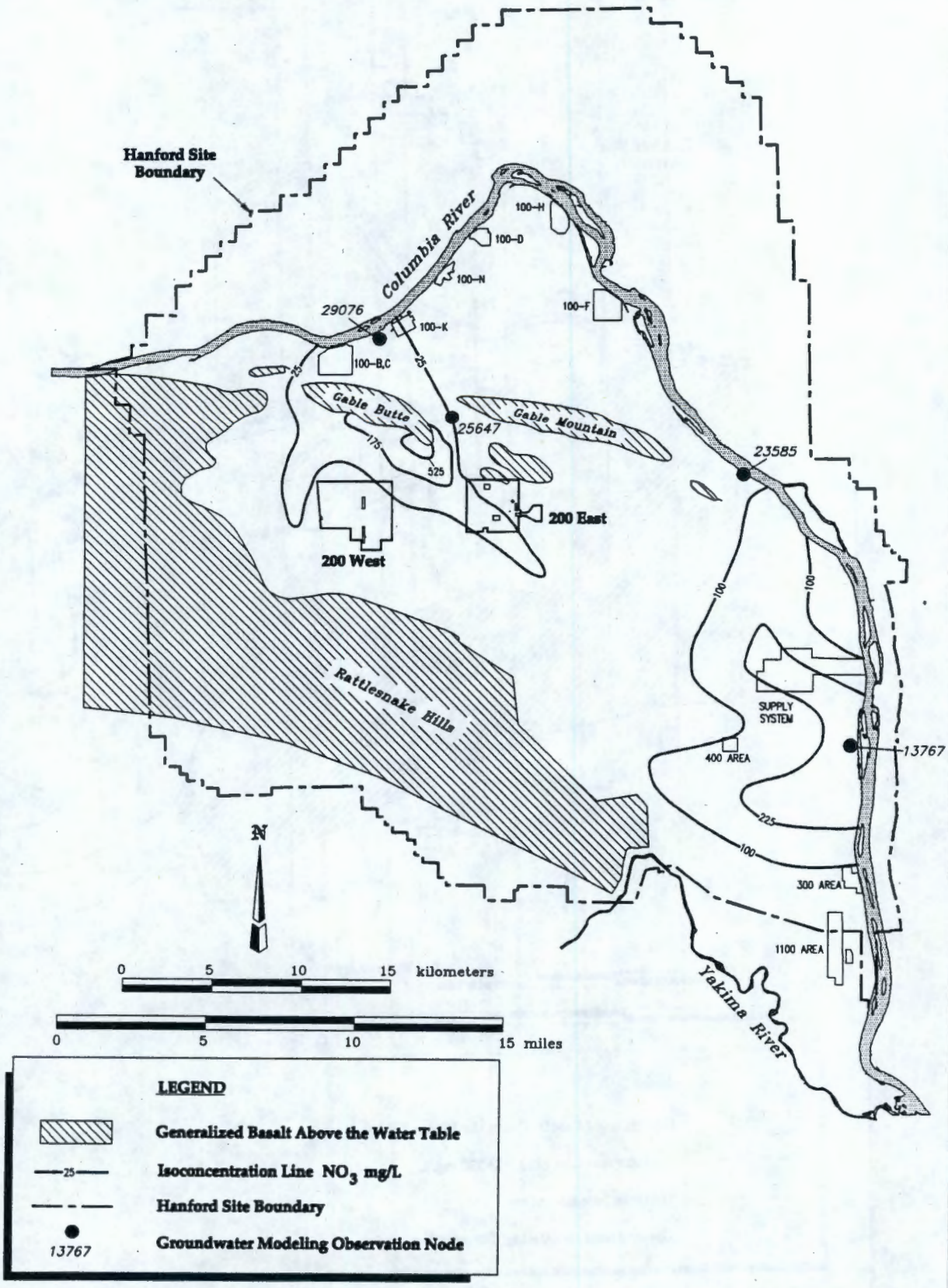


Figure F.3.2.15 Predicted Nitrate Concentrations in Groundwater at 500 Years for the Long-Term Management Alternative



9613409.1575

Figure F.3.2.16 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

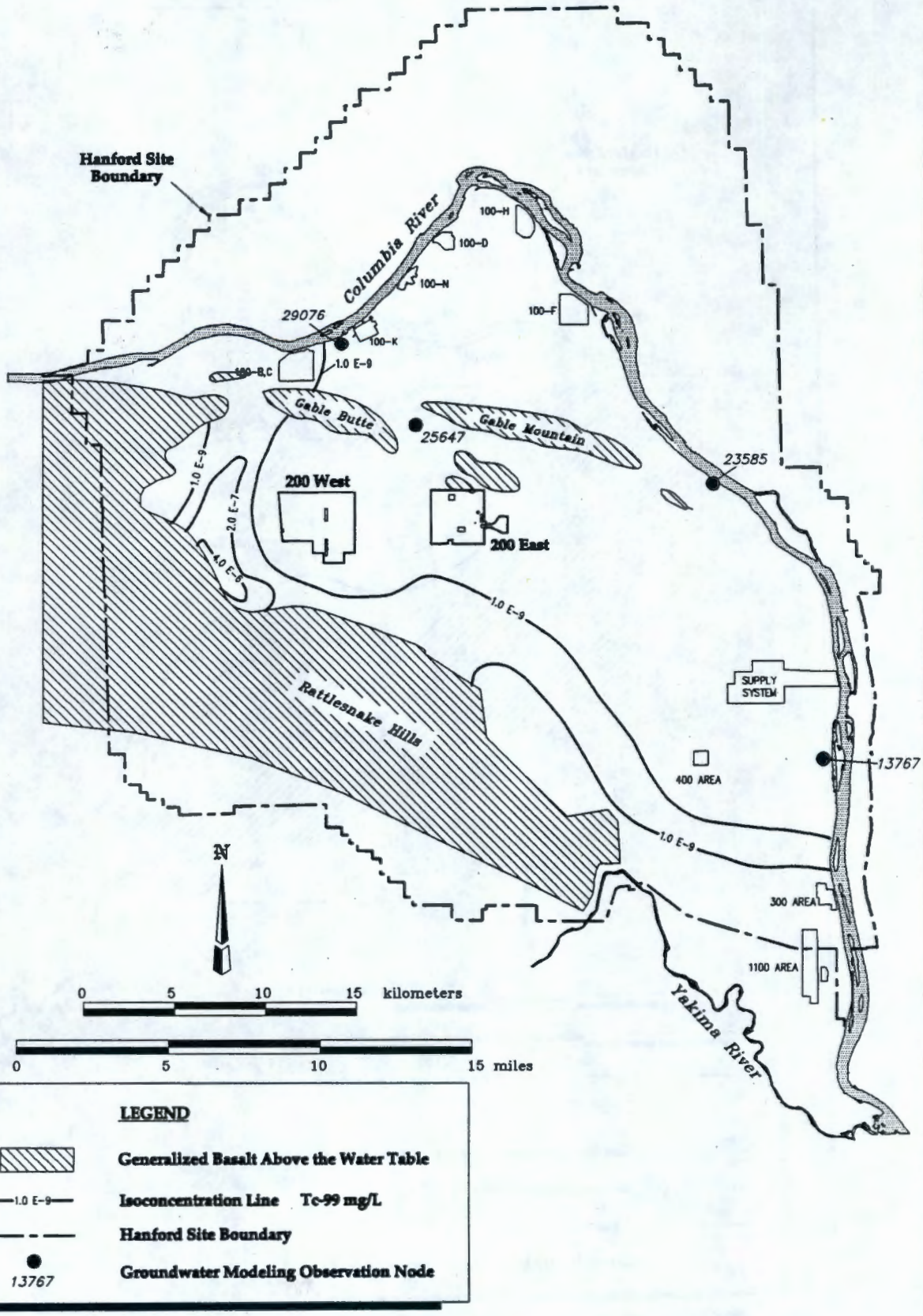
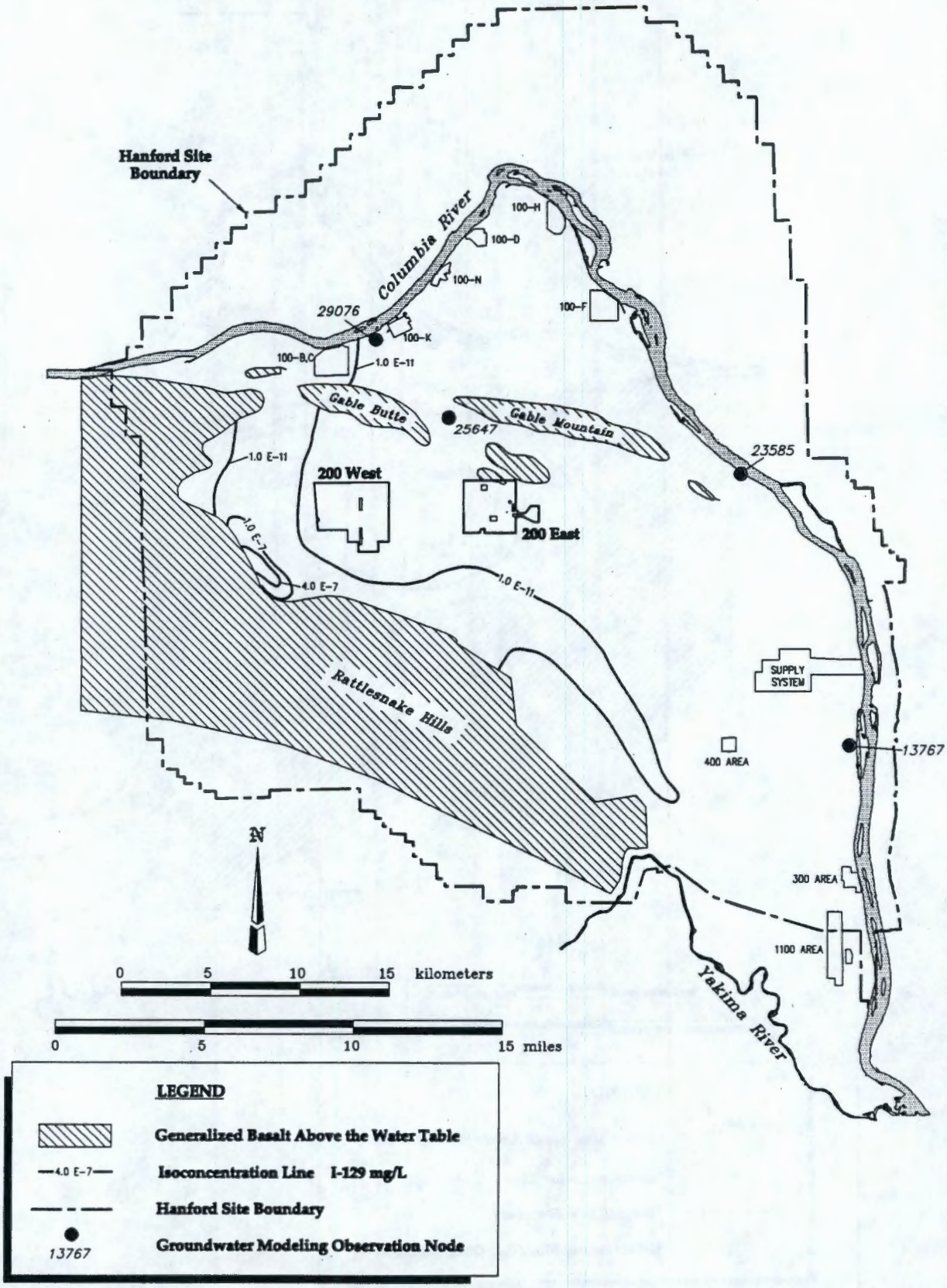


Figure F.3.2.17 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative



9613409.1576

Figure F.3.2.18 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

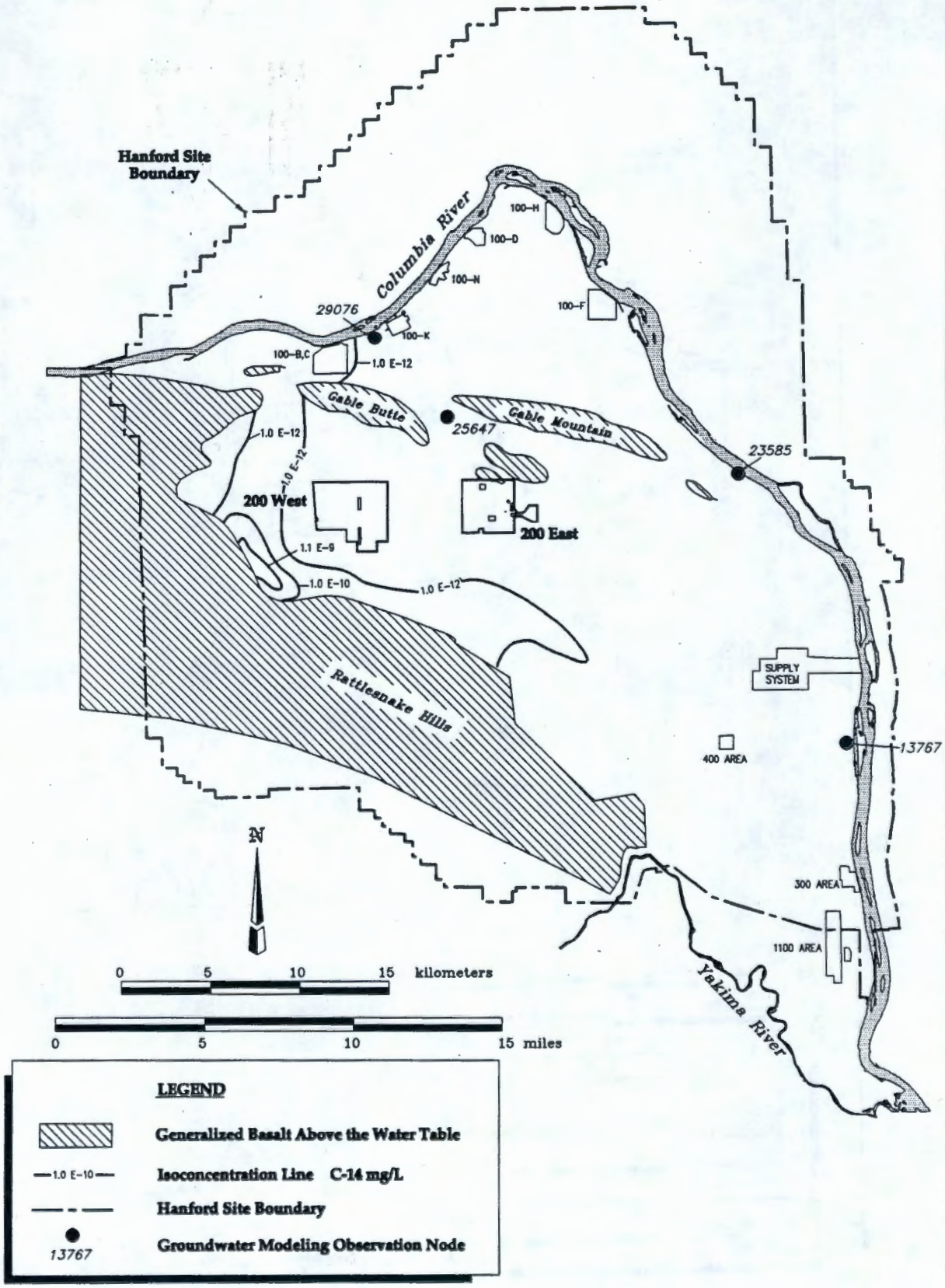
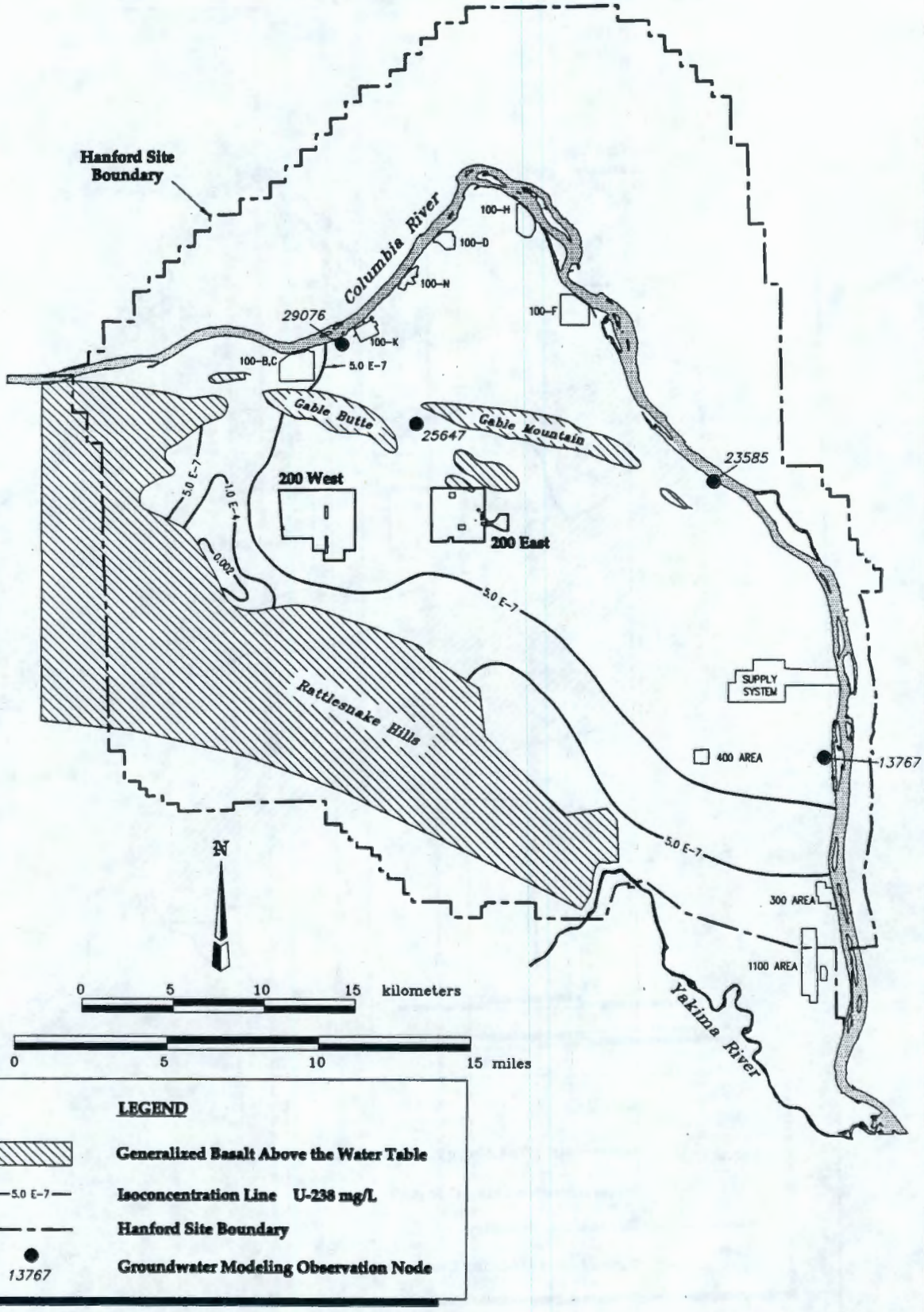


Figure F.3.2.19 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative



9613409.1577

Figure F.3.2.20 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the Long-Term Management Alternative

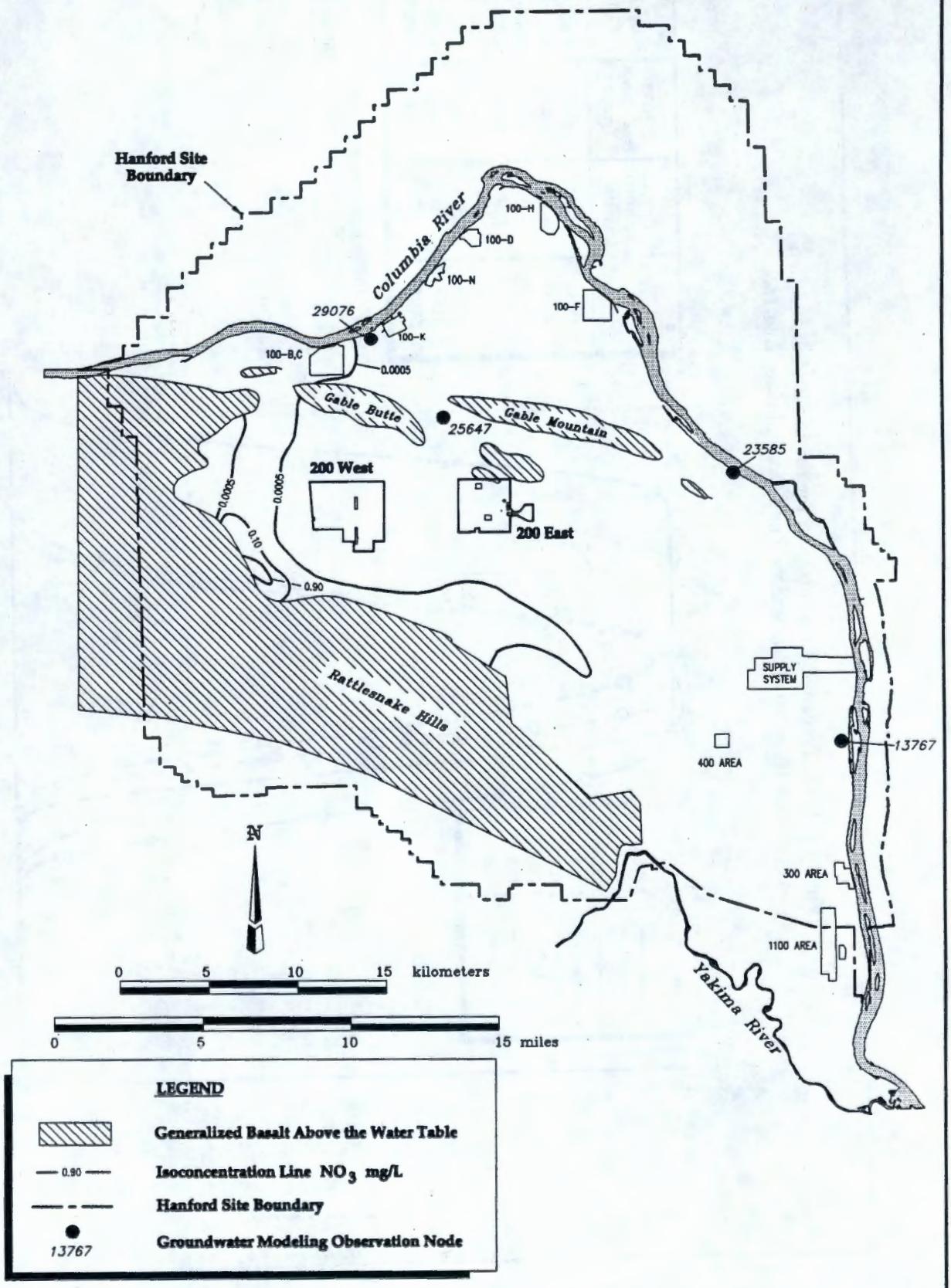
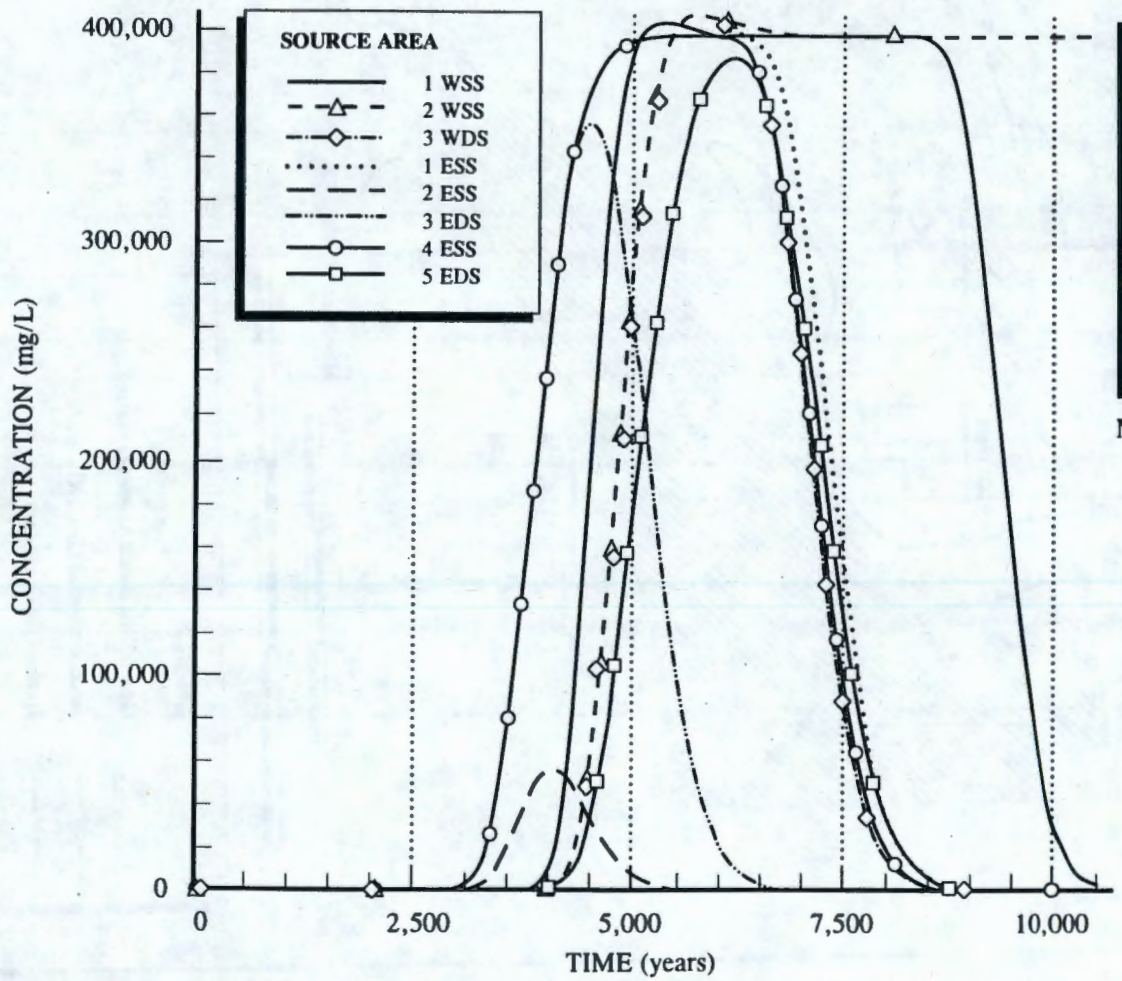


Figure F.3.3.1 Predicted Concentration for the In Situ Fill and Cap Alternative (K_d = 0) at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	3,250	4,830	4.00E+05
2WSS	3,380	5,370	4.00E+05
3WDS	3,380	5,480	4.00E+05
1ESS	2,340	5,300	4.00E+05
2ESS	2,450	4,080	5.51E+04
3EDS	2,330	4,600	3.57E+05
4ESS	2,330	5,940	4.00E+05
5EDS	3,230	6,300	3.99E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

9613409.1578

Figure F.3.3.2 Predicted Distribution of Nitrate in Groundwater at 5,000 Years for In Situ Fill and Cap Alternative

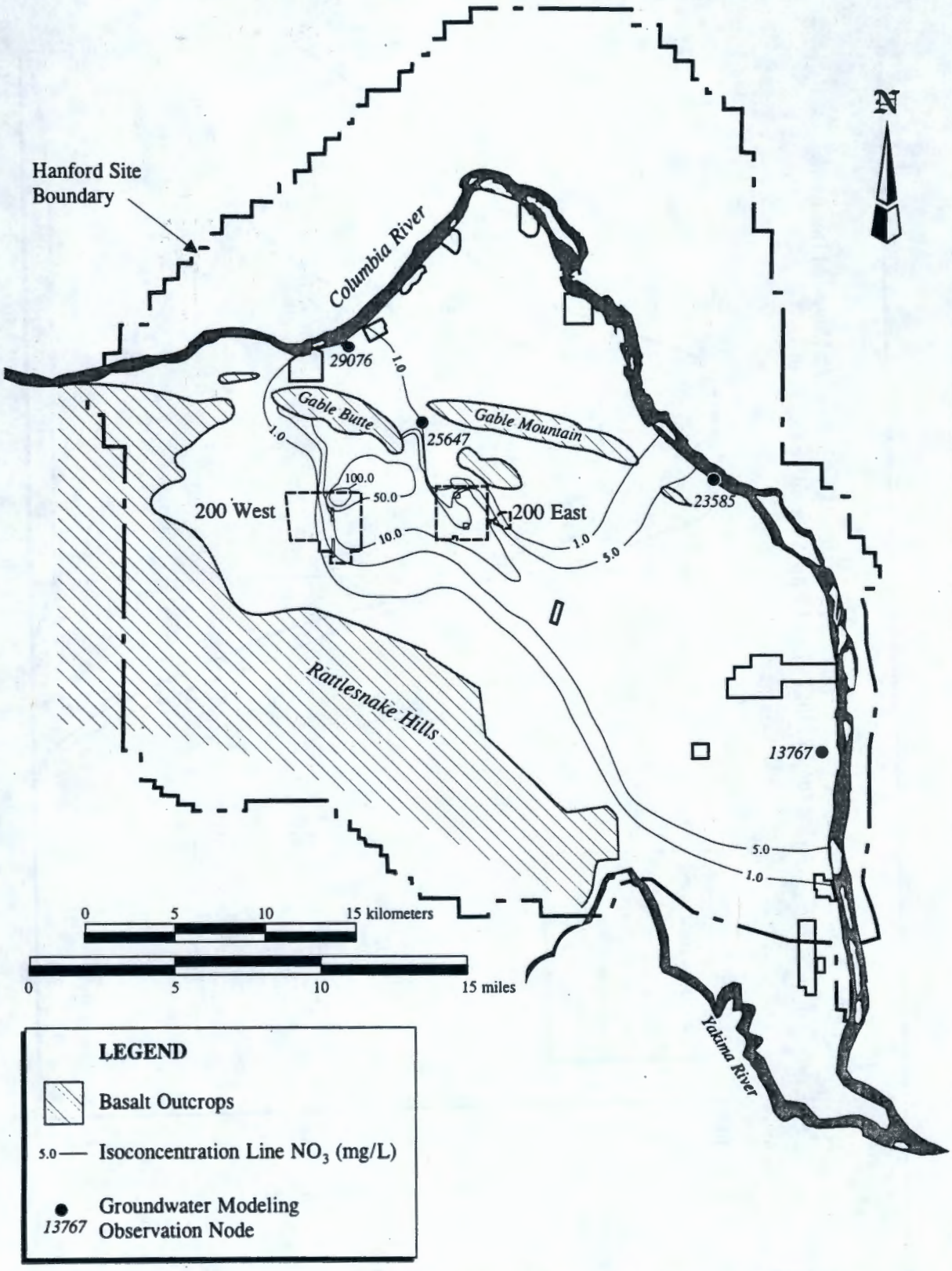
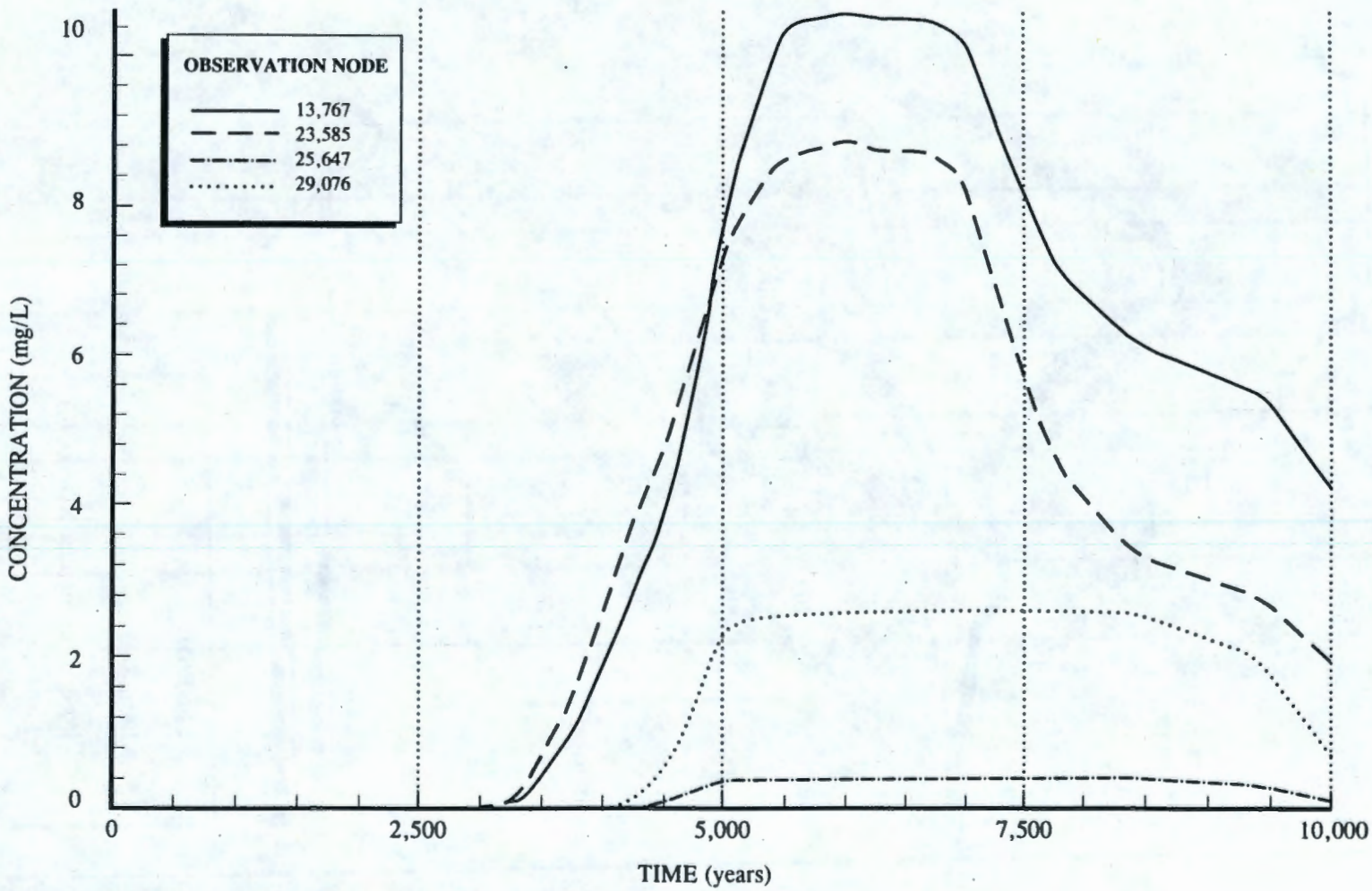


Figure F.3.3.3 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (K_d = 0)



NOTE: See Figure F.3.3.2 for observation node location

9613409.1579

Figure F.3.3.4 Predicted Technetium-99 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

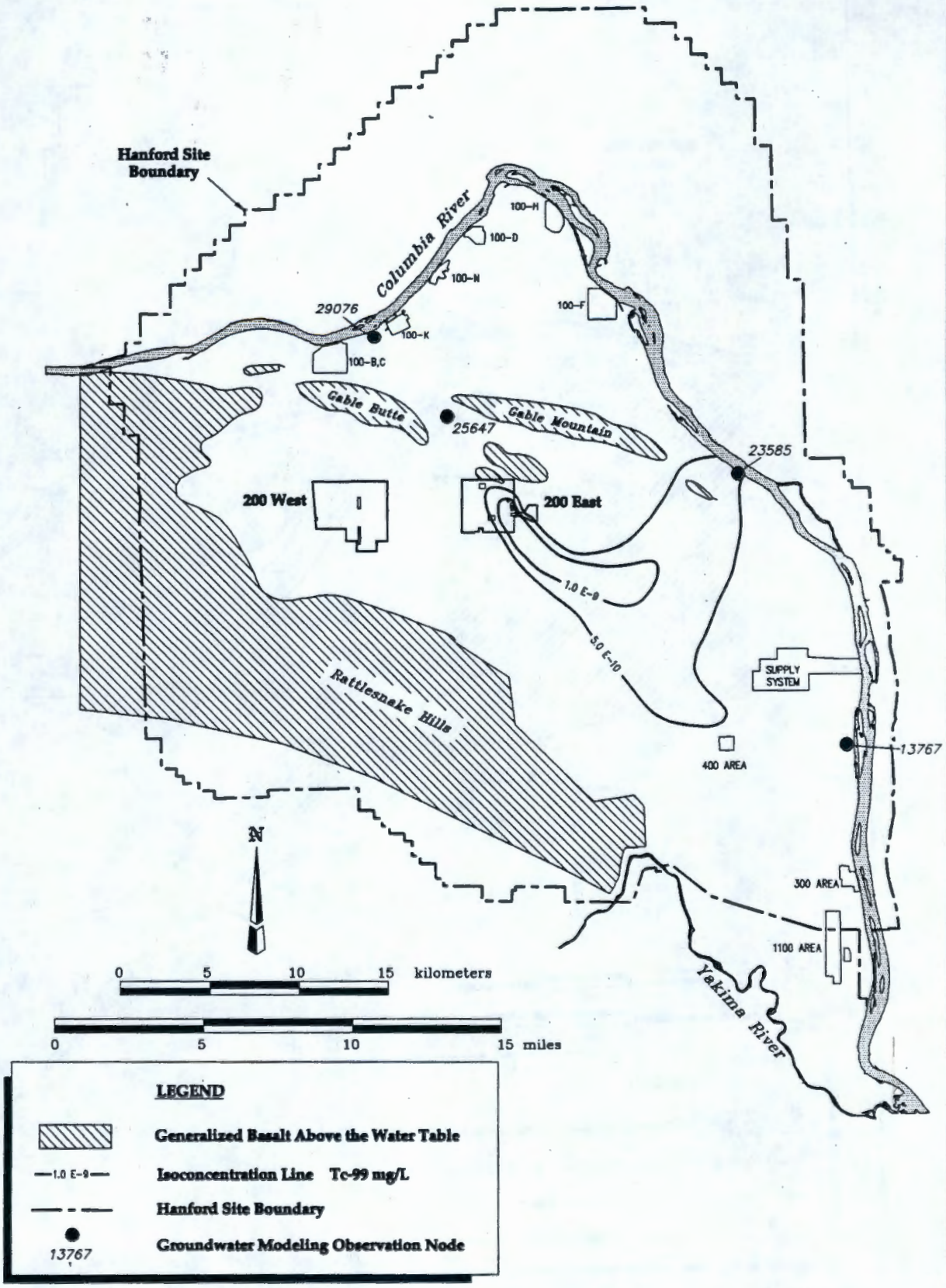
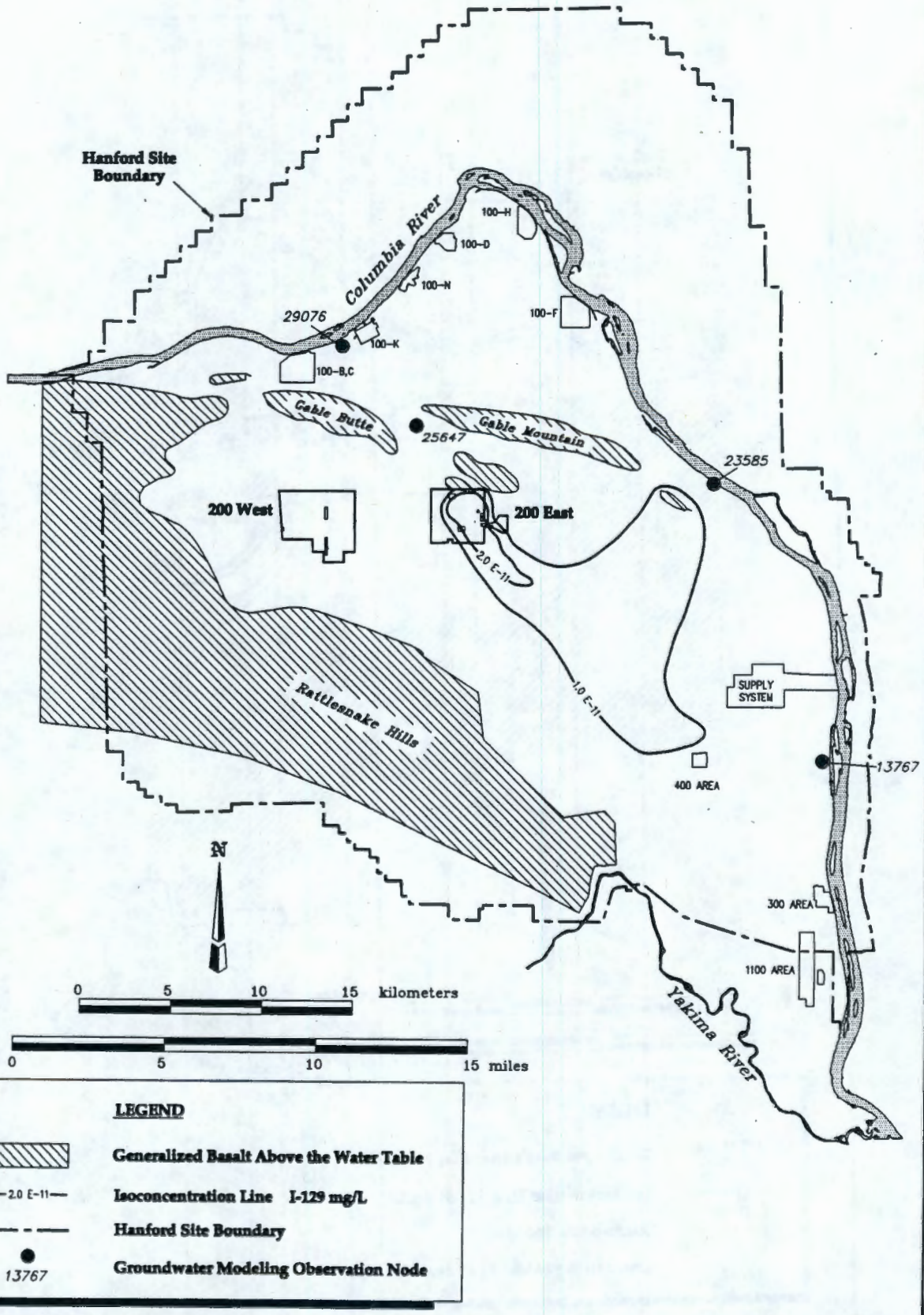


Figure F.3.3.5 Predicted Iodine-129 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative



9613409.1580

Figure F.3.3.6 Predicted Carbon-14 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

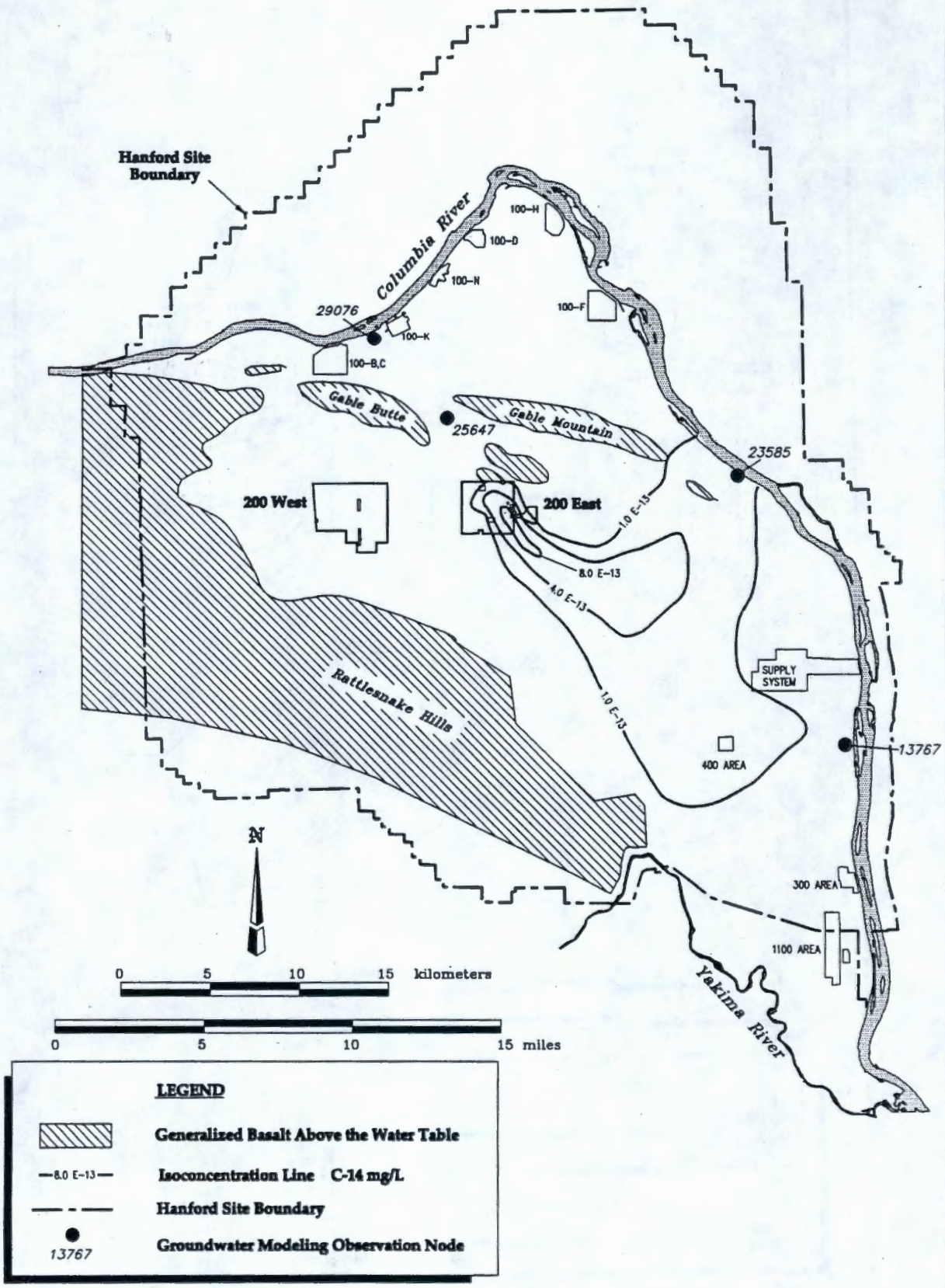
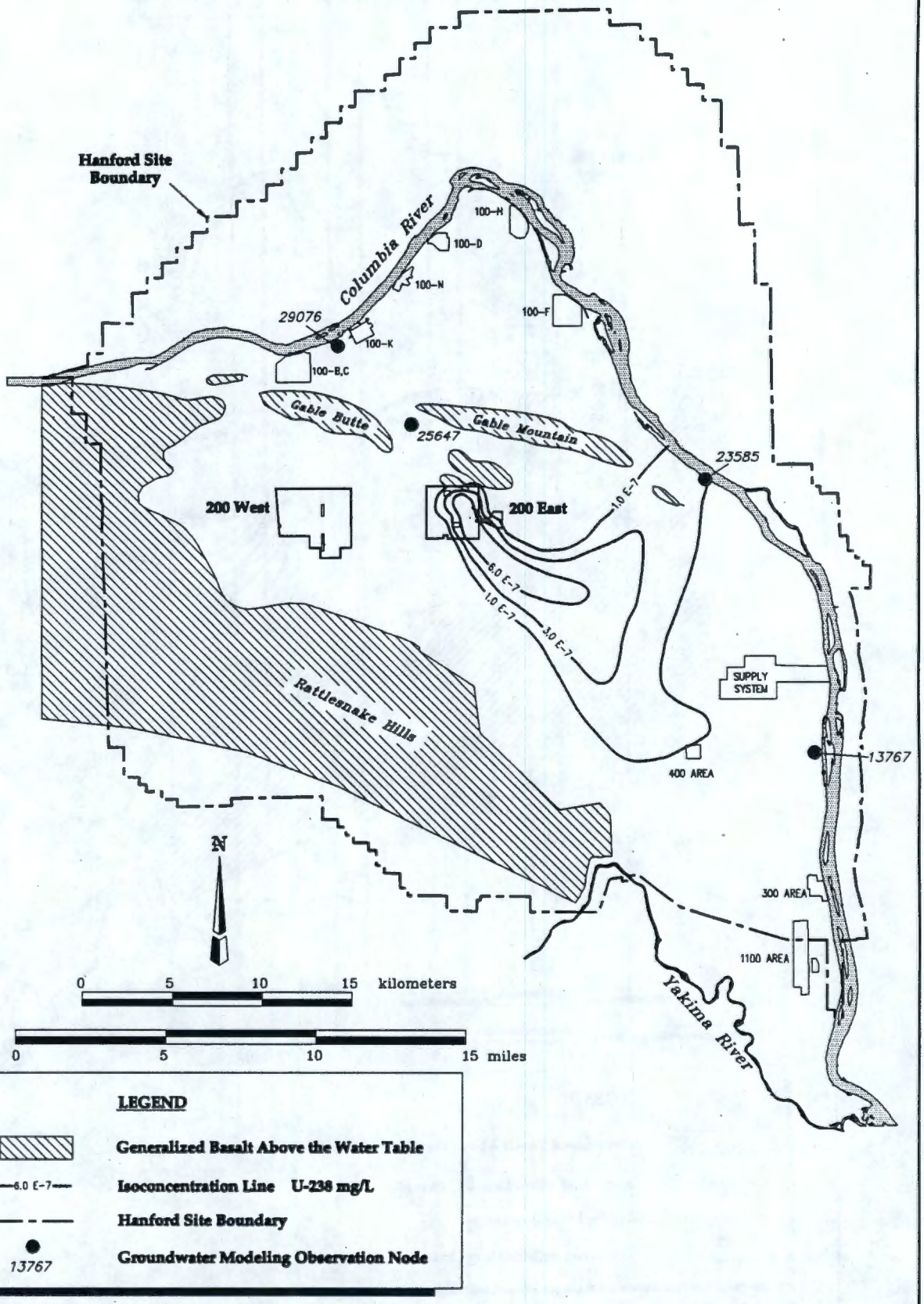


Figure F.3.3.7 Predicted Uranium-238 Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative



9613409.1581

Figure F.3.3.8 Predicted Nitrate Concentrations in Groundwater at 2,500 Years for the In Situ Fill and Cap Alternative

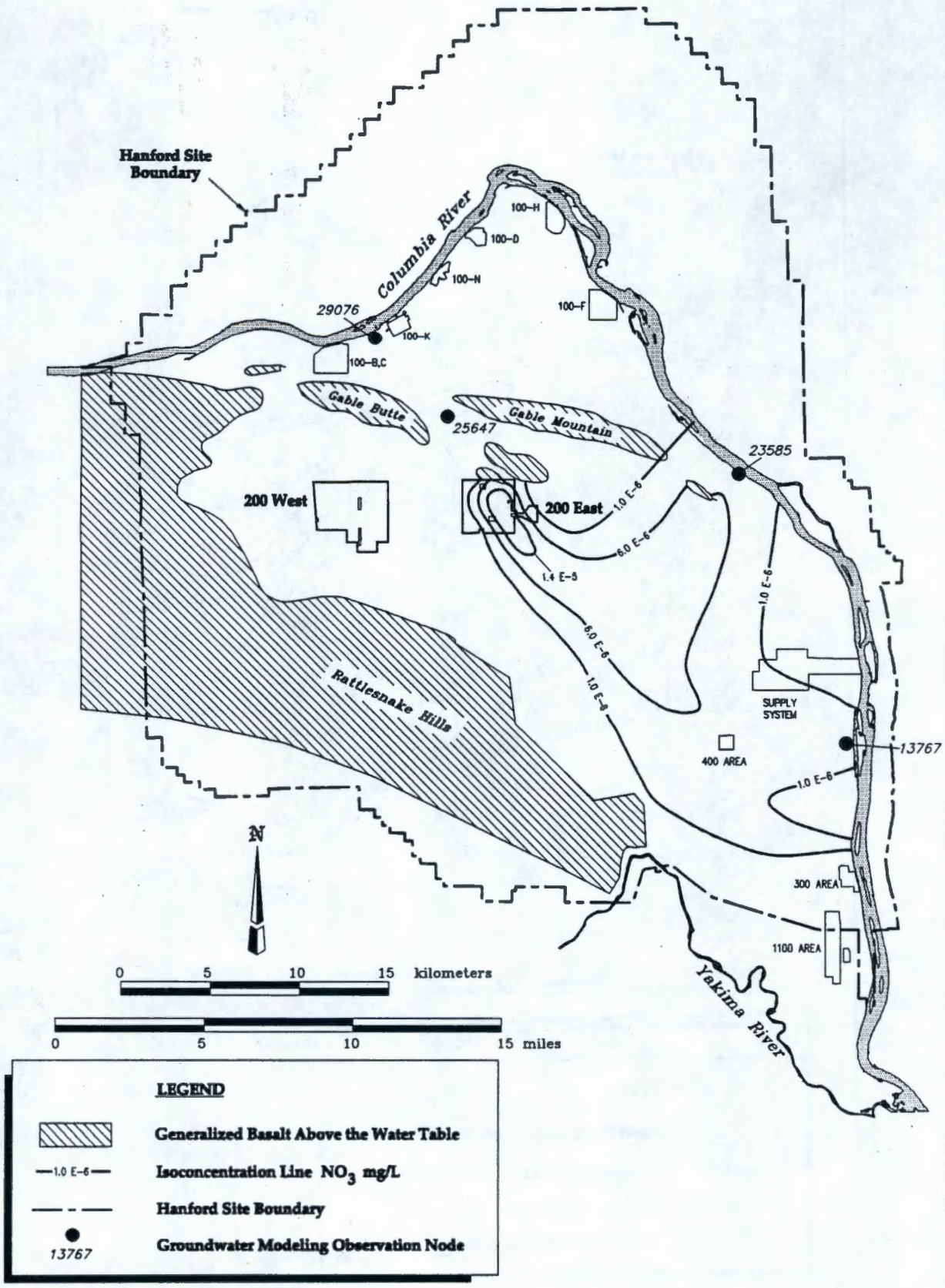
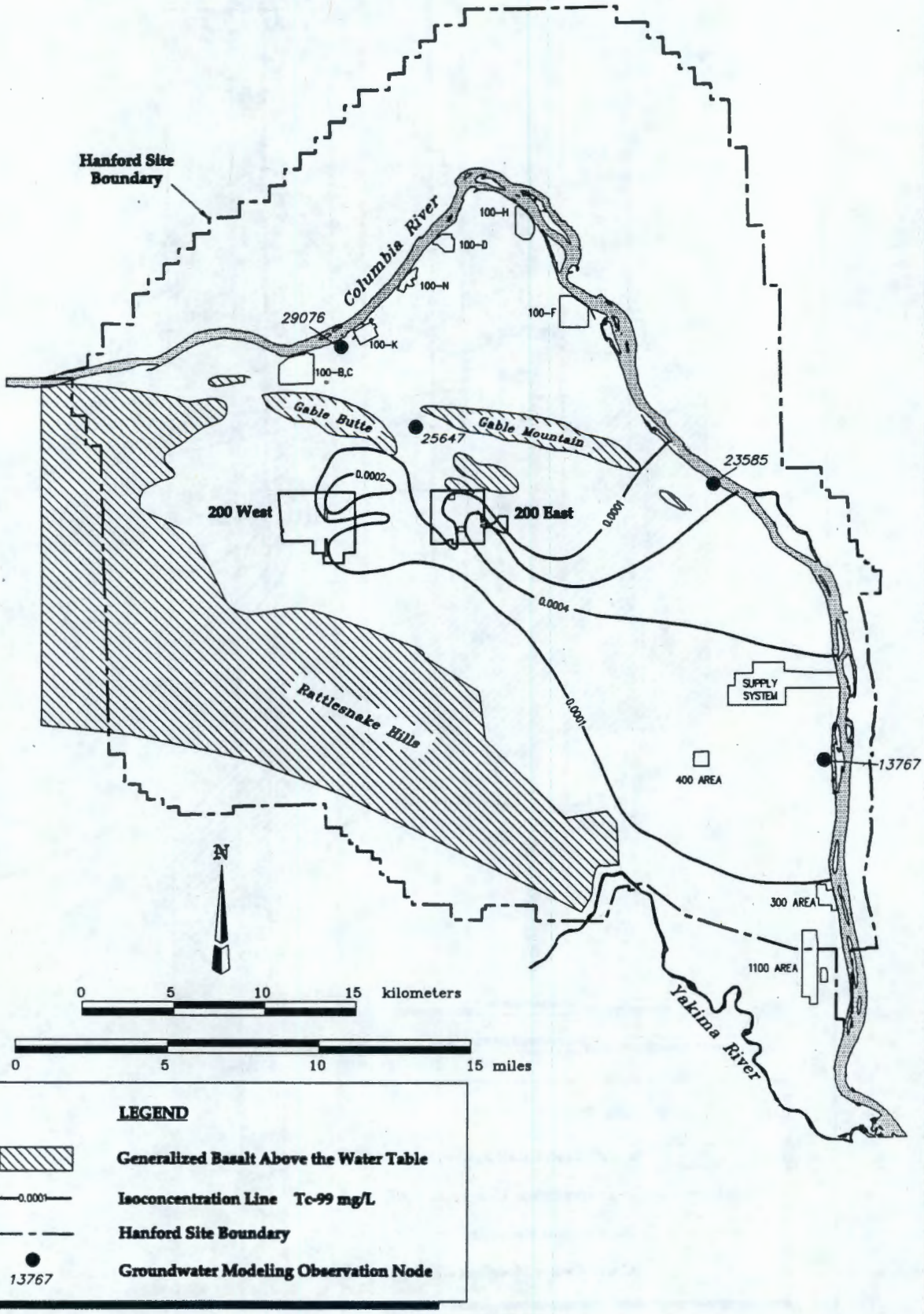


Figure F.3.3.9 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative



9613409.1582

Figure F.3.3.10 Predicted Iodine-129 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

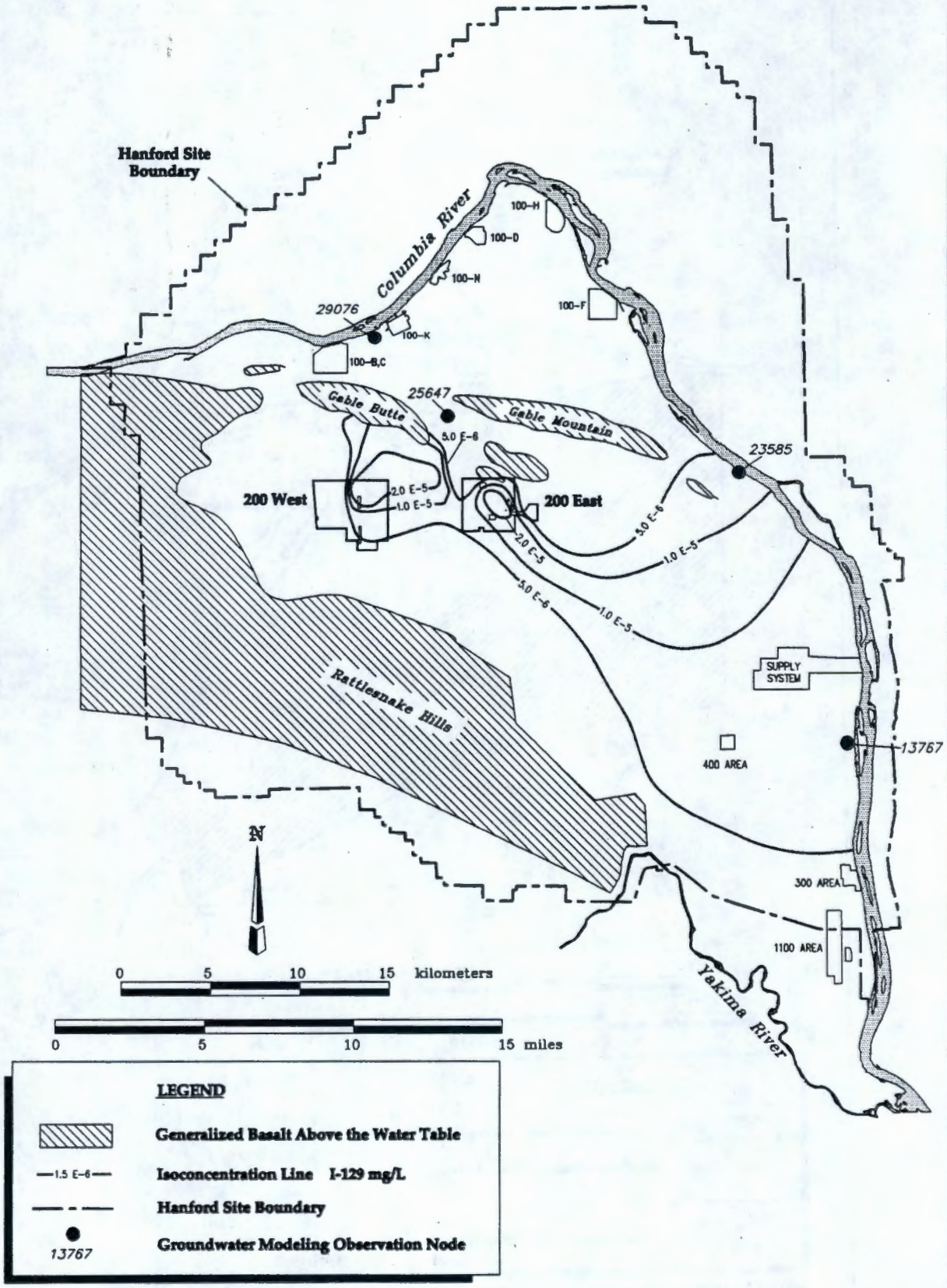
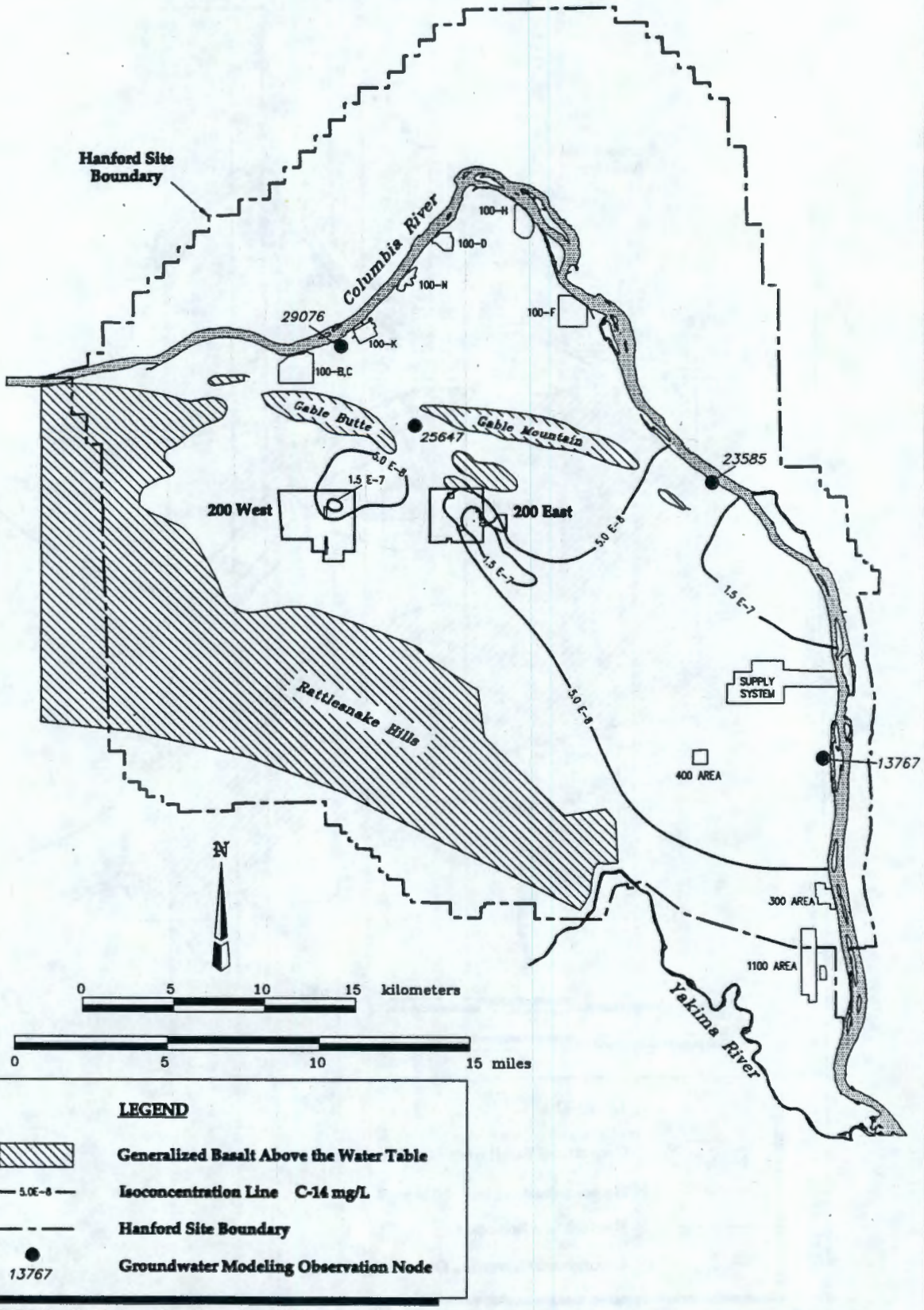


Figure F.3.3.11 Predicted Carbon-14 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative



SOURCE: Jacobs Engineering Group Inc. 1995

9613409.1583

Figure F.3.3.12 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Fill and Cap Alternative

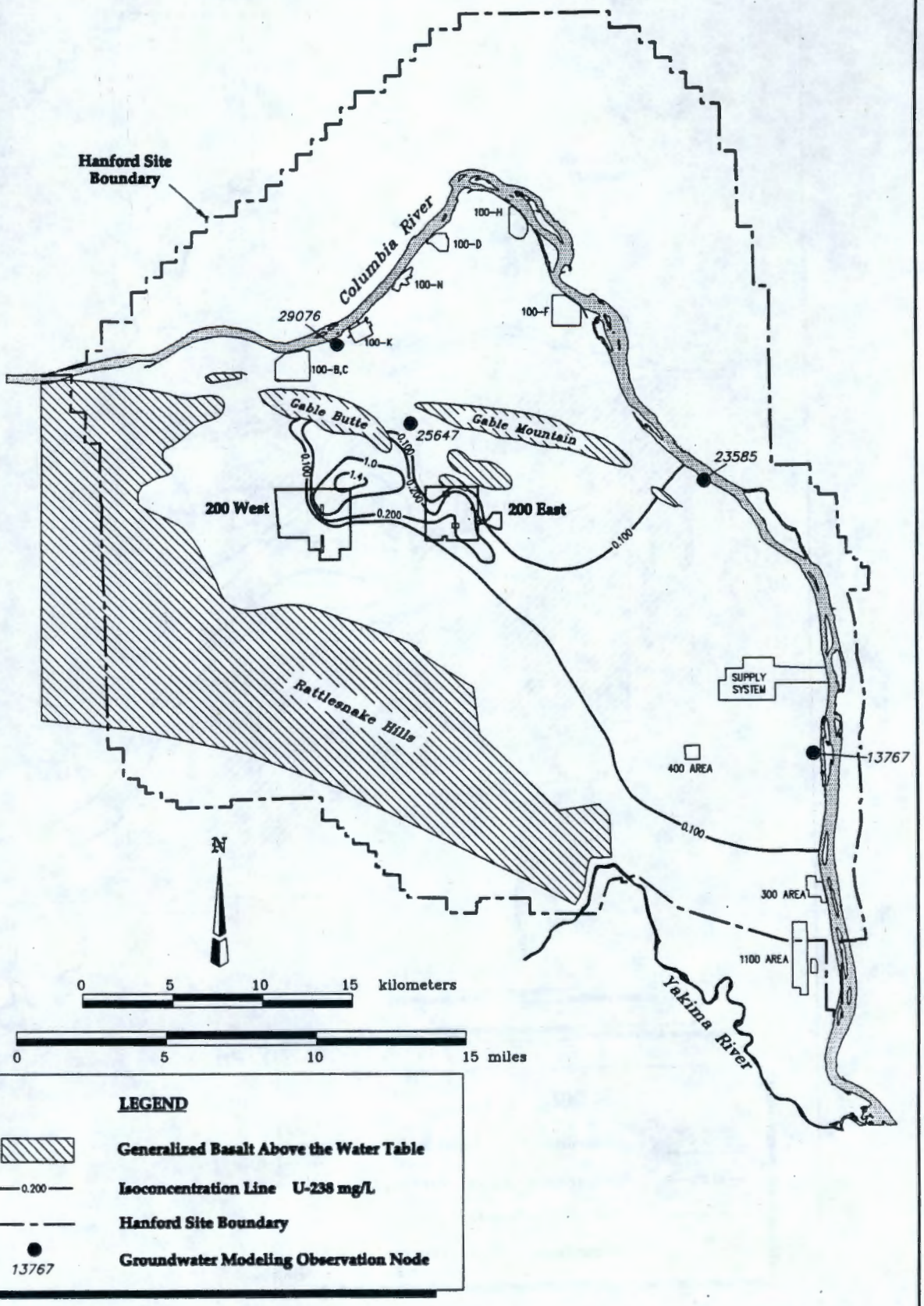
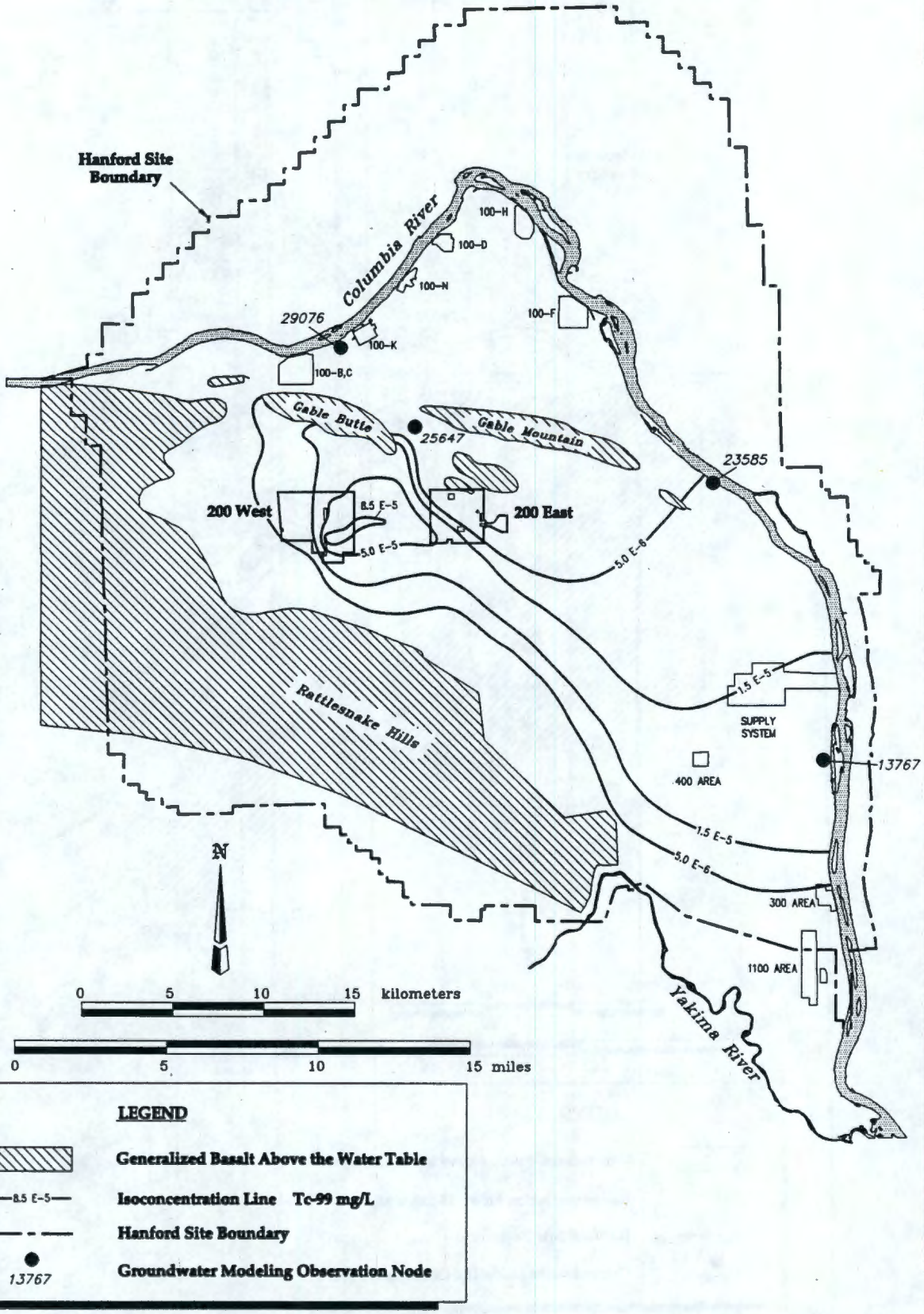


Figure F.3.3.13 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative



9613409.1584

Figure F.3.3.14 Predicted Iodine-129 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

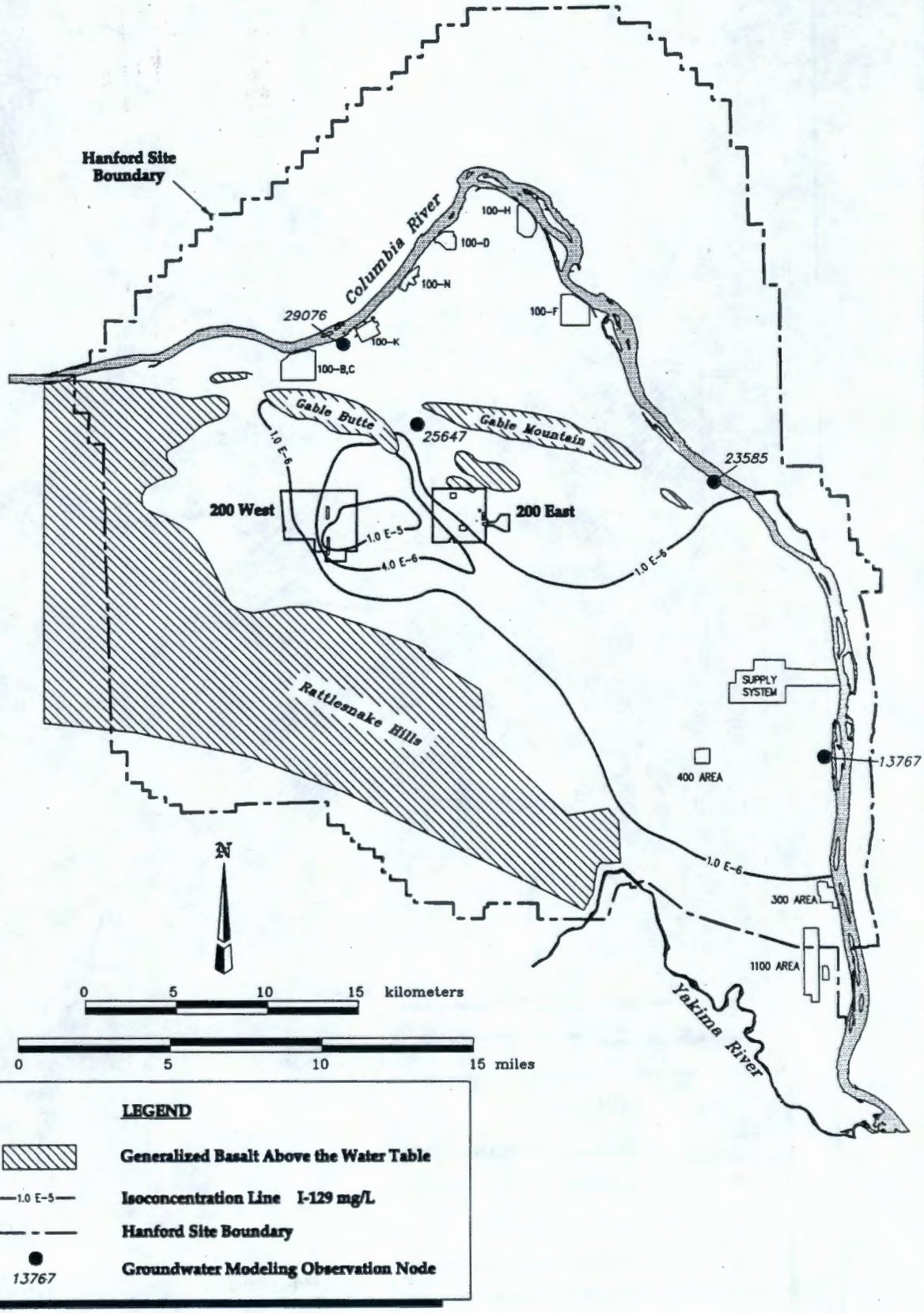
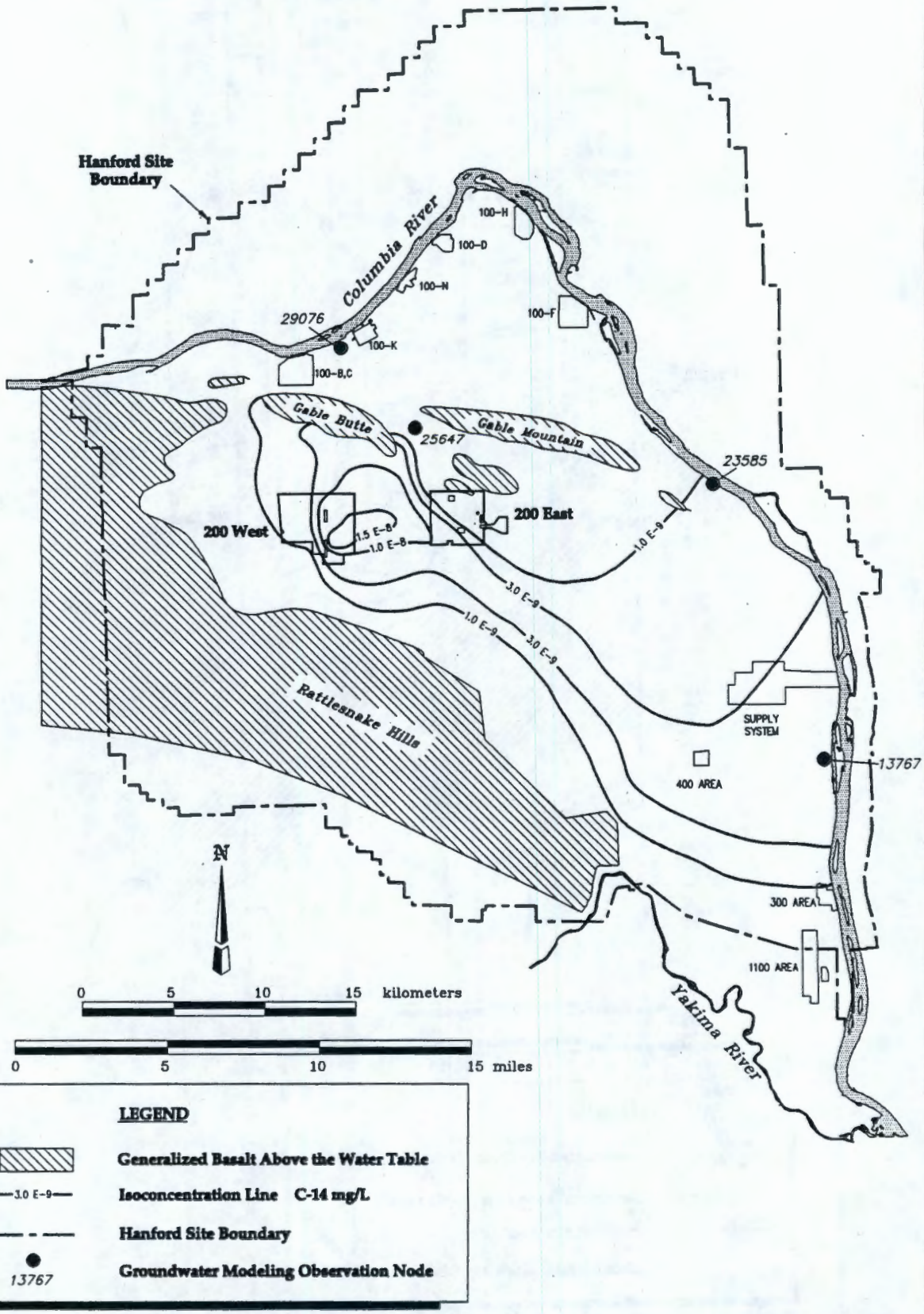


Figure F.3.3.15 Predicted Carbon-14 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative



9613409.1585

Figure F.3.3.16 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative

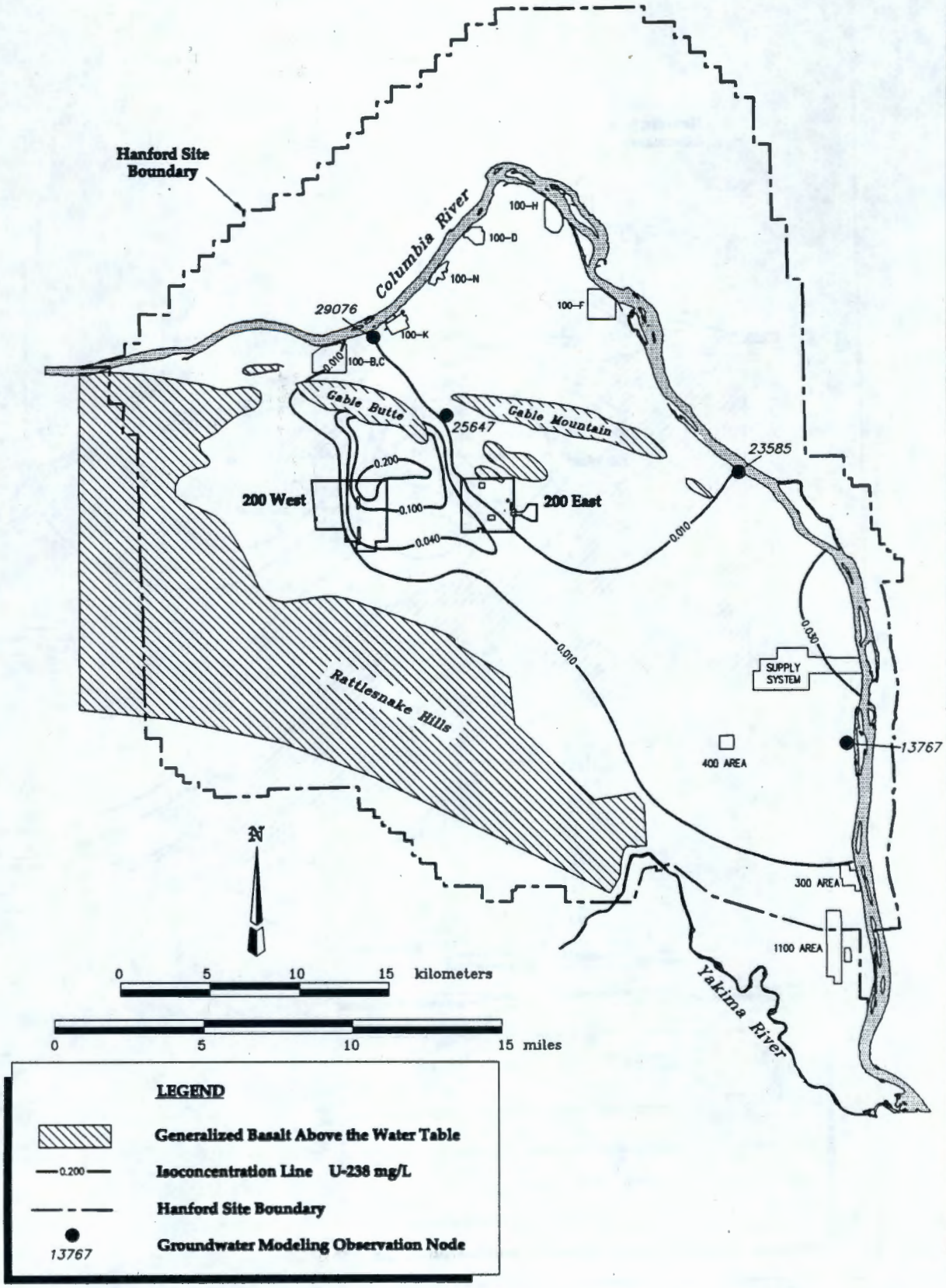
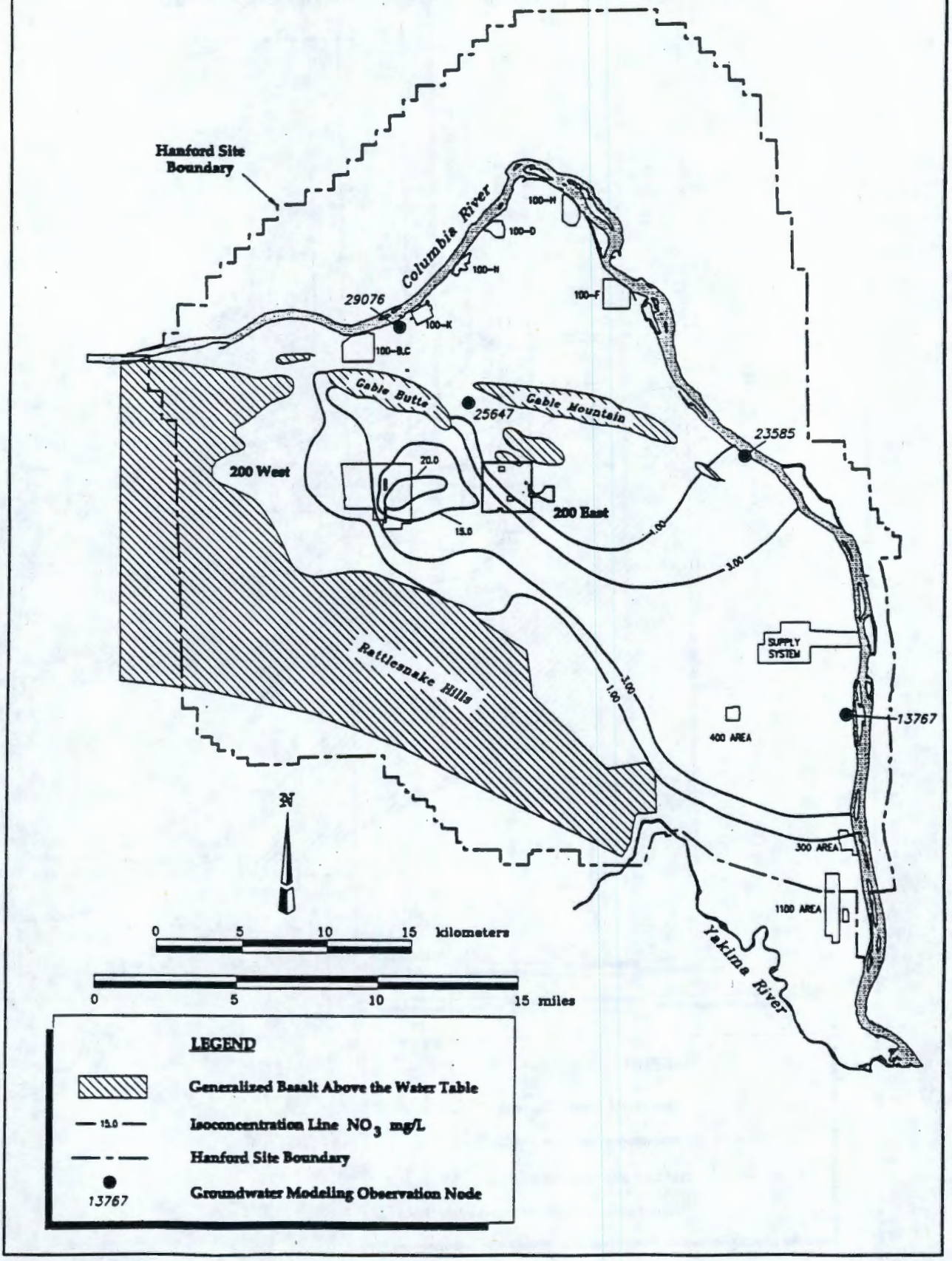
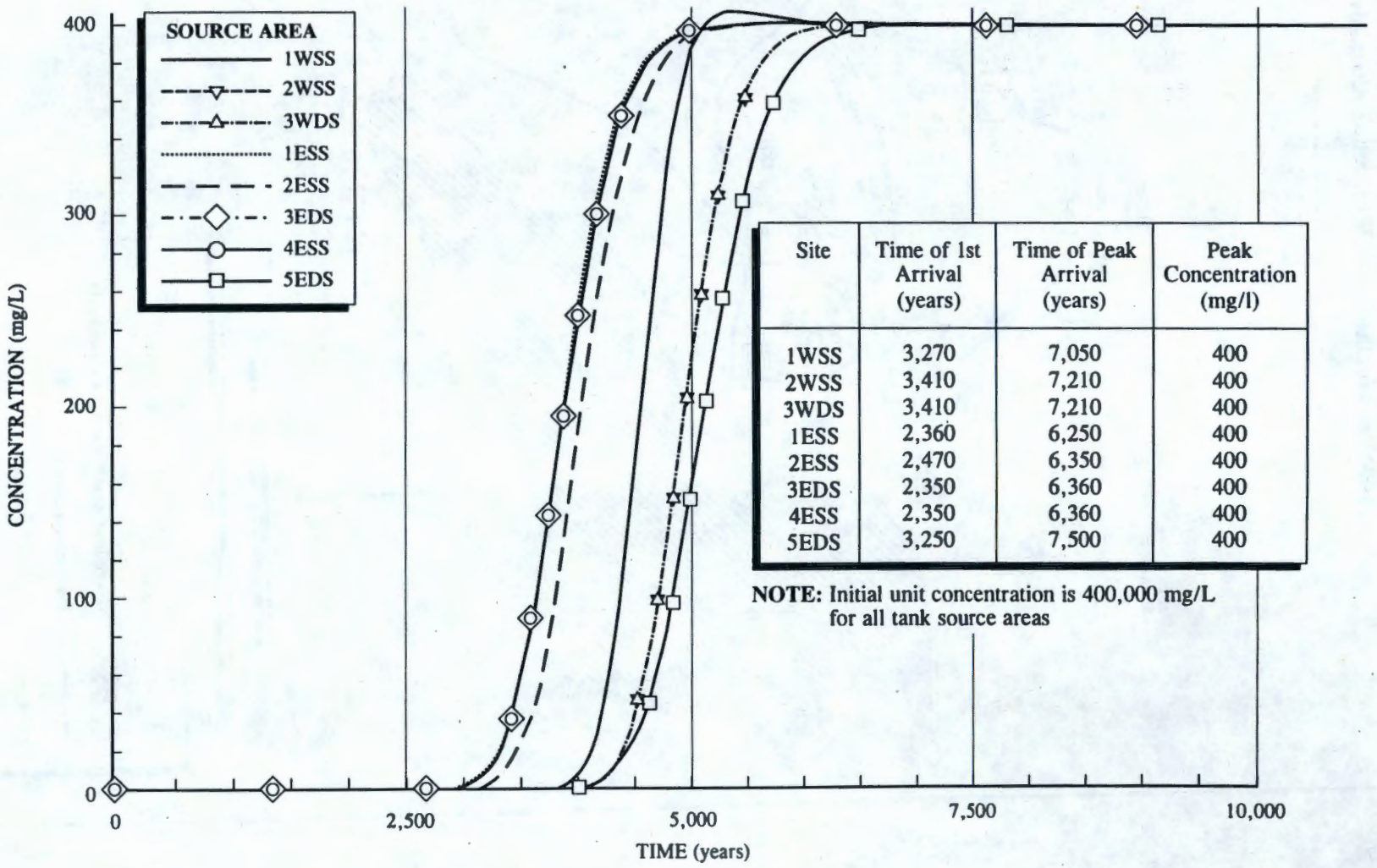


Figure F.3.3.17 Calculated Nitrate Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative



9613409.1586

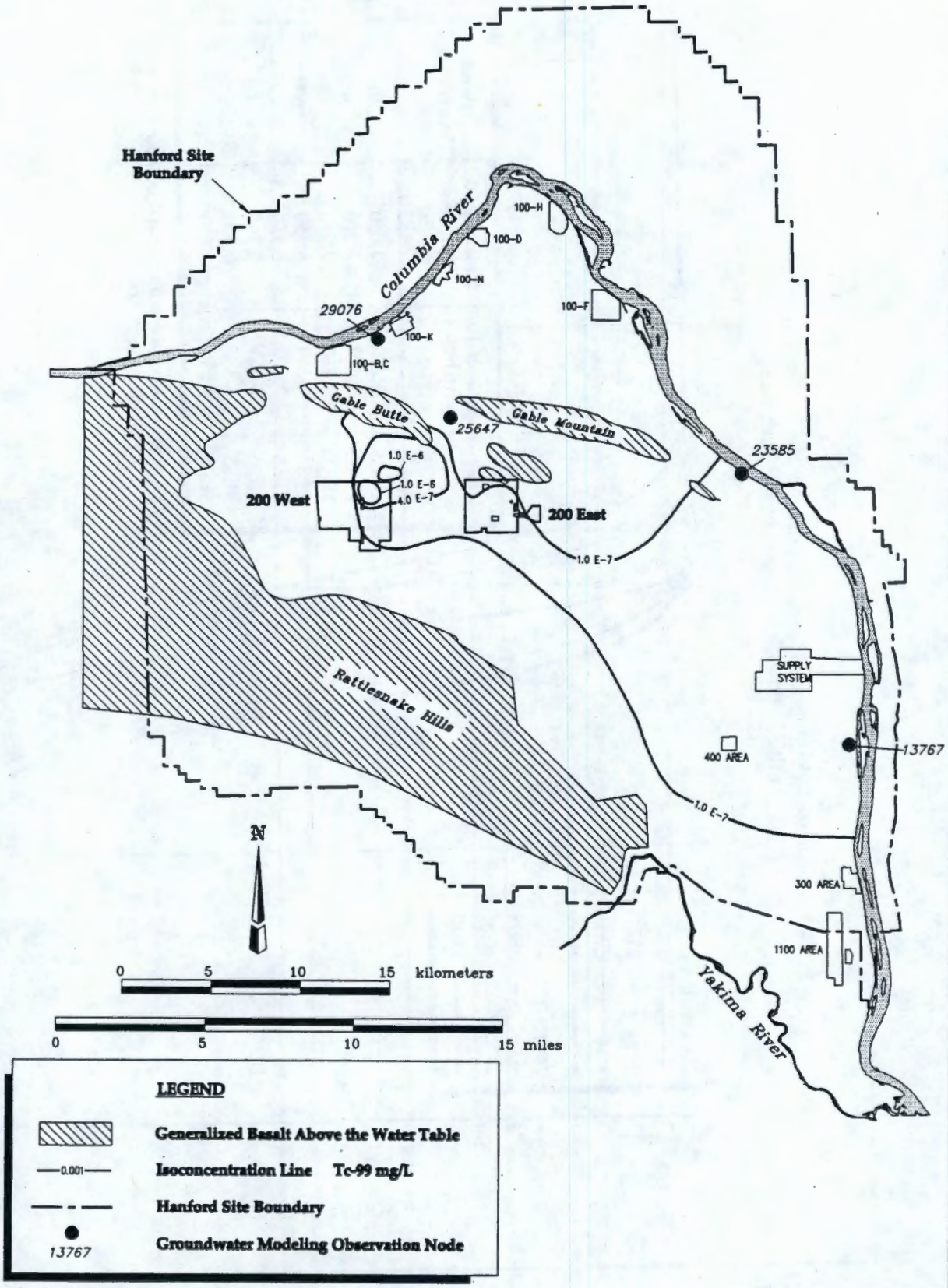
Figure F.3.4.1 Calculated Contaminant Concentration for the In Situ Vitrification Alternative at the Vadose Zone/Groundwater Interface



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Concentration (mg/l)
1WSS	3,270	7,050	400
2WSS	3,410	7,210	400
3WDS	3,410	7,210	400
1ESS	2,360	6,250	400
2ESS	2,470	6,350	400
3EDS	2,350	6,360	400
4ESS	2,350	6,360	400
5EDS	3,250	7,500	400

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas

Figure F.3.4.2 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative



9613409.1587

Figure F.3.4.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Vitrification Alternative

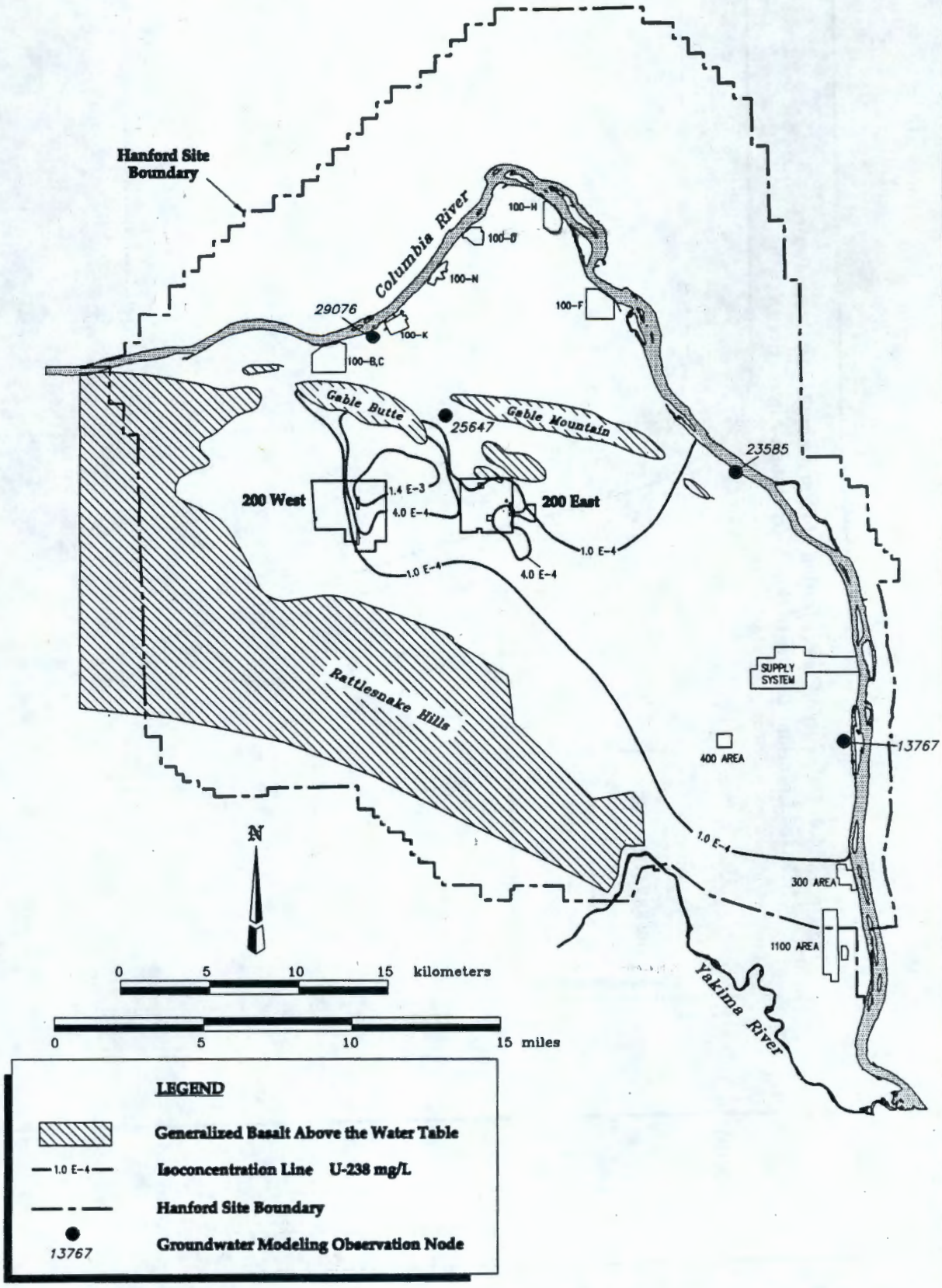
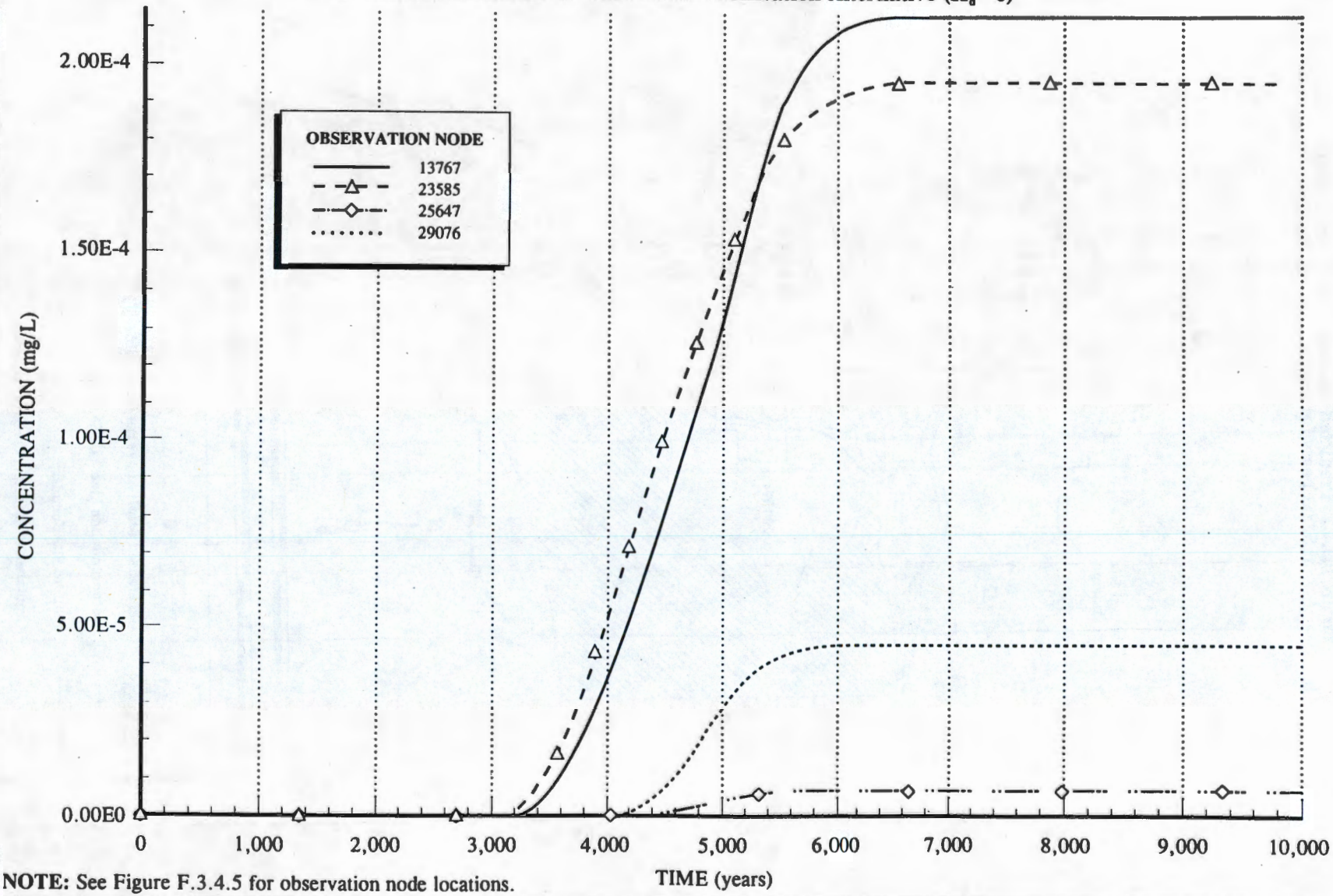


Figure F.3.4.4 Calculated Concentration of Uranimum-238 in Groundwater at Selected Locations for the In Situ Vitrification Alternative (K_d=0)



NOTE: See Figure F.3.4.5 for observation node locations.

9613409.1588

Figure F.3.4.5 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative

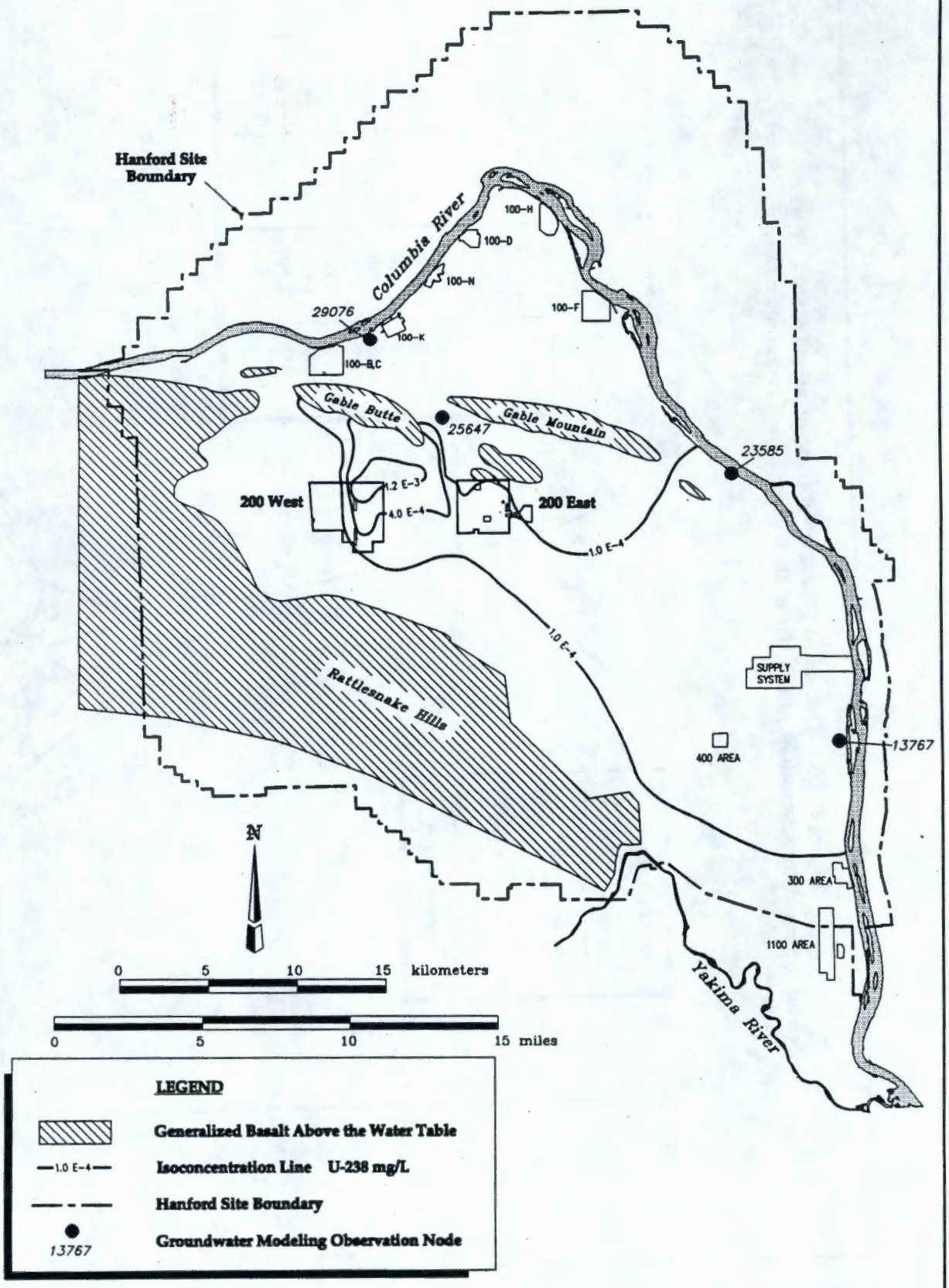
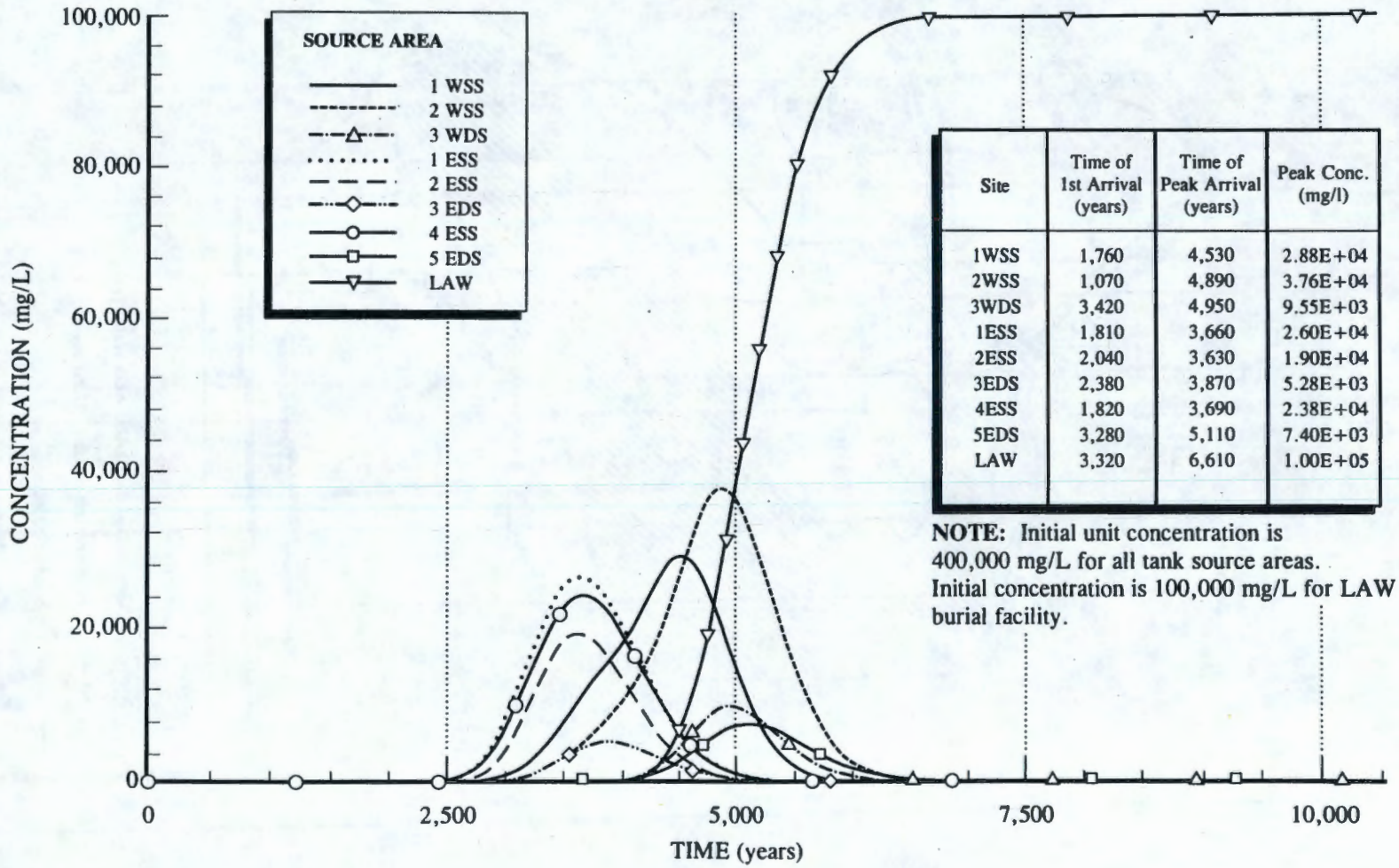


Figure F.3.5.1 Calculated Contaminant Concentration for the Ex Situ Intermediate Separations Alternative at the Vadose Zone/Groundwater Interface (K_d=0)



Site	Time of 1st Arrival (years)	Time of Peak Arrival (years)	Peak Conc. (mg/l)
1WSS	1,760	4,530	2.88E+04
2WSS	1,070	4,890	3.76E+04
3WDS	3,420	4,950	9.55E+03
1ESS	1,810	3,660	2.60E+04
2ESS	2,040	3,630	1.90E+04
3EDS	2,380	3,870	5.28E+03
4ESS	1,820	3,690	2.38E+04
5EDS	3,280	5,110	7.40E+03
LAW	3,320	6,610	1.00E+05

NOTE: Initial unit concentration is 400,000 mg/L for all tank source areas. Initial concentration is 100,000 mg/L for LAW burial facility.

9613409.1589

Figure F.3.5.2 Predicted Nitrate Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)

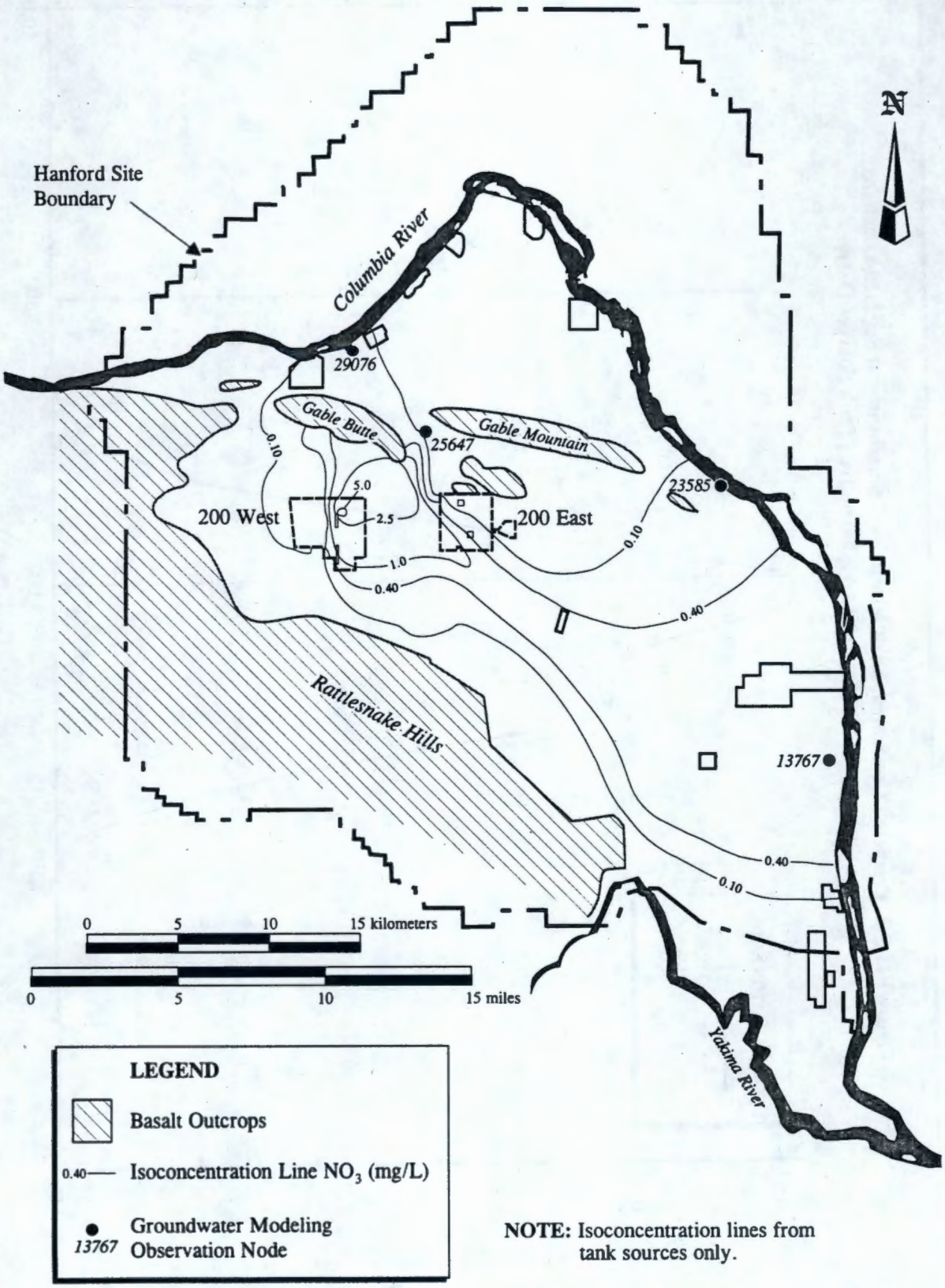
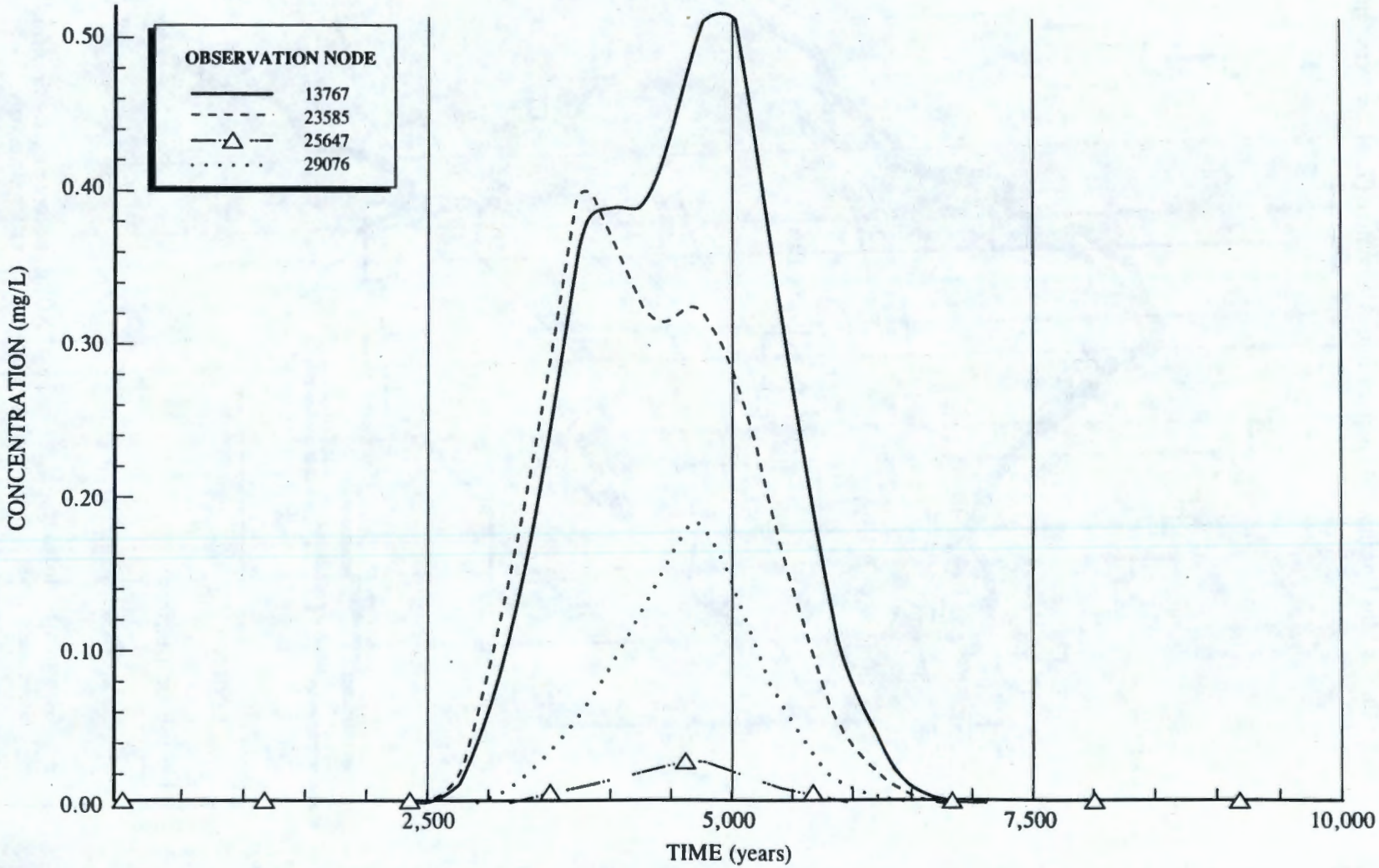


Figure F.3.5.3 Predicted Concentration of Nitrate in Groundwater at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)



NOTE: See Figure F.3.5.2 for Observation Node locations

9613409.1590

Figure F.3.5.4 Predicted Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (Tank Sources Only)

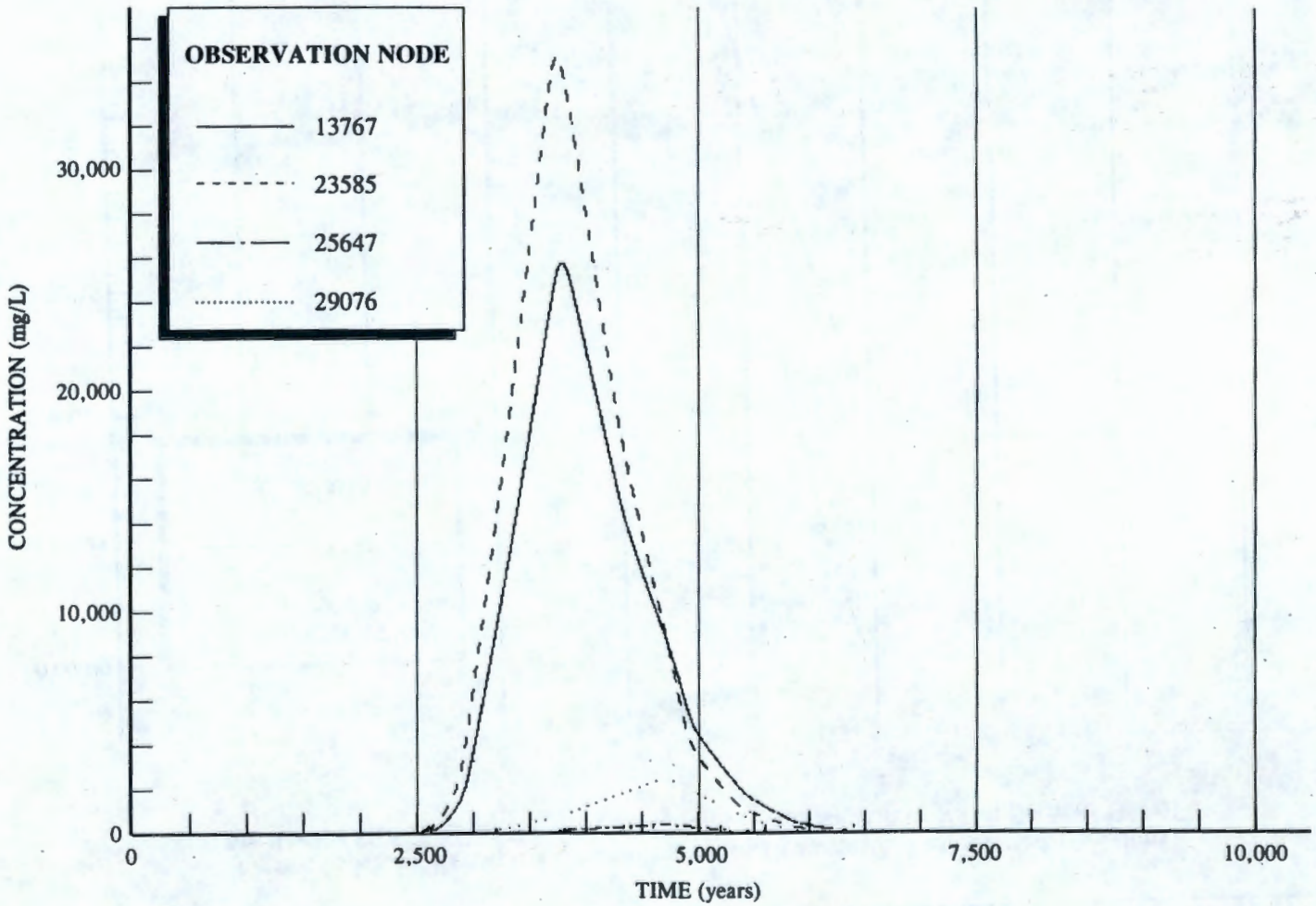
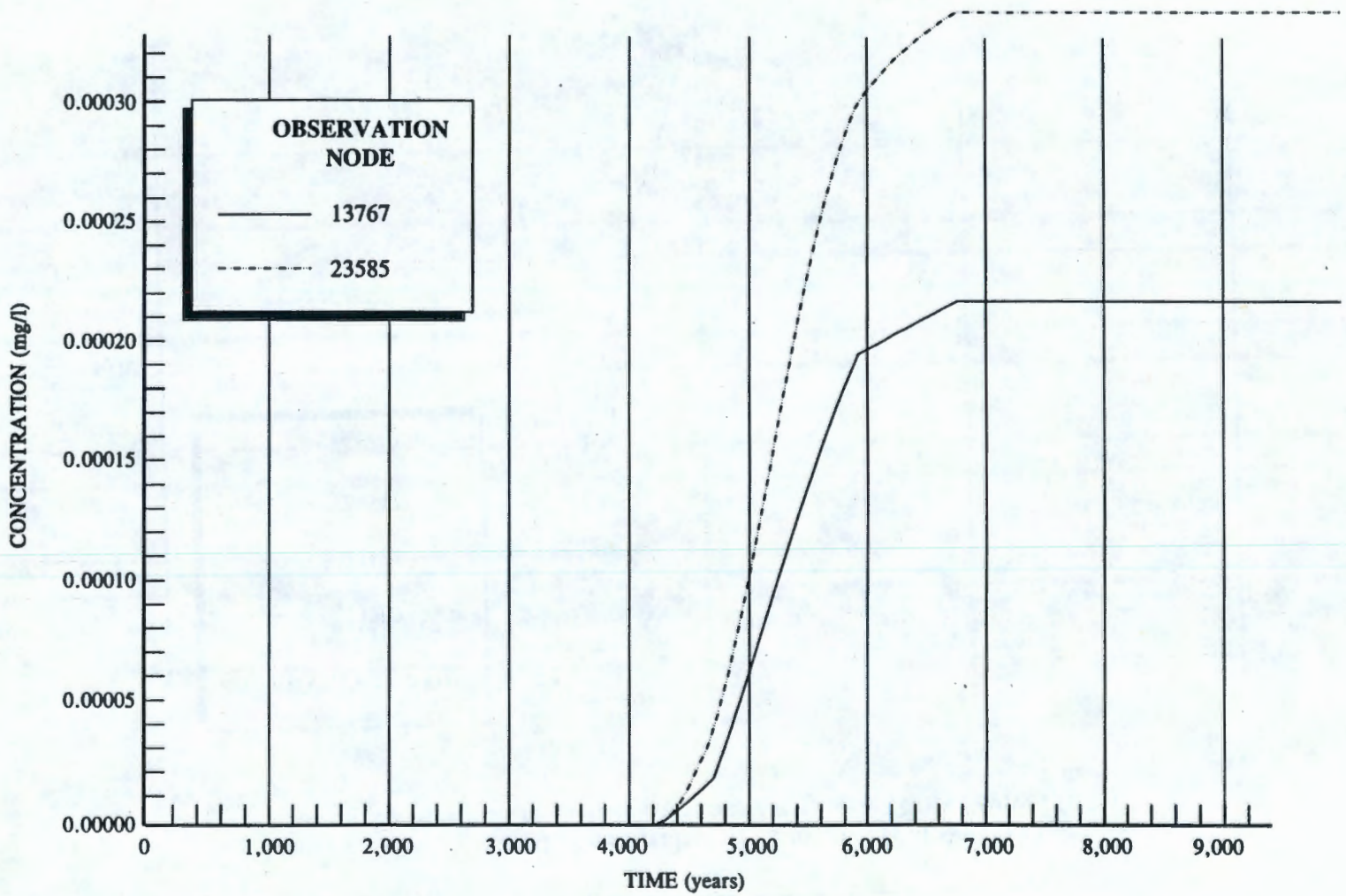


Figure F.3.5.5 Predicted Concentration of Uranium-238 at Selected Locations for the Ex Situ Intermediate Separations Alternative (LAW Vault Sources Only))



NOTE: See Figure F.3.5.2 for observation node locations

9613409.1591

Figure F.3.5.6 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Intermediate Separations Alternative (Tank and LAW Vault Sources Combined)

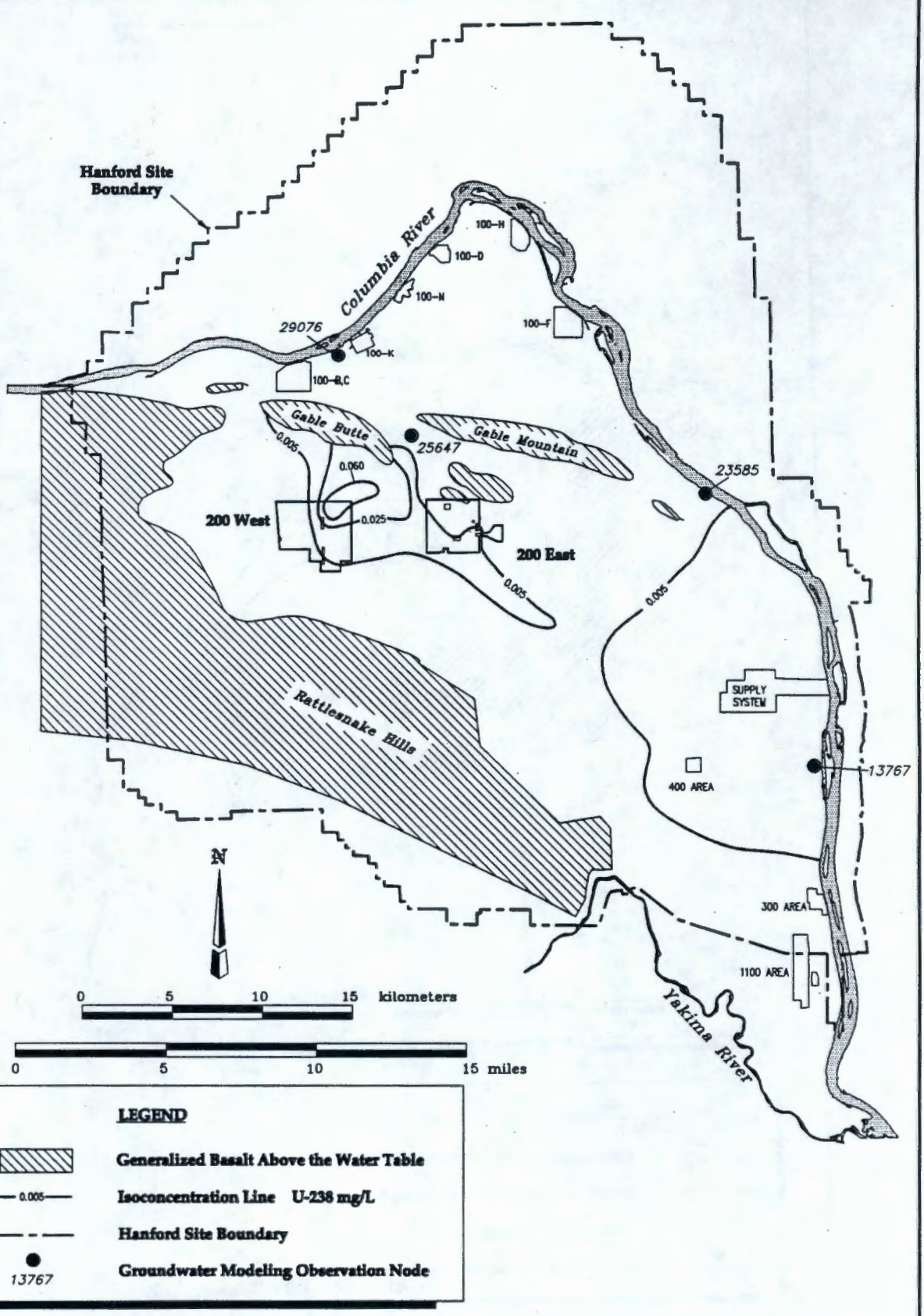
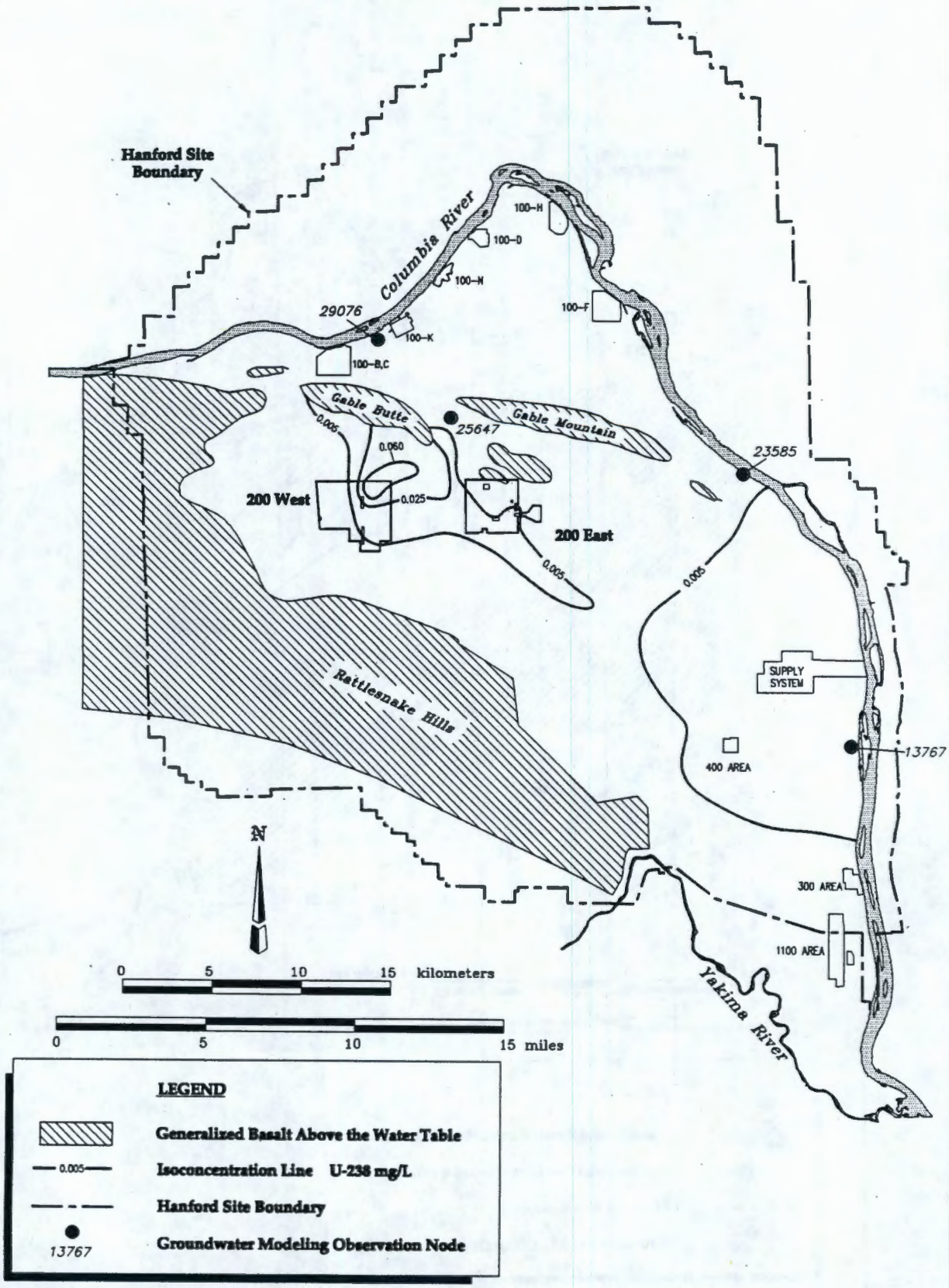


Figure F.3.6.1 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ No Separations Alternative (Tank Sources Only)



9613409.1592

Figure F.3.7.1 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ Extensive Separations Alternative (Tank and LAW Vault Sources Combined)

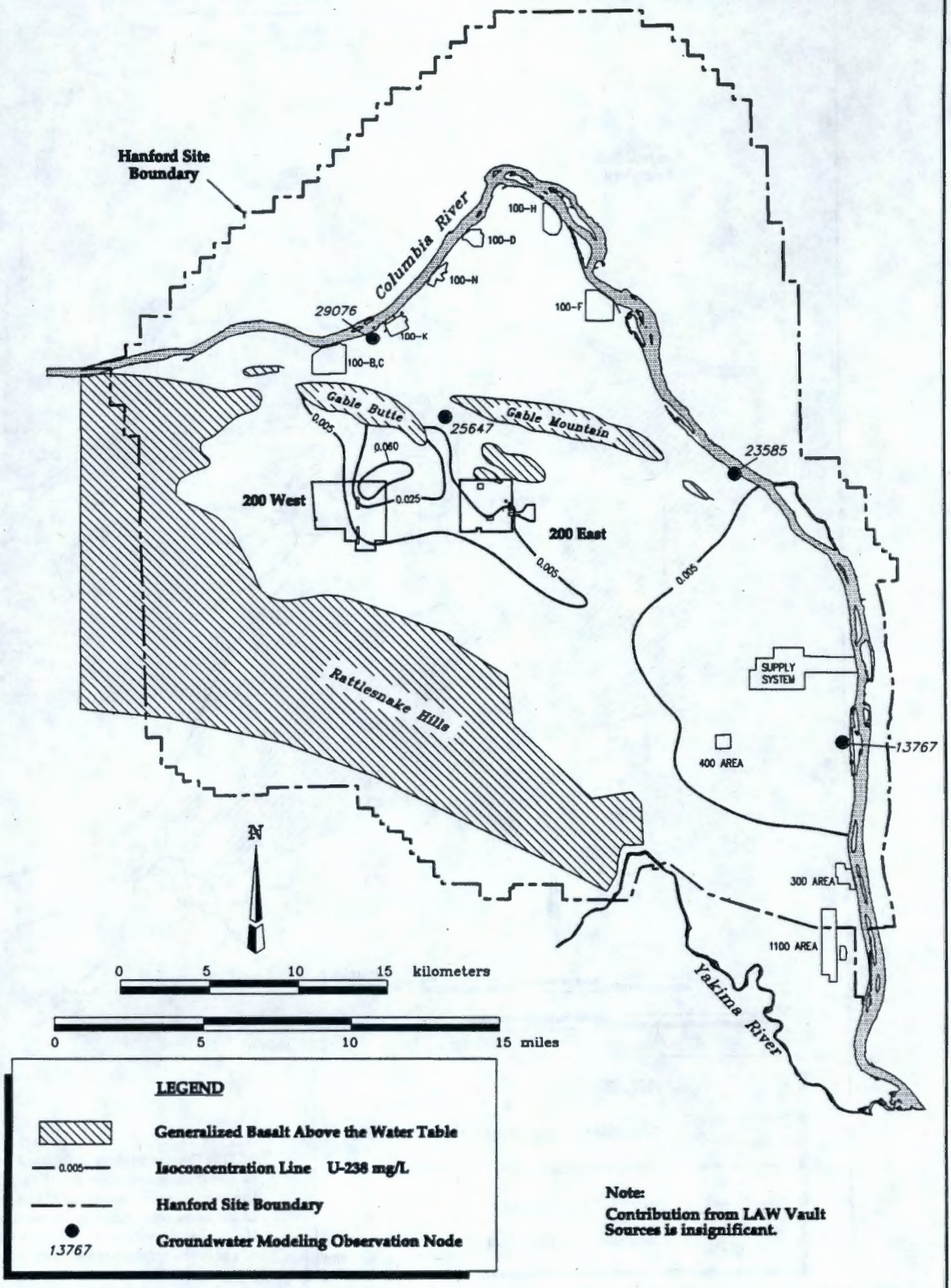
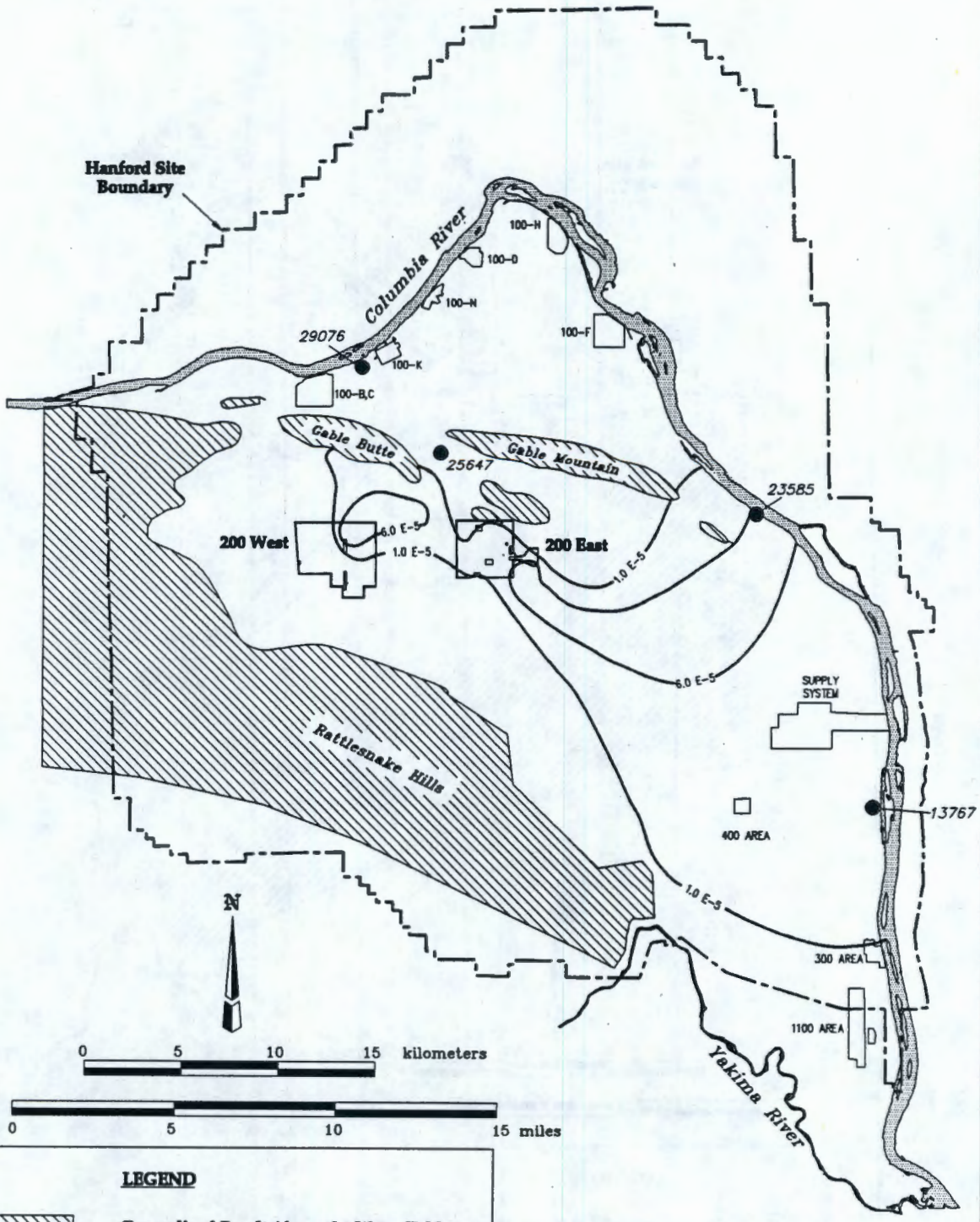


Figure F.3.8.1 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)



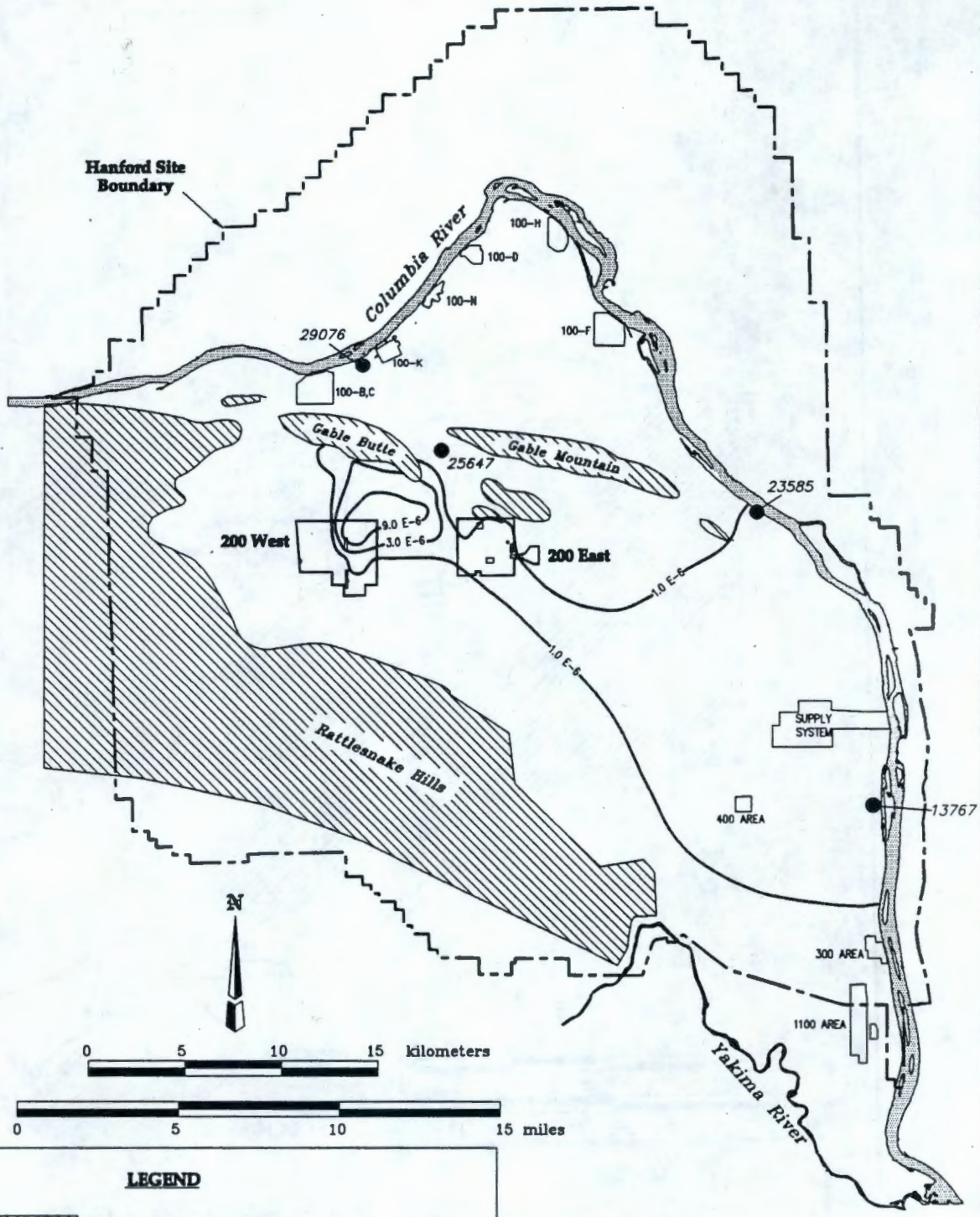
LEGEND

- Generalized Basalt Above the Water Table
- 1.0 E-5 — Isoconcentration Line Tc-99 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by two orders of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

9613409.1593

Figure F.3.8.2 Predicted Iodine-129 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)

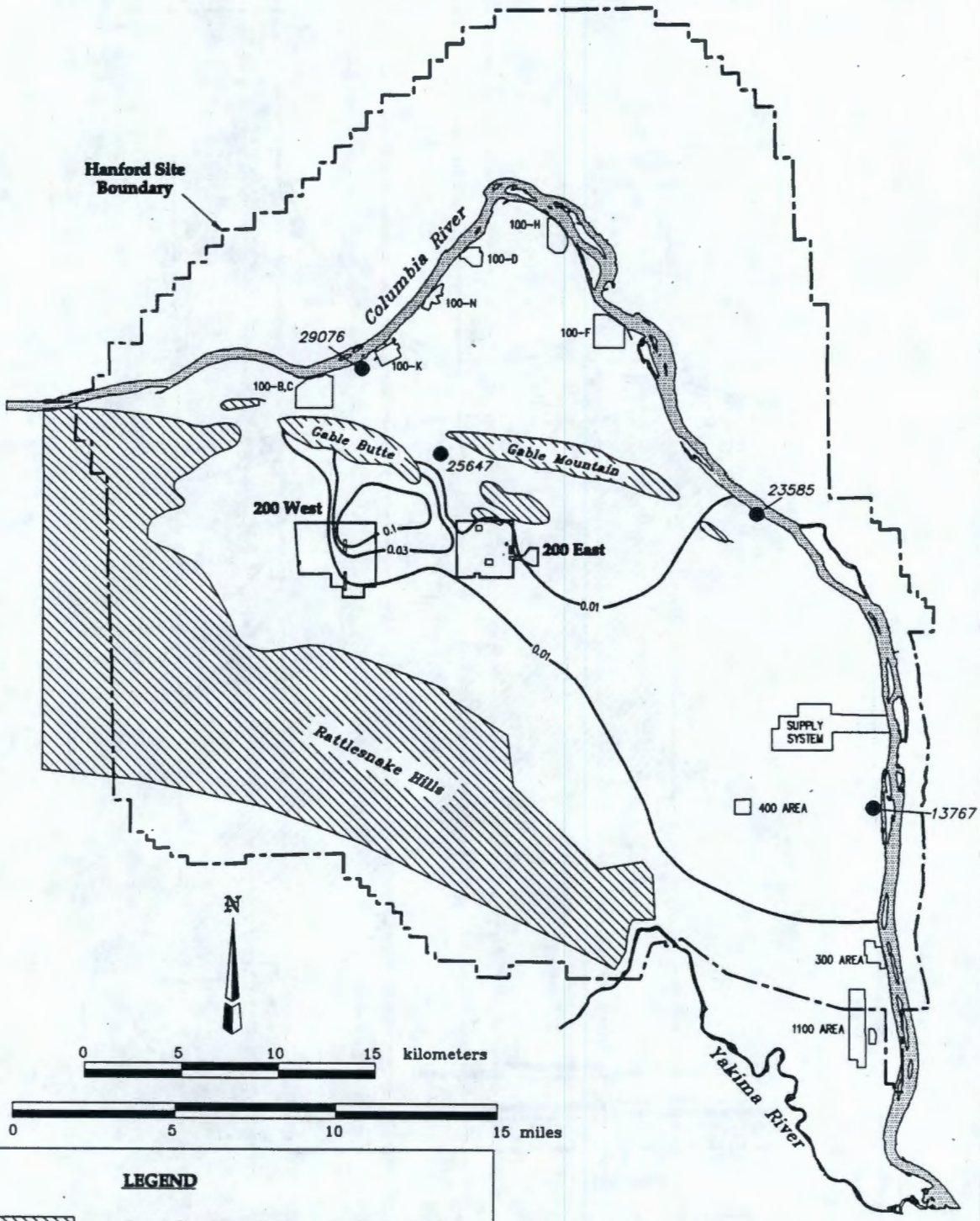


LEGEND

- Generalized Basalt Above the Water Table
- 1.0 E-6 — Isoconcentration Line I-129 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one order of magnitude) and generally in the same configuration as the contours shown herein which are the predicted results of the tanks remediated In Situ.

Figure F.3.8.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)



LEGEND

- Generalized Basalt Above the Water Table
- 0.01 — Isoconcentration Line U-238 mg/L
- Hanford Site Boundary
- 13767 — Groundwater Modeling Observation Node

NOTE: Concentrations associated with the retrieval from tanks are significantly lower (by one to two orders of magnitude) and generally in the same configuration as the contours shown herein which are the calculated results of the tanks remediated In Situ.

9613409.1594

Figure F.3.8.4 Predicted Technetium-99 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only)

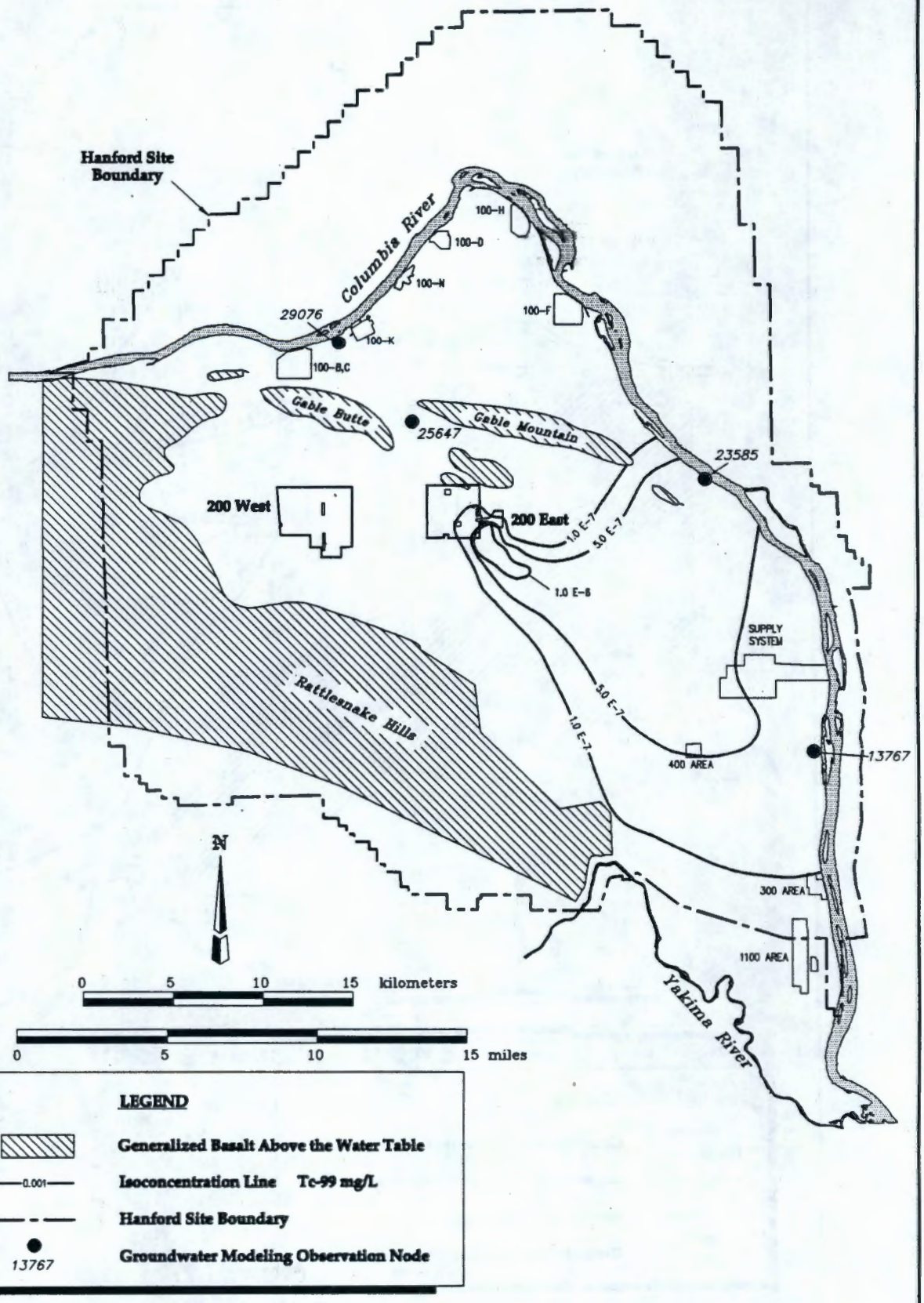
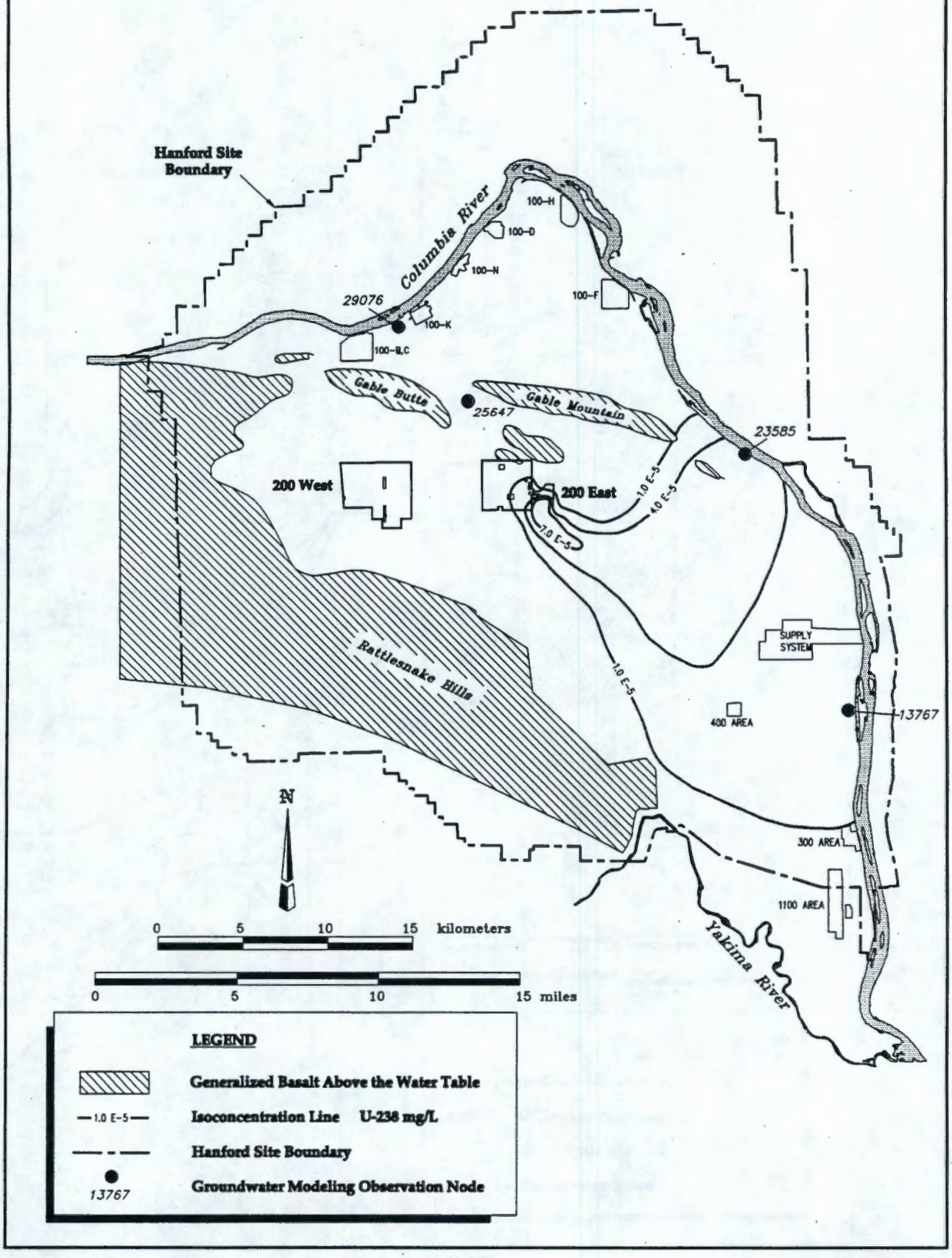


Figure F.3.8.5 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only)



9613409.1599

Figure F.3.8.6 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)

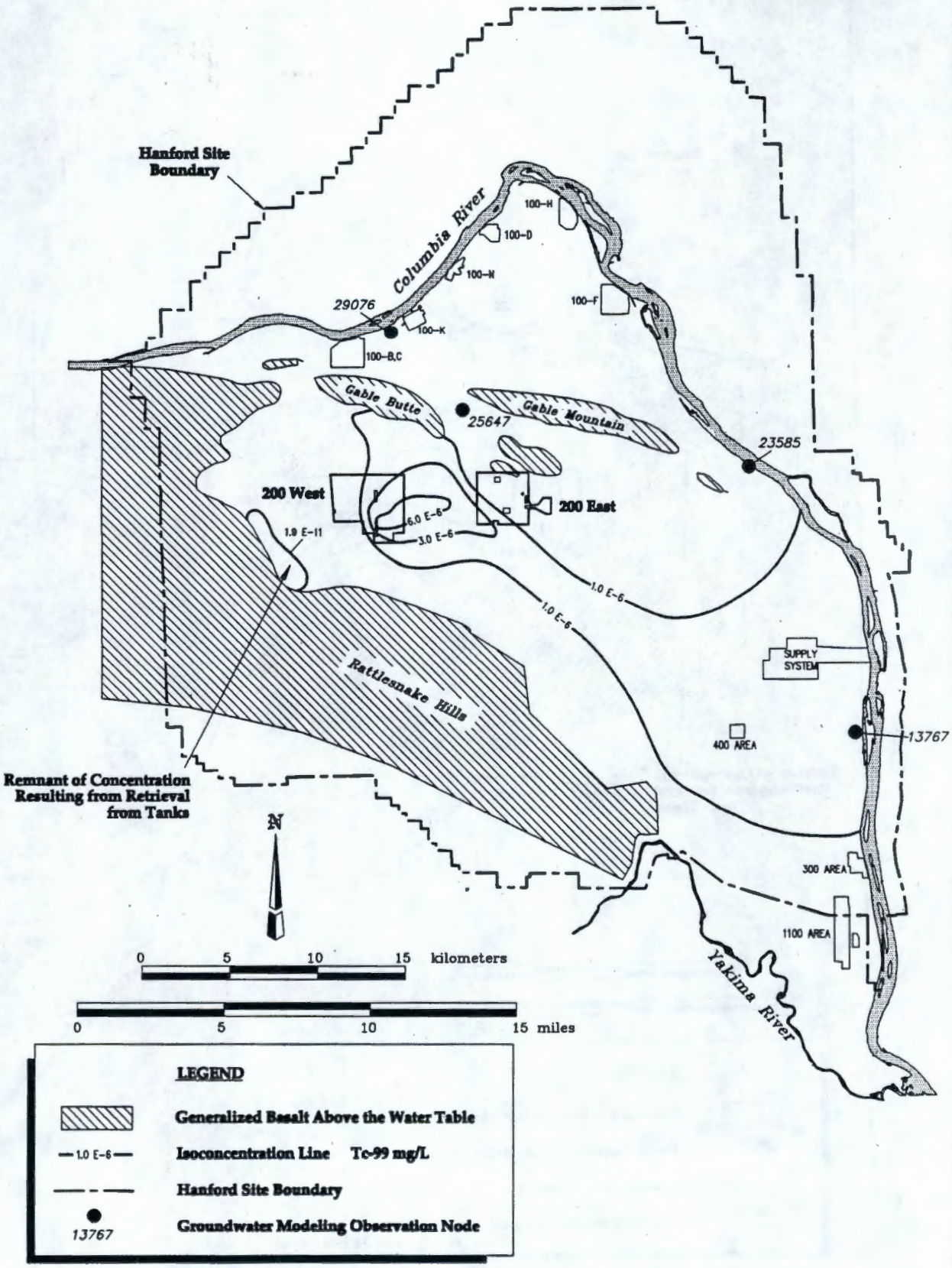
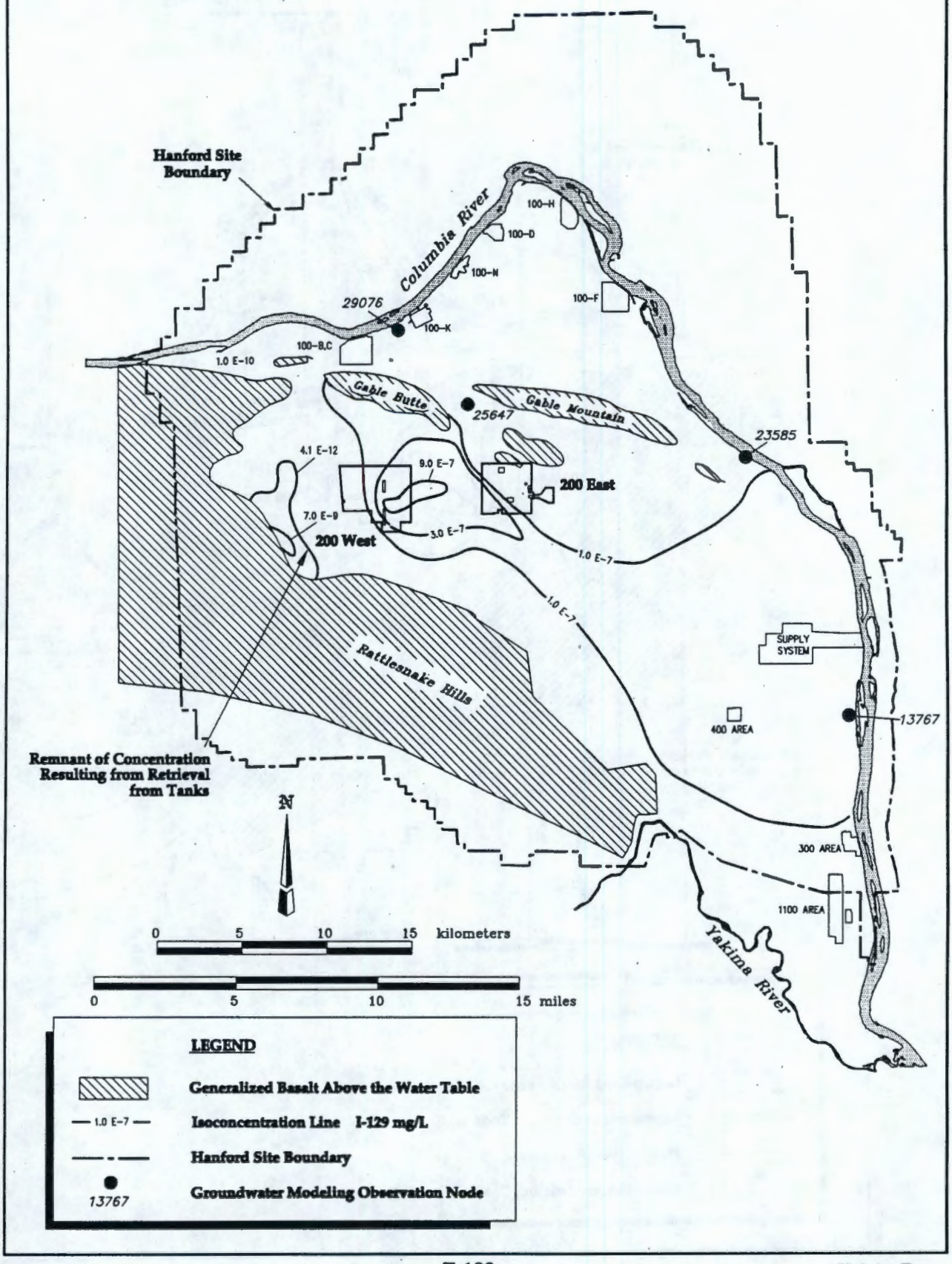


Figure F.3.8.7 Predicted Iodine-129 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)



9613409.1596

Figure F.3.8.8 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (Tank Sources Only)

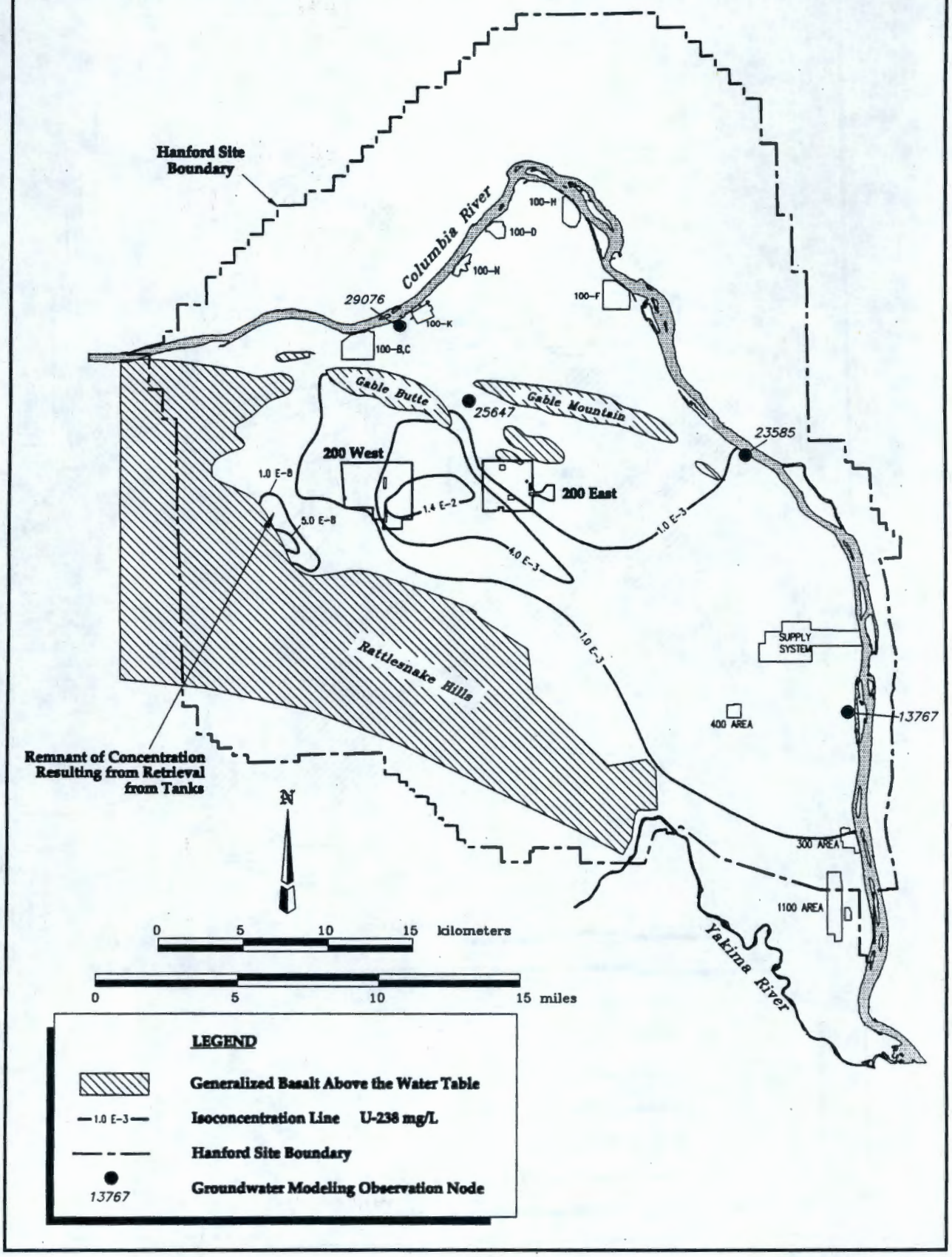
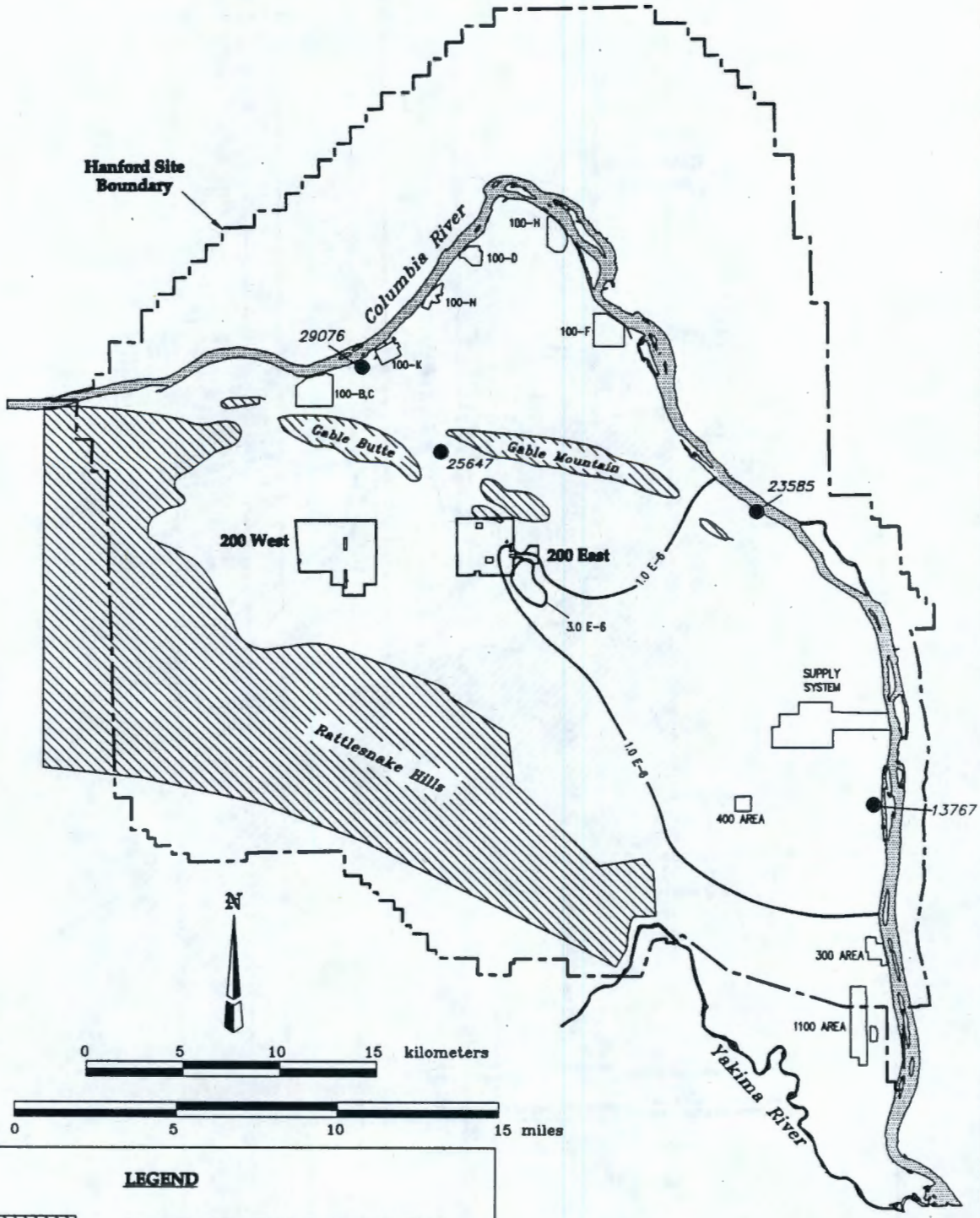


Figure F.3.8.9 Predicted Technetium-99 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only)



9613409.1597

Figure F.3.8.10 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the Ex Situ/In Situ Combination Alternative (LAW Vault Sources Only)

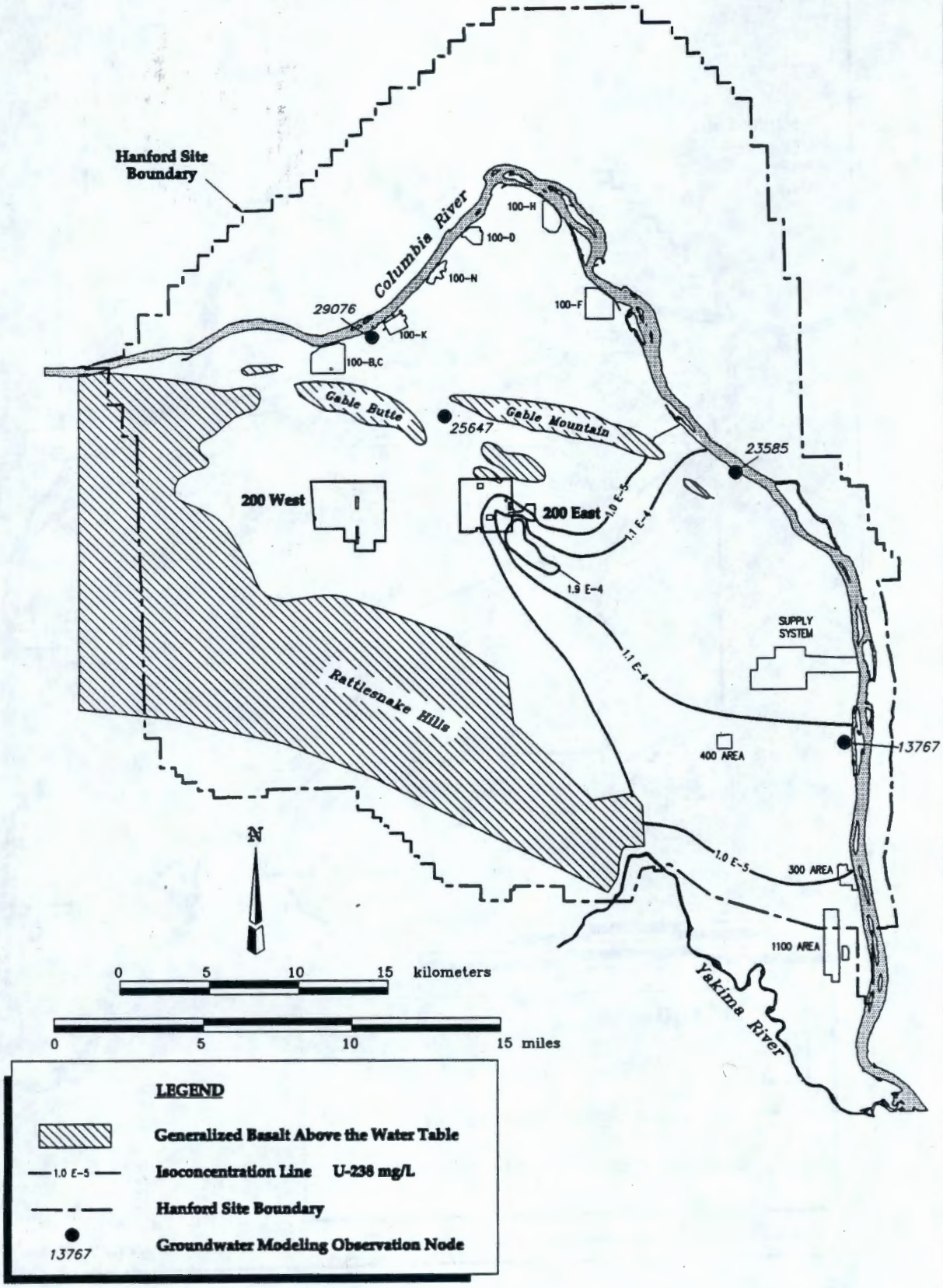
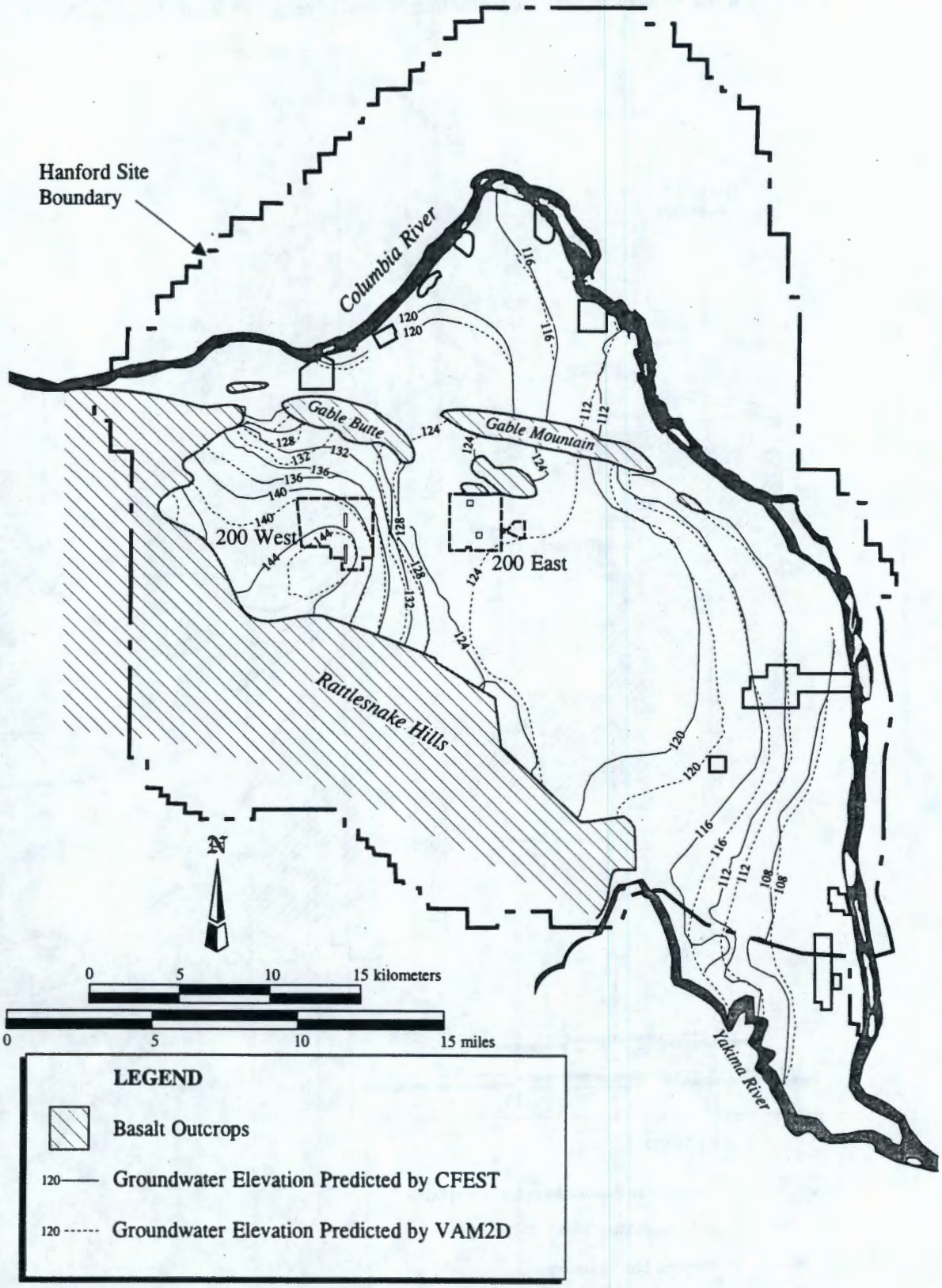


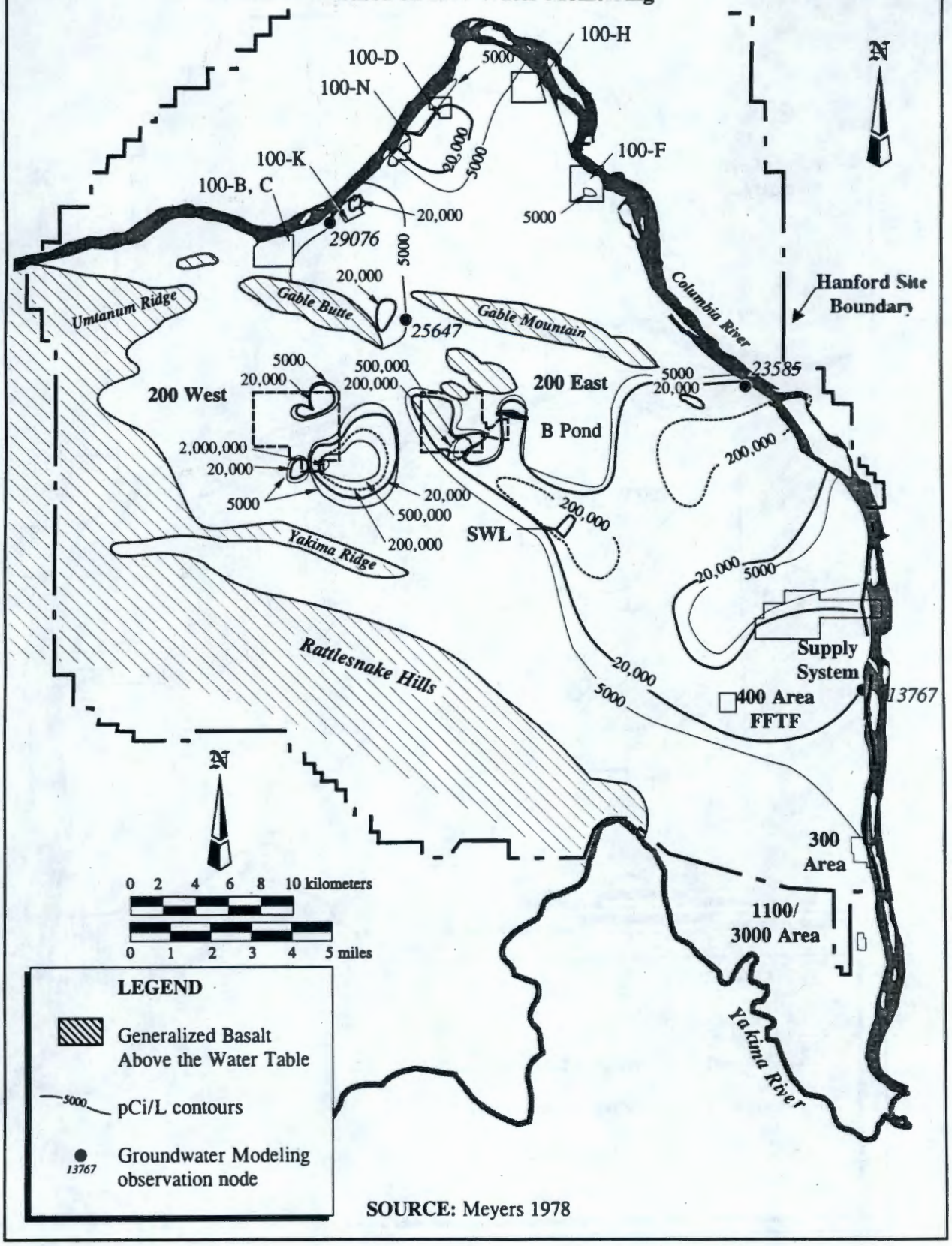
Figure F.4.3.1 Comparison of Groundwater Elevations Predicted by VAM2D and CFEST



SOURCE: Groundwater elevations predicted by CFEST are from Wurstner and Devary 1993

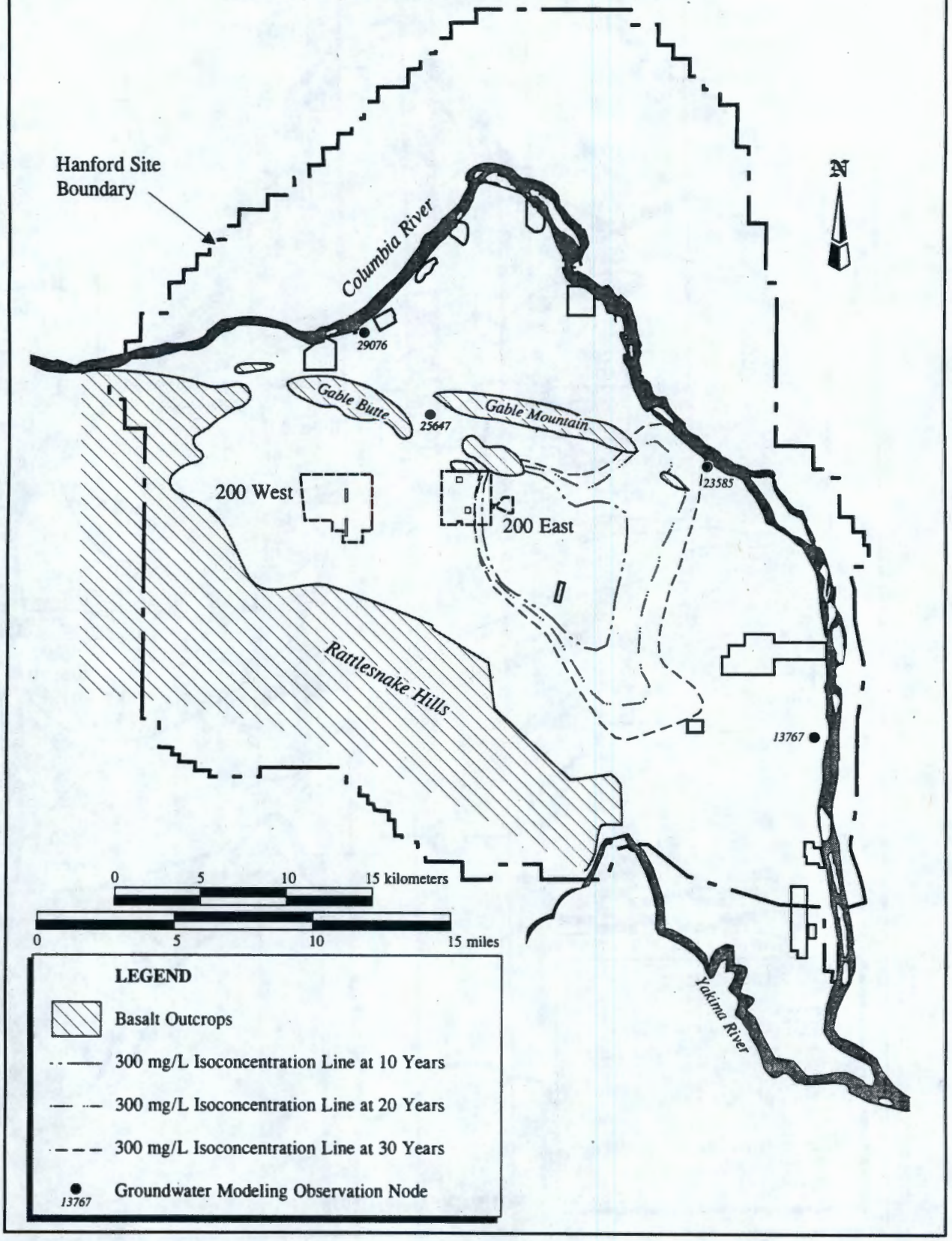
9613409.1598

Figure F.4.3.2 Distribution of Tritium in Unconfined Groundwater Based on 1977 Water Monitoring



SOURCE: Meyers 1978

Figure F.4.3.3 Predicted Tritium Concentrations in Groundwater at 10, 20, and 30 Years from a B Pond Source



9613409.1599

Figure F.4.3.4 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Virtification Alternative (High Glass Corrosion Concentration)

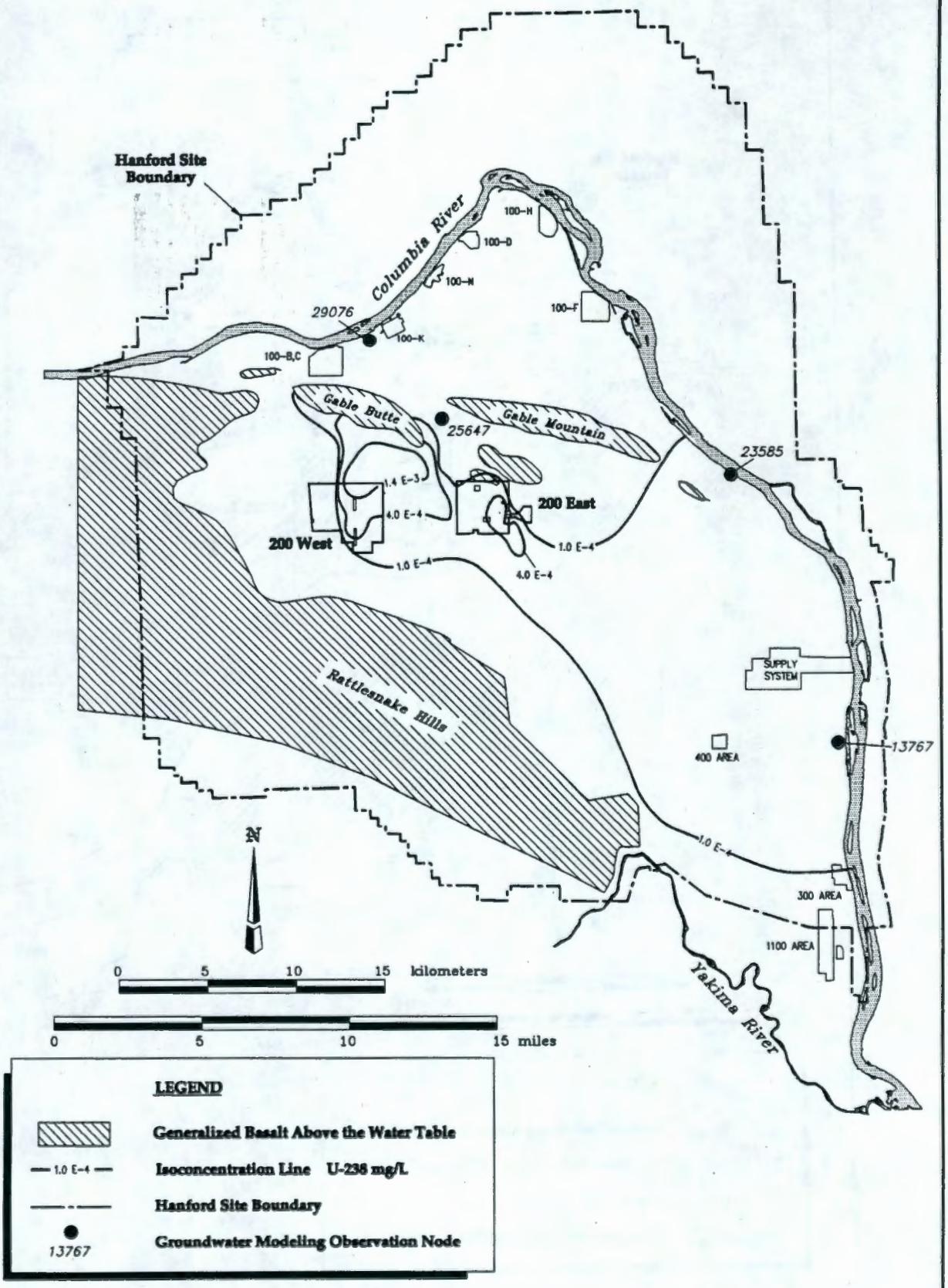
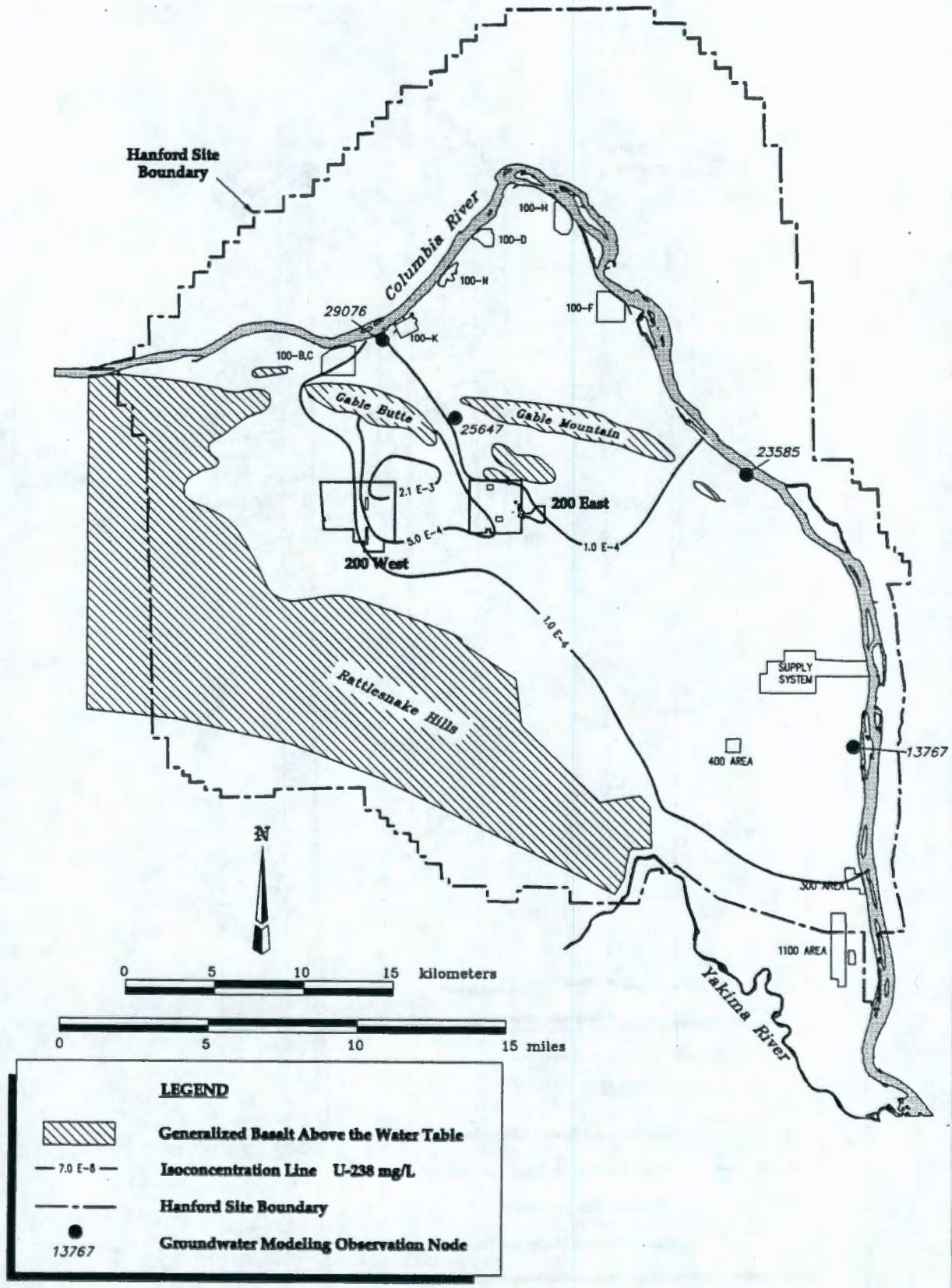
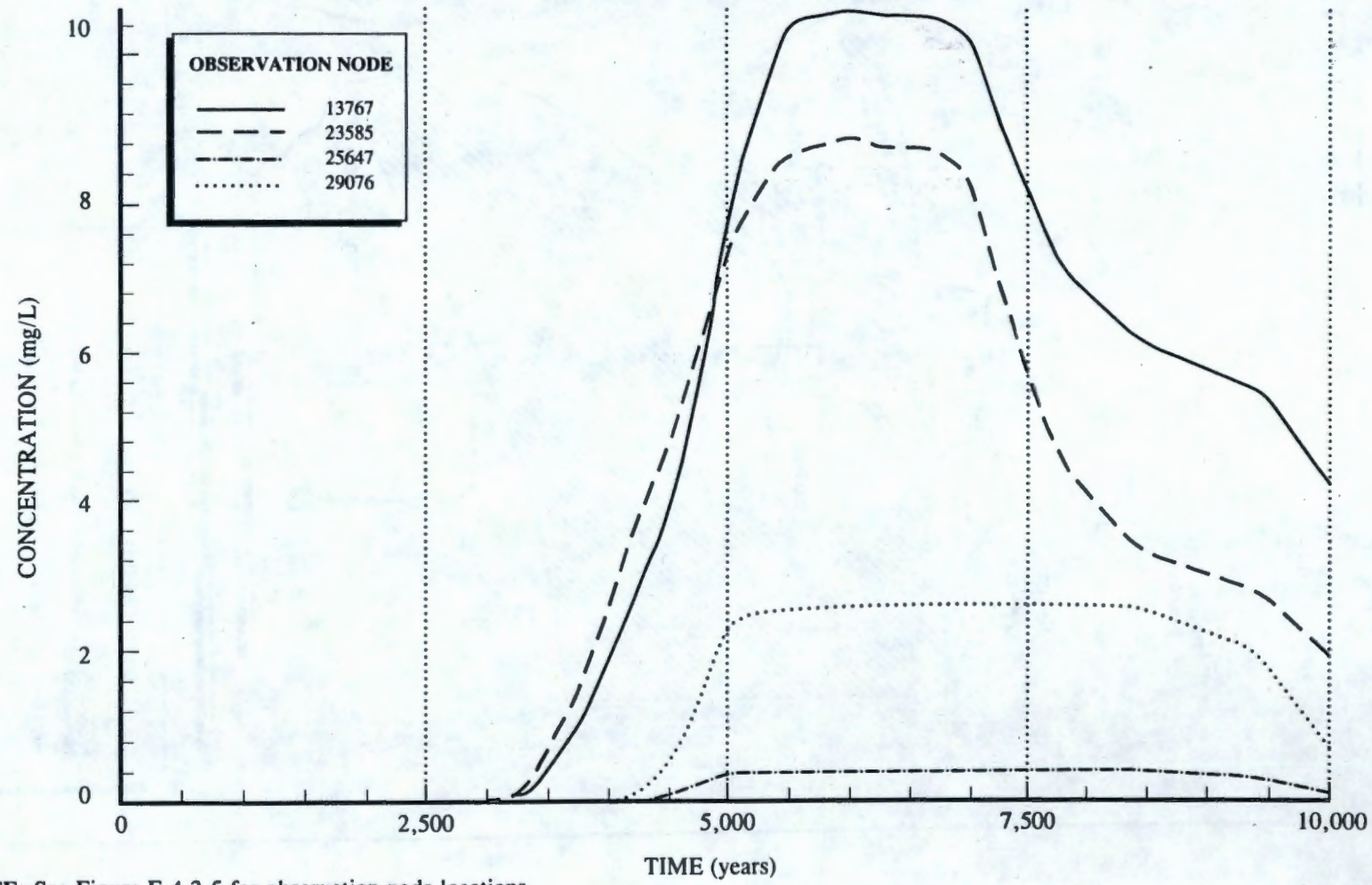


Figure F.4.3.5 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative (High Glass Corrosion Concentration)



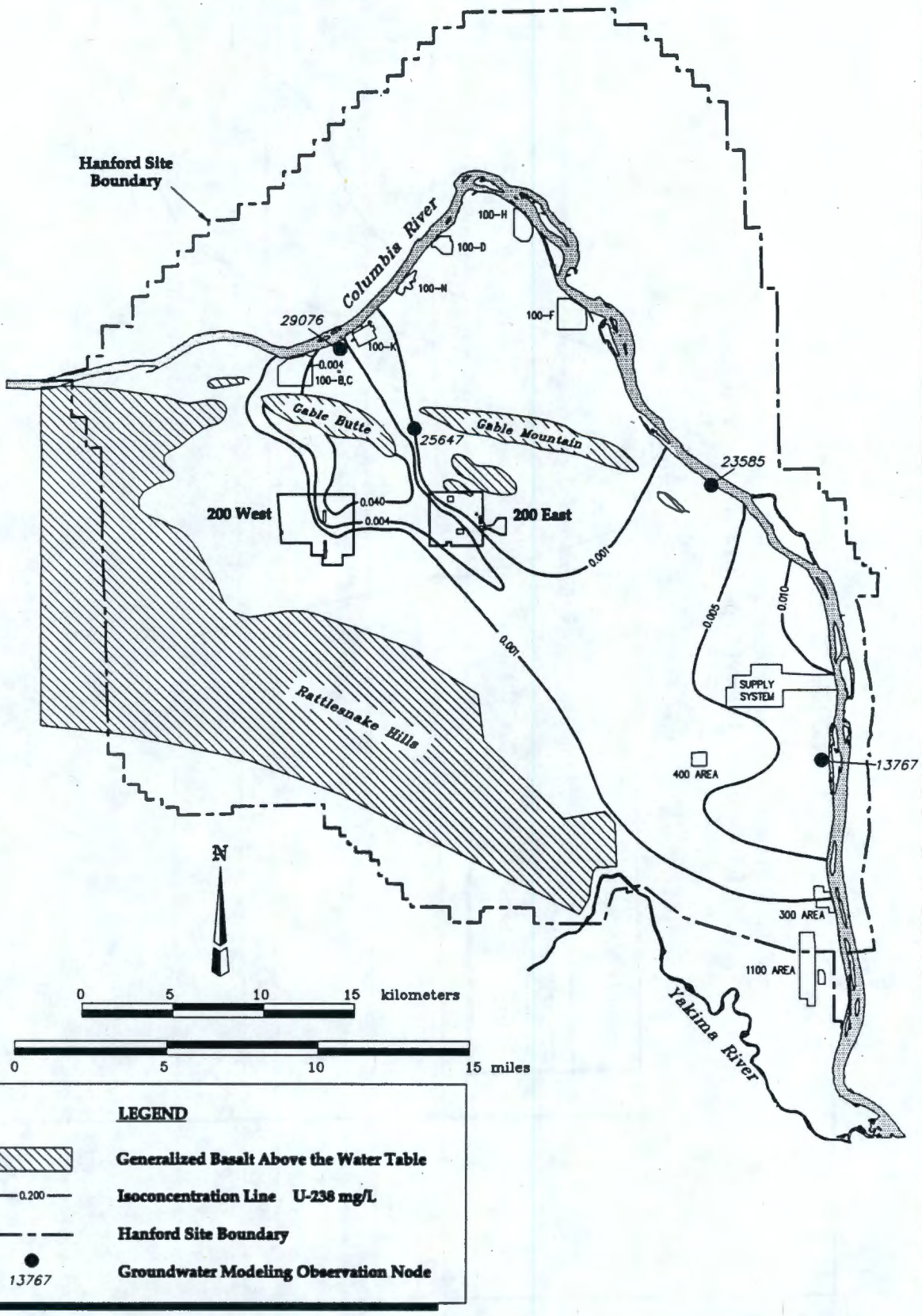
9613409.1600

Figure F.4.3.6 Predicted Nitrate Concentration in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (500-Year Cap)



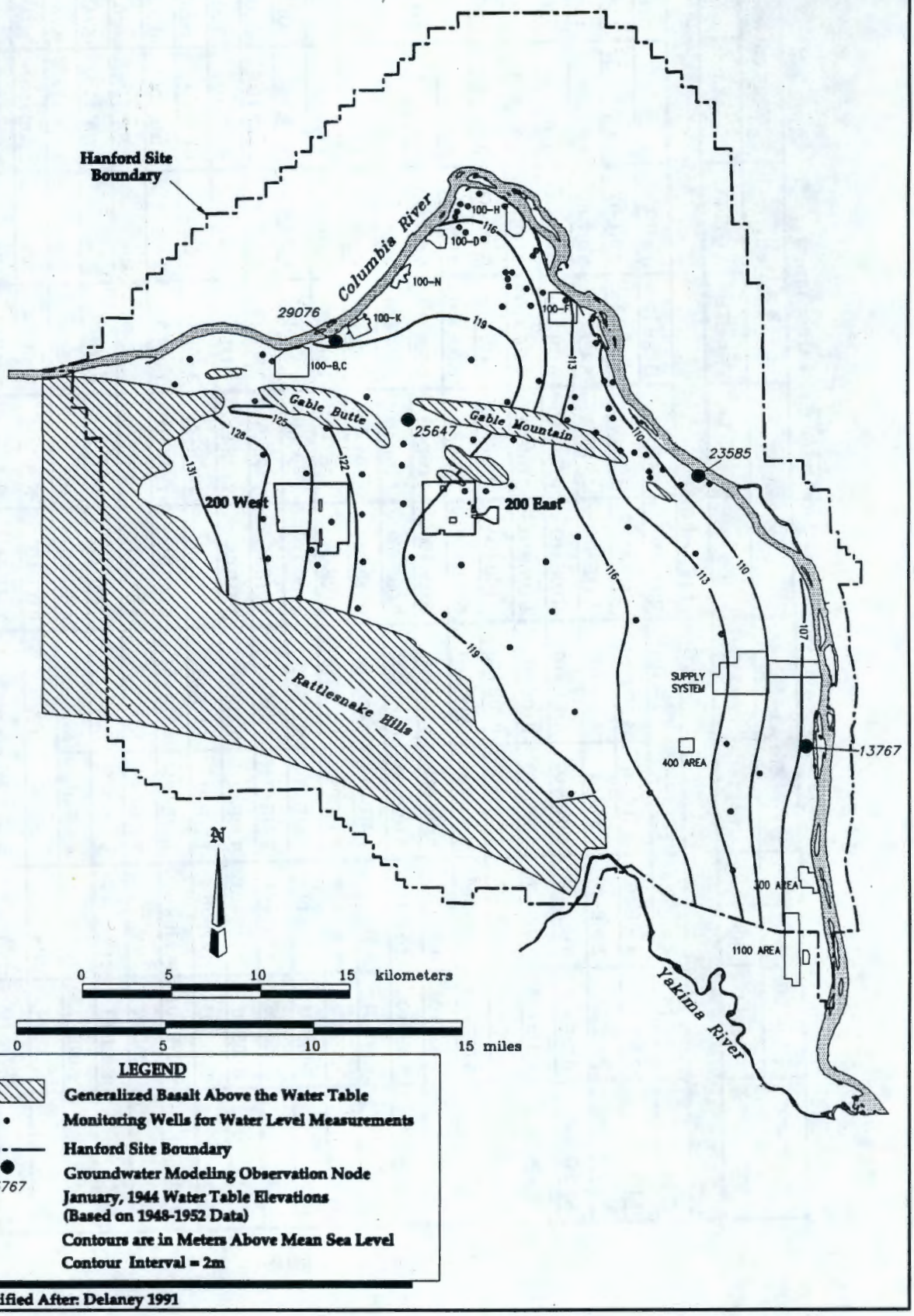
NOTE: See Figure F.4.3.5 for observation node locations.

Figure F.4.3.7 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative (500-Year Cap)



9613409.1601

Figure F.4.3.8 Hindcast of Water Levels in the Unconfined Aquifer



Modified After: Delaney 1991

Table F.3.1.1 Maximum Concentrations Calculated for the No Action Alternative

Constituent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
K_d Group 1 (K_d = 0.0 mL/g)										
C-14	1.55E-05	6.90E+04	4.57E-06	2.03E+04	2.13E-09	9.48E-00	3.18E-11	1.42E-01	0.00E+00	0.00E+00
I-129	2.50E-03	4.40E+02	3.21E-04	5.65EE+01	6.51E-07	1.15E-01	1.31E-08	2.31E-03	1.10E-12	1.94E-07
Np-237	2.92E-03	2.06E+03	6.45E-04	4.54E+02	4.18E-07	2.94E-01	8.42E-09	5.93E-03	7.00E-13	4.93E-07
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	4.64E-04	3.23E+04	3.45E-04	2.40E+04	9.18E-08	6.39E+00	1.80E-09	1.25E-01	1.00E-13	6.96E-06
Tc-99	1.87E-02	3.16E+05	7.45E-03	1.26E+05	8.02E-06	1.36E+02	1.58E-07	2.67E-00	1.34E-11	2.26E-04
U-233	3.91E-08	3.77E-01	2.61E-08	2.52E-01	4.70E-12	4.53E-05	1.00E-13	9.64E-07	0.00E+00	0.00E+00
U-234	1.93E-06	1.20E+01	2.84E-07	1.77E-00	1.91E-10	1.19E-03	3.80E-12	2.37E-05	0.00E+00	0.00E+00
U-235	8.03E-01	1.73E+03	9.30E-02	2.01E+02	3.55E-05	7.67E-02	7.15E-07	1.54E-03	6.15E-11	1.33E-07
U-236	8.48E-07	5.48E-02	1.21E-07	7.82E-03	1.69E-10	1.09E-05	3.40E-12	2.20E-07	0.00E+00	0.00E+00
U-238	1.23E+02	4.13E+04	1.42E+01	4.77E+03	5.04E-03	1.69E+00	1.02E-04	3.43E-02	0.00E+00	0.00E+00
Ag^{+}	1.23E-02	N/A	7.77E-03	N/A	9.07E-07	N/A	1.76E-08	N/A	1.50E-12	N/A
As^{+5}	8.92E-03	N/A	5.54E-03	N/A	3.15E-06	N/A	6.12E-08	N/A	5.20E-12	N/A
B^{+3}	1.09E-02	N/A	6.50E-03	N/A	6.68E-06	N/A	1.30E-07	N/A	1.11E-11	N/A
Be^{+2}	6.14E-04	N/A	4.09E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Cl^{-}	5.52E+00	N/A	1.23E+00	N/A	1.31E-03	N/A	2.56E-05	N/A	2.19E-09	N/A
CO_3^{-2}	1.69E+02	N/A	1.94E+01	N/A	4.22E-03	N/A	8.51E-05	N/A	7.31E-09	N/A
Cr^{+3}	2.72E+00	N/A	3.80E-01	N/A	8.38E-07	N/A	1.69E-08	N/A	1.50E-12	N/A
CrO_4^{-2}	6.60E-01	N/A	9.20E-02	N/A	1.48E-03	N/A	2.91E-05	N/A	2.49E-09	N/A
F-	3.44E+01	N/A	4.67E+00	N/A	9.31E-04	N/A	1.87E-05	N/A	1.60E-09	N/A
$Fe(CN)_6^{-4}$	1.90E+00	N/A	1.45E+00	N/A	3.58E-05	N/A	7.21E-07	N/A	6.20E-11	N/A

9613409.1602

Table F.3.1.1 Maximum Concentrations Calculated for the No Action Alternative (cont'd)

Constituent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Hg^{+}	5.00E-02	N/A	6.04E-03	N/A	6.29E-06	N/A	1.27E-07	N/A	1.09E-11	N/A
K^{+}	3.40E+00	N/A	2.52E+00	N/A	5.87E-04	N/A	1.14E-05	N/A	9.74E-10	N/A
Li^{+}	2.12E-04	N/A	1.33E-04	N/A	8.76E-08	N/A	1.70E-09	N/A	1.00E-13	N/A
Mo^{+6}	3.72E-02	N/A	2.43E-02	N/A	1.33E-05	N/A	2.59E-07	N/A	2.21E-11	N/A
Na^{+}	3.63E+03	N/A	4.46E+02	N/A	5.86E-01	N/A	1.18E-02	N/A	1.01E-06	N/A
NO_2^{-}	4.25E+02	N/A	4.96E+01	N/A	2.48E-02	N/A	4.98E-04	N/A	4.27E-08	N/A
NO_3-	6.62E+03	N/A	8.22E+02	N/A	1.21E+00	N/A	2.43E-02	N/A	2.09E-06	N/A
OH^{-}	1.27E+02	N/A	1.79E+01	N/A	6.02E-02	N/A	1.21E-03	N/A	1.04E-07	N/A
SiO_3^{-2}	1.35E+02	N/A	1.57E+01	N/A	6.39E-03	N/A	1.29E-04	N/A	1.11E-08	N/A
SO_4^{-2}	1.53E+02	N/A	1.77E+01	N/A	7.15E-03	N/A	1.44E-04	N/A	1.23E-08	N/A
UO_2^{+2}	2.10E-01	N/A	1.42E-01	N/A	7.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
V^{+5}	1.51E-03	N/A	1.12E-03	N/A	2.14E-07	N/A	4.16E-09	N/A	4.00E-13	N/A
W^{+4}	8.01E-01	N/A	9.67E-02	N/A	1.01E-04	N/A	2.03-06	N/A	1.74E-10	N/A
K_d Group 2 (K_d = 1.0 mL/g)										
Bi-210	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-63	N/A	N/A	N/A	N/A	5.81E-06	3.42E+05	1.73E-06	1.02E+05	5.58E-08	3.28E+03
Pa-231	N/A	N/A	N/A	N/A	8.20E-09	3.87E-01	5.67E-10	2.68E-02	3.79E-11	1.79E-03
Pa-233	N/A	N/A	N/A	N/A	1.73E-11	3.58E+02	0.00E+00	0.00E+00	1.00E-13	2.07E+00
Pa-234m	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Po-211	N/A	N/A	N/A	N/A	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bi^{+3}	N/A	N/A	N/A	N/A	6.86E+00	N/A	4.70E-01	N/A	3.40E-02	N/A
Ca^{+2}	N/A	N/A	N/A	N/A	2.04E-01	N/A	6.48E-02	N/A	1.88E-03	N/A
Cd^{+2}	N/A	N/A	N/A	N/A	3.72E-02	N/A	3.81E-03	N/A	2.14E-04	N/A
Cu^{+2}	N/A	N/A	N/A	N/A	2.21E-03	N/A	3.88E-04	N/A	1.55E-05	N/A
Fe^{+3}	N/A	N/A	N/A	N/A	7.14E+00	N/A	5.11E-01	N/A	3.77E-02	N/A
Mg^{+2}	N/A	N/A	N/A	N/A	2.63E-02	N/A	5.36E-03	N/A	2.04E-04	N/A
Ni^{+2}	N/A	N/A	N/A	N/A	2.13E-01	N/A	8.37E-02	N/A	2.31E-03	N/A

Notes:
N/A = Not Applicable

Table F.3.2.1 Maximum Concentrations Calculated for the Long-Term Management Alternative

Constituent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
K_d Group 1 (K_d = 0.0 mL/g)										
C-14	3.15E-06	1.40E+04	3.96E-06	1.76E+04	2.13E-09	9.48E+00	3.18E-11	1.42E-01	0.00E+00	0.00E+00
I-129	4.09E-04	7.20E+01	3.21E-04	5.65E+01	6.51E-07	1.15E-01	1.31E-08	2.31E-03	1.10E-12	1.94E-07
Np-237	2.92E-03	2.06E+03	6.45E-04	4.54E+02	4.19E-07	2.95E-01	8.46E-09	5.96E-03	7.00E-13	4.93E-07
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	2.12E-04	1.48E+04	3.45E-04	2.40E+04	9.18E-08	6.39E+00	1.80E-09	1.25E-01	1.00E-13	6.96E-06
Tc-99	5.40E-03	9.13E+04	6.48E-03	1.10E+05	8.44E-06	1.43E+02	1.71E-07	2.89E+00	1.45E-11	2.45E-04
U-233	1.53E-08	1.47E-01	2.89E-08	2.79E-01	4.70E-12	4.53E-05	1.00E-13	9.64E-07	0.00E+00	0.00E+00
U-234	3.82E-05	2.38E+02	3.20E-05	2.00E+02	1.91E-10	1.19E-03	3.80E-12	2.37E-05	0.00E+00	0.00E+00
U-235	1.20E-01	2.59E+02	9.30E-02	2.01E+02	5.28E-06	1.14E-02	1.06E-07	2.29E-04	6.33E-11	1.37E-07
U-236	1.36E-07	8.79E-03	1.27E-07	8.20E-03	2.52E-11	1.63E-06	5.00E-13	3.23E-08	0.00E+00	0.00E+00
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	1.83E+01	6.15E+03	1.42E+01	4.77E+03	7.50E-04	2.52E-01	1.51E-05	5.07E-03	9.00E-09	3.02E-06
Ag^{+}	8.52E-03	N/A	9.19E-03	N/A	1.02E-06	N/A	2.11E-08	N/A	1.80E-12	N/A
As^{+5}	6.19E-03	N/A	6.37E-03	N/A	3.54E-06	N/A	7.32E-08	N/A	6.30E-12	N/A
B^{+3}	7.73E-03	N/A	6.84E-03	N/A	7.52E-06	N/A	1.55E-07	N/A	1.34E-11	N/A
Be^{+2}	4.39E-04	N/A	4.84E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Cl^{-}	1.4E+00	N/A	1.27E+00	N/A	1.46E-03	N/A	3.01E-05	N/A	2.59E-09	N/A
CO_3^{-2}	2.50E+01	N/A	1.94E+01	N/A	4.22E-03	N/A	8.51E-05	N/A	7.31E-09	N/A
Cr^{+3}	5.87E-01	N/A	4.45E-01	N/A	8.39E-07	N/A	1.69E-08	N/A	1.50E-12	N/A
CrO_4^{-2}	1.10E-01	N/A	9.20E-02	N/A	1.60E-03	N/A	3.27E-05	N/A	2.82E-09	N/A
F^{-}	5.10E+00	N/A	4.04E+00	N/A	9.49E-04	N/A	1.92E-07	N/A	1.65E-09	N/A
$Fe(CN)_6^{-4}$	8.73E-01	N/A	1.49E+00	N/A	5.32E-06	N/A	1.07E-07	N/A	6.39E-11	N/A

9613409.1603

Table F.3.2.1 Maximum Concentrations Calculated for the Long-Term Management Alternative (cont'd)

Constituent	300 years		500 years		2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Hg^{+}	3.06E-04	N/A	3.30E-04	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
K^{+}	2.38E+00	N/A	2.69E+00	N/A	6.60E-04	N/A	1.36E-05	N/A	1.18E-09	N/A
Li^{+}	1.47E-04	N/A	1.50E-04	N/A	9.86E-08	N/A	2.04E-09	N/A	2.00E-13	N/A
Mo^{+6}	2.69E-02	N/A	2.81E-02	N/A	1.50E-05	N/A	3.10E-07	N/A	2.67E-11	N/A
Na^{+}	5.70E+02	N/A	4.44E+02	N/A	5.90E-01	N/A	1.19E-02	N/A	1.03E-06	N/A
NO_2^{-}	6.38E+01	N/A	4.94E+01	N/A	2.53E-02	N/A	5.12E-04	N/A	4.41E-08	N/A
NO_3^{-}	1.05E+03	N/A	8.21E+02	N/A	1.21E+00	N/A	2.44E-02	N/A	2.10E-06	N/A
OH^{-}	2.26E+01	N/A	1.79E+01	N/A	6.02E-02	N/A	1.21E-03	N/A	1.04E-07	N/A
SiO_3^{-2}	2.02E+01	N/A	1.56E+01	N/A	6.40E-03	N/A	1.29E-04	N/A	1.11E-08	N/A
SO_4^{-2}	2.28E+01	N/A	1.77E+01	N/A	7.23E-03	N/A	1.46E-04	N/A	1.26E-08	N/A
UO_2^{+2}	1.26E-01	N/A	1.49E-01	N/A	3.80E-12	N/A	0.00E+00	N/A	0.00E+00	N/A
V^{+5}	1.06E-03	N/A	1.20E-03	N/A	2.41E-07	N/A	4.98E-09	N/A	4.00E-13	N/A
W^{+4}	3.92E-03	N/A	4.22E-03	N/A	2.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
K_d Group 2 (K_d = 1.0 mL/g)										
Bi-210	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Ni-63	N/A	N/A	N/A	N/A	2.00E-13	N/A	0.00E+00	N/A	0.00E+00	N/A
Pa-231	N/A	N/A	N/A	N/A	8.20E-09	N/A	5.67E-10	N/A	3.79E-11	N/A
Pa-233	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Pa-234m	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Po-211	N/A	N/A	N/A	N/A	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
Bi^{+3}	N/A	N/A	N/A	N/A	6.86E+00	N/A	4.70E-01	N/A	3.40E-02	N/A
Ca^{+2}	N/A	N/A	N/A	N/A	2.04E-01	N/A	6.48E-02	N/A	1.88E-03	N/A
Cd^{+2}	N/A	N/A	N/A	N/A	3.72E-02	N/A	3.81E-03	N/A	2.14E-04	N/A
Cu^{+2}	N/A	N/A	N/A	N/A	6.00E-06	N/A	1.24E-07	N/A	1.07E-11	N/A
Fe^{+3}	N/A	N/A	N/A	N/A	7.14E+00	N/A	5.11E-01	N/A	3.77E-02	N/A
Mg^{+2}	N/A	N/A	N/A	N/A	2.63E-02	N/A	5.36E-03	N/A	2.04E-04	N/A
Ni^{+2}	N/A	N/A	N/A	N/A	2.13E-01	N/A	8.37E-02	N/A	2.31E-03	N/A

Notes:
N/A = Not Applicable

Table F.3.3.1 Maximum Concentrations Calculated for the In Situ Fill and Cap Alternative

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	1.40E-12	6.23E-03	2.99E-07	1.33E+03	1.93E-08	8.59E+01
I-129	9.82E-11	1.73E-05	4.74E-05	8.34E+00	1.46E-05	2.57E+00
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	1.00E-13	3.34E-01	0.00E+00	0.00E+00
Sb-126m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	1.35E-11	9.40E-04	6.51E-06	4.53E+02	1.91E-06	1.33E+02
Tc-99	2.72E-09	4.60E-02	8.70E-04	1.47E+04	1.03E-04	1.74E+03
U-233	0.00E+00	0.00E+00	5.84E-10	5.63E-03	1.03E-10	9.93E-04
U-234	1.00E-13	6.24E-07	3.70E-08	2.31E-01	4.41E-09	2.75E-02
U-235	2.02E-08	4.36E-05	1.57E-02	3.39E+01	1.61E-03	3.48E+00
U-236	1.00E-13	6.46E-09	1.62E-08	1.05E-03	3.81E-09	2.46E-04
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	3.00E-06	1.01E-03	2.40E+00	8.06E+02	2.44E-01	8.20E+01
Ag^{+}	5.40E-10	N/A	5.53E-04	N/A	1.68E-07	N/A
As^{+5}	6.70E-11	N/A	3.00E-04	N/A	5.79E-07	N/A
B^{+3}	1.72E-10	N/A	4.12E-04	N/A	1.23E-06	N/A
Be^{+2}	5.76E-11	N/A	3.61E-05	N/A	7.80E-09	N/A
Cl	1.41E-07	N/A	1.09E-01	N/A	9.95E-03	N/A
CO_3^{-2}	1.47E-06	N/A	3.31E+00	N/A	3.19E-01	N/A
Cr^{+3}	2.20E-11	N/A	8.83E-05	N/A	1.86E-05	N/A
CrO_4^{-2}	7.22E-10	N/A	6.19E-02	N/A	1.21E-02	N/A
F^{-}	5.96E-06	N/A	6.75E-01	N/A	6.44E-02	N/A
$Fe(CN)_6^{-4}$	1.16E-06	N/A	1.93E-01	N/A	1.14E-03	N/A
Hg^{+}	2.40E-12	N/A	1.61E-05	N/A	6.68E-09	N/A
K^{+}	9.74E-07	N/A	3.47E-01	N/A	1.08E-04	N/A
Li^{+}	0.00E+00	N/A	6.63E-06	N/A	1.61E-08	N/A
Mo^{+6}	2.06E-09	N/A	1.73E-03	N/A	2.45E-06	N/A
Na^{+}	4.43E-05	N/A	7.00E+01	N/A	1.24E+01	N/A

Table F.3.3.1 Maximum Concentrations Calculated for the In Situ Fill and Cap Alternative (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
NO_2^-	3.66E-06	N/A	8.31E+00	N/A	8.64E-01	N/A
NO_3^-	3.17E-05	N/A	1.27E+02	N/A	2.68E+01	N/A
Np-237	2.02E-10	1.42E-04	6.87E-05	4.84E+01	9.19E-06	6.47E+00
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OH^-	1.94E-05	N/A	2.34E+00	N/A	1.35E+00	N/A
Rh-106	0.00E+00	N/A	0.00E+00	N/A	0.00E+00	N/A
SO_4^{-2}	2.43E-06	N/A	2.98E+00	N/A	3.04E-01	N/A
SO_4^{-2}	2.43E-06	N/A	2.98E+00	N/A	3.04E-01	N/A
UO_2^{+2}	6.95E-08	N/A	2.27E-02	N/A	3.46E-07	N/A
V^{+5}	4.28E-10	N/A	1.54E-04	N/A	3.94E-08	N/A
W^{+4}	0.00E+00	N/A	2.00E-04	N/A	8.67E-08	N/A

Notes:
N/A = Not Applicable

Table F.3.4.1 Maximum Concentrations Calculated for the In Situ Vitrification Alternative

Constituents	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc_2O_7	1.72E-06	2.91E+01	2.21E-06	3.73E+01
U-233	1.40E-12	1.35E-05	1.80E-12	1.74E-05
U-234	3.92E-11	2.45E-04	4.99E-11	3.11E-04
U-235	1.25E-05	2.70E-02	1.61E-05	3.48E-02
U-236	4.51E-11	2.91E-06	5.82E-11	3.76E-06
U-238	1.84E-03	6.18E-01	2.37E-03	7.96E-01
Ag_2O	1.90E-06	N/A	2.45E-06	N/A
As_2O_5	1.42E-06	N/A	1.83E-06	N/A
B_2O_3	4.86E-06	N/A	6.27E-06	N/A
BeO	1.01E-07	N/A	1.31E-07	N/A
Cr_2O_3	7.11E-05	N/A	9.18E-05	N/A
Li_2O	3.38E-08	N/A	4.36E-08	N/A
Na_2O	7.39E-02	N/A	9.54E-02	N/A
MoO_3	6.31E-06	N/A	8.14E-06	N/A
NpO_2	1.63E-07	N/A	2.10E-07	N/A
V_2O_5	2.78E-07	N/A	3.59E-07	N/A
WO_2	5.63E-07	N/A	7.26E-07	N/A
WO_3	1.12E-06	N/A	1.45E-06	N/A

Notes:
N/A = Not Applicable

Table F.3.5.1 Maximum Concentrations Calculated for the Ex Situ Intermediate Separations Alternative - Tank Sources

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	3.42E-10	1.52E+00	6.80E-09	3.03E+01	2.00E-13	8.90E-04
I-129	5.32E-08	9.36E-05	2.01E-06	3.54E-01	1.21E-10	2.13E-05
Rn-219	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ru-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb-126	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Se-79	7.49E-09	5.21E-01	2.75E-07	1.91E+01	1.71E-11	1.19E-03
Tc-99	3.78E-07	6.39E+00	1.50E-05	2.54E+02	1.55E-09	2.62E-02
U-233	7.00E-13	6.75E-06	2.32E-11	2.24E-04	0.00E+00	0.00E+00
U-234	2.45E-11	1.53E-04	1.42E-09	9.96E-03	0.00E+00	0.00E+00
U-235	7.44E-06	1.61E-02	5.82e-04	1.26E+00	7.16E-09	1.55E-05
U-236	4.57E-11	2.95E-06	6.63E-10	4.28E-05	N/A	0.00E+00
U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-238	1.11E-03	3.73E-01	8.90E-02	2.99E+01	1.02E-06	3.43E-04
Ag^{+}	3.24E-10	N/A	1.94E-05	N/A	1.72E-10	N/A
As^{+5}	4.02E-11	N/A	1.39E-05	N/A	5.95E-10	N/A
B^{+3}	1.03E-10	N/A	1.82E-05	N/A	1.26E-09	N/A
Be^{+2}	3.46E-11	N/A	9.15E-07	N/A	0.00E+00	N/A
Cl^{-}	1.71E-05	N/A	4.06E-03	N/A	2.50E-07	N/A
CrO_4^{-2}	2.57E-06	N/A	3.16E-03	N/A	2.87E-07	N/A
F^{-}	1.80E-03	N/A	2.47E-02	N/A	1.86E-07	N/A
$Fe(CN)_6^{-4}$	4.47E-04	N/A	4.27E-03	N/A	7.22E-09	N/A
Hg^{+}	1.5E-12	N/A	7.64E-07	N/A	0.00E+00	N/A
Li^{+}	0.00E+00	N/A	3.29E-07	N/A	1.66E-11	N/A
Na^{+}	1.61E-03	N/A	2.78E+00	N/A	1.18E-04	N/A
NO_2^{-}	2.10E-03	N/A	3.10E-01	N/A	4.96E-06	N/A
NO_3^{-}	2.18E-02	N/A	5.13E+00	N/A	2.43E-04	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A
UO_2^{+2}	4.23E-08	N/A	8.93E-05	N/A	0.00E+00	N/A
V^{+5}	2.57E-10	N/A	1.23E-06	N/A	4.05E-11	N/A
W^{+6}	0.00E+00	N/A	9.90E-06	N/A	0.00E+00	N/A
Np-237	7.19E-08	5.06E-02	2.22E-06	1.56E+00	8.42E-11	5.93E-05
Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table F.3.5.1 Maximum Concentrations Calculated for the Ex Situ Intermediate Separations Alternative - Tank Sources (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
CO_3^{-2}	6.66E-04	N/A	1.21E-01	N/A	8.51E-07	N/A
Cr^{+3}	1.52E-08	N/A	3.56E-06	N/A	1.69E-10	N/A
K^+	5.85E-07	N/A	2.68E-03	N/A	1.11E-07	N/A
Mo^{+6}	1.24E-09	N/A	5.51E-05	N/A	2.52E-09	N/A
OH^-	6.53E-03	N/A	1.14E-01	N/A	1.22E-05	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A

Notes:
N/A = Not Applicable

Table F.3.5.2 Maximum Concentrations Calculated for the LAW Vaults - Ex Situ Intermediate Separations Alternative

Constituent	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	4.56E-06	7.71E+01	1.23E-05	2.08E+02
U-233	2.00E-13	1.93E-06	6.00E-13	5.78E-06
U-234	6.60E-12	4.12E-05	1.76E-11	1.10E-04
U-235	2.06E-06	4.45E-03	5.56E-06	1.20E-02
U-236	7.60E-12	4.91E-07	2.05E-11	1.32E-06
U-238	3.09E-04	1.04E-01	8.35E-04	2.81E-01
Ag_2O	1.19E-06	N/A	3.23E-06	N/A
As_2O_5	2.80E-06	N/A	7.57E-06	N/A
B_2O_3	5.46E-06	N/A	1.48E-05	N/A
BeO	2.98E-07	N/A	8.06E-07	N/A
Cr_2O_3	3.52E-06	N/A	9.51E-06	N/A
Li_2O	2.11E-08	N/A	5.71E-08	N/A
MoO_3	1.77E-05	N/A	4.79E-05	N/A
Na_2O	2.66E-01	N/A	7.19E-01	N/A
NpO_2	5.33E-08	N/A	1.44E-07	N/A
V_2O_5	2.27E-07	N/A	6.13E-07	N/A
WO_2	1.22E-10	N/A	3.29E-10	N/A
WO_3	3.66E-06	N/A	9.89E-06	N/A

Notes:
N/A = Not Applicable

9613409.1606

Table F.3.8.1 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (Tank Retrieval Component)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	2.30E-10	1.02E+00	6.71E-10	2.99E+00	0.00	0.00E+00
I-129	3.91E-08	6.88E-03	1.18E-07	2.08E-02	1.08E-11	1.90E-06
Np-237	5.23E-08	3.68E-02	9.63E-08	6.78E-02	6.20E-12	4.36E-06
Np-238	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rh-106	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rn-219	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Rn-222	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Ru-106	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Sb-126m	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
Se-79	5.49E-09	3.82E-01	1.59E-08	1.11E+00	1.40E-12	9.74E-05
Tc-99	2.78E-07	4.70E+00	8.15E-07	1.38E+01	7.55E-11	1.28E-03
U-233	4.00E-13	3.86E-06	1.60E-12	1.54E-05	0.00	0.00E+00
U-234	1.01E-11	6.30E-05	9.16E-11	5.72E-04	0.00	0.00E+00
U-235	3.36E-06	7.26E-03	2.59E-05	5.59E-02	5.02E-10	1.08E-06
U-236	1.71E-11	1.10E-06	1.74E-10	1.12E-05	0.00	0.00E+00
U-237	0.00	0.00E+00	0.00	0.00E+00	0.00	0.00E+00
U-238	4.99E-04	1.68E-01	3.95E-03	1.33E+00	7.20E-08	2.42E-05
Cl^-	6.63E-06		1.20E-04		1.99E-09	
CO_3^{-2}	3.70E-04		4.22E-03		6.97E-08	
Cr^{+3}	7.72E-09		1.35E-07		8.50E-12	
CrO_4^{-2}	7.90E-07		5.23E-05		4.91E-09	
F^-	7.15E-04		7.25E-03		1.05E-08	
$Fe(CN)_6^{-4}$	1.75E-04		1.33E-04		3.52E-10	
Hg^+	2.94E-07		2.91E-06		1.05E-10	
Na^+	7.30E-03		1.02E-01		5.42E-06	
NO_2^-	1.33E-03		1.23E-02		2.76E-07	
NO_3^-	1.11E-02		1.95E-01		1.23E-05	
OH^-	2.39E-03		2.43E-02		5.45E-07	
SiO_3^{-2}	2.95E-04		3.42E-03		2.27E-08	
SO_4^{-2}	4.05E-04		3.94E-03		1.01E-07	
W^{+4}	4.72E-06		4.67E-05		1.68E-09	

Source: Jacobs 1996

Table F.3.8.2 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (In Situ Tank Remediation Component)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	1.0E-13	4.45E-04	5.89E-08	2.62E+02	1.45E-09	6.45E+00
I-129	9.50E-12	1.67E-06	2.16E-05	3.80E+00	1.07E-06	1.88E-01
Np-237	1.48E-11	1.04E-05	2.47E-05	1.74E+01	1.26E-06	8.87E-01
Np-238	0.00	0.00	0.00	0.00	0.00	0.00
Rh-106	0.00	0.00	0.00	0.00	0.00	0.00
Rn-219	0.00	0.00	0.00	0.00	0.00	0.00
Rn-222	0.00	0.00	0.00	0.00	0.00	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00
Sb-126m	0.00	0.00	0.00	0.00	0.00	0.00
Se-79	1.30E-12	9.05E-05	2.98E-06	2.07E+02	1.38E-07	9.60E+00
Tc-99	1.21E-10	2.04E-03	1.64E-04	2.77E+03	7.49E-06	1.27E+02
U-233	0.00	0.00	4.96E-10	4.78E-03	4.06E-11	3.91E-04
U-234	0.00	0.00	1.33E-08	8.30E-02	1.32E-09	8.24E-03
U-235	1.04E-09	2.25E-06	2.03E-03	4.38E+00	1.47E-04	3.18E-01
U-236	0.00	0.00	2.18E-09	1.41E-04	6.99E-10	4.52E-05
U-237	0.00	0.00	0.00	0.00	0.00	0.00
U-238	1.49E-07	5.01E-05	3.07E-01	1.03E+02	1.99E-02	6.69E+00
Ag^{+}	1.10E-10	N/A	2.80E-03	N/A	3.59E-08	N/A
As^{+5}	4.11E-11	N/A	4.92E-04	N/A	1.25E-07	N/A
B^{+3}	1.05E-10	N/A	1.91E-03	N/A	4.07E-08	N/A
Be^{+2}	3.45E-11	N/A	9.49E-06	N/A	1.00E-13	N/A
Cl^{-}	5.19E-08	N/A	8.49E-02	N/A	5.69E-04	N/A
CO_3^{-2}	1.51E-06	N/A	1.94E+00	N/A	6.18E-03	N/A
Cr^{+3}	9.40E-12	N/A	5.44E-05	N/A	6.38E-06	N/A
CrO_4^{-2}	1.84E-08	N/A	2.60E-02	N/A	4.82E-03	N/A
F^{-}	5.63E-07	N/A	2.99E-01	N/A	3.68E-03	N/A
$Fe(CN)_6^{-4}$	1.86E-07	N/A	5.64E-02	N/A	2.93E-04	N/A
Hg^{+}	3.52E-10	N/A	1.03E-03	N/A	8.35E-06	N/A
K^{+}	3.19E-07	N/A	3.20E-02	N/A	5.09E-06	N/A
Li^{+}	0.00	N/A	1.37E-05	N/A	3.48E-09	N/A
Mo^{+6}	8.81E-10	N/A	3.33E-04	N/A	2.62E-08	N/A
Na^{+}	9.14E-06	N/A	4.38E+01	N/A	4.54E+00	N/A
NO_2^{-}	1.71E-06	N/A	3.15E+00	N/A	1.02E-01	N/A
NO_3^{-}	1.35E-05	N/A	7.83E+01	N/A	9.19E+00	N/A
OH^{-}	1.42E-06	N/A	2.84E+00	N/A	5.38E-01	N/A
SiO_3^{-2}	9.51E-08	N/A	1.45E+00	N/A	9.01E-02	N/A
SO_4^{-2}	4.31E-07	N/A	1.92E+00	N/A	1.65E-02	N/A

Table F.3.8.2 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (In Situ Tank Remediation Component) (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
UO_2^{+2}	4.17E-08	N/A	8.61E-03	N/A	4.56E-11	N/A
V^{+5}	2.63E-10	N/A	3.35E-05	N/A	8.50E-09	N/A
W^{+4}	5.65E-09	N/A	1.74E-02	N/A	1.34E-04	N/A

Notes:
N/A = Not Applicable
Source: Jacobs 1996.

Table F.3.8.3 Maximum Concentrations Calculated in Groundwater for the Ex Situ/In Situ Combination Alternative (LAW Vault Component)

Constituent	5,000 years		10,000 year	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	2.34E-06	3.95E+01	6.30E-06	1.06E+02
U-233	1.00E-13	9.64E-07	3.00E-13	2.89E-06
U-234	3.40E-12	2.12E-05	9.00E-12	5.62E-05
U-235	1.05E-06	2.27E-03	9.00E-12	1.94E-08
U-236	3.90E-12	2.52E-07	1.05E-11	6.78E-07
U-238	1.58E-04	5.31E-02	4.28E-04	1.44E-01
Ag^{+}	6.12E-07	N/A	1.65E-06	N/A
As^{+5}	1.43E-06	N/A	3.88E-06	N/A
B^{+}	2.80E-06	N/A	7.56E-06	N/A
Be^{+2}	1.53E-07	N/A	4.13E-07	N/A
Cr^{+3}	1.80E-06	N/A	4.87E-06	N/A
K^{+}	4.11E-07	N/A	1.11E-06	N/A
Li^{+}	1.08E-08	N/A	2.92E-08	N/A
Mo^{+6}	9.08E-06	N/A	2.46E-05	N/A
Na^{+}	1.36E-01	N/A	3.68E-01	N/A
NpO_2	2.73E-08	N/A	7.39E-08	N/A
SiO_3^{-2}	1.20E-01	N/A	5.40E-01	N/A
V^{+}	1.16E-07	N/A	3.14E-07	N/A
WO_3	1.87E-06	N/A	5.07E-06	N/A
WO_2	6.23E-11	N/A	1.69E-10	N/A

Notes:
N/A = Not Applicable
Source: Jacobs 1996

Table F.3.9.1 Maximum Concentrations Calculated in Groundwater for the Phased Implementation Total Alternative (Tank Sources)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
C-14	3.42E-10	1.52E+00	6.80E-09	3.03E+01	2.00E-13	8.90E-04
I-129	5.32E-08	9.36E-03	2.01E-06	3.54E-01	1.21E-10	2.13E-05
Rn-219	0.00	0.00	0.00	0.00	0.00	0.00
Rn-222	0.00	0.00	0.00	0.00	0.00	0.00
Ru-106	0.00	0.00	0.00	0.00	0.00	0.00
Sb-126	0.00	0.00	0.00	0.00	0.00	0.00
Se-79	7.49E-09	5.21E-01	2.75E-07	1.91E+01	1.71E-11	1.19E-03
Tc-99	3.78E-07	6.39E+00	1.50E-05	2.54E+02	1.55E-09	2.62E-02
U-233	7.00E-13	6.75E-06	2.32E-11	2.24E-04	0.00	0.00
U-234	2.45E-11	1.53E-04	1.42E-09	8.86E-03	0.00	0.00
U-235	7.44E-06	1.61E-02	5.82E+04	1.26E+06	7.16E-09	1.55E-05
U-236	4.57E-11	2.95E-06	6.63E-10	4.28E-05	0.00	0.00
U-237	0.00	0.00	0.00	0.00	0.00	0.00
U-238	1.11E-03	3.73E-01	8.90E-01	2.99E+02	1.02E-06	3.43E-04
Ag^{+}	3.24E-10	N/A	1.94E-05	N/A	1.72E-10	N/A
As^{+5}	4.02E-11	N/A	1.39E-05	N/A	5.95E-10	N/A
B^{+3}	1.03E-10	N/A	1.82E-05	N/A	1.26E-09	N/A
Be^{+2}	3.46E-11	N/A	9.15E-07	N/A	0.00	N/A
Cl^{-}	1.71E-05	N/A	4.06E-03	N/A	2.50E-07	N/A
CrO_4^{-2}	2.57E-06	N/A	3.16E-03	N/A	2.87E-07	N/A
F^{-}	1.80E-03	N/A	2.47E-02	N/A	1.86E-07	N/A
$Fe(CN)_6^{-4}$	4.47E-04	N/A	4.27E-03	N/A	7.22E-09	N/A
Hg^{+}	1.50E-12	N/A	7.64E-07	N/A	0.00	N/A
Li^{+}	0.00	N/A	3.29E-07	N/A	1.66E-11	N/A
Na^{+}	1.62E-02	N/A	2.78E+00	N/A	1.18E-04	N/A
NO_2	2.11E-03	N/A	3.09E-01	N/A	4.96E-06	N/A
NO_3	2.18E-02	N/A	5.13E-01	N/A	2.44E-04	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A
UO_2^{+2}	4.23E-08	N/A	8.93E-05	N/A	0.00	N/A
V^{+5}	2.57E-10	N/A	1.23E-06	N/A	4.05E-11	N/A
W^{+6}	0.00	N/A	9.90E-06	N/A	0.00	N/A
Np-237	7.19E-08	5.06E-02	2.22E-06	1.56E+00	8.42E-11	5.93E-05
Np-238	0.00	0.00	0.00	0.00	0.00	0.00
Rh-106	0.00	0.00	0.00	0.00	0.00	0.00

9613409.1608

Table F.3.9.1 Maximum Concentrations in Groundwater Calculated for the Phased Implementation Total Alternative (Tank Sources) (cont'd)

Constituent	2,500 years		5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
CO_3^{-2}	6.66E-04	N/A	1.21E-01	N/A	8.51E-07	N/A
Cr^{+3}	1.52E-08	N/A	3.56E-06	N/A	1.69E-10	N/A
K^+	5.85E-07	N/A	2.68E-03	N/A	1.11E-07	N/A
Mo^{+6}	1.24E-09	N/A	5.51E-05	N/A	2.52E-09	N/A
OH^-	6.53E-03	N/A	1.14E-01	N/A	1.22E-05	N/A
SO_4^{-2}	9.07E-04	N/A	1.11E-01	N/A	1.44E-06	N/A

Notes
N/A = Not Applicable
Source: Jacobs 1996

Table F.3.9.2 Maximum Concentration Calculated in Groundwater for the Phased Implementation Total Alternative (LAW Vaults)

Constituent	5,000 years		10,000 years	
	(mg/L)	(pCi/L)	(mg/L)	(pCi/L)
Tc-99	4.56E-06	7.71E+01	1.23E-05	2.08E+02
U-233	2.00E-13	1.93E-06	6.00E-13	5.78E-06
U-234	6.60E-12	4.12E-05	1.76E-11	1.10E-04
U-235	2.06E-06	4.45E-03	5.56E-06	1.20E-02
U-236	7.60E-12	4.91E-07	2.05E-11	1.32E-06
U-238	3.09E-04	1.04E-01	8.35E-04	2.81E-01
Ag_2O	1.19E-06	N/A	3.23E-06	N/A
As_2O_5	2.80E-06	N/A	7.57E-06	N/A
B_2O_3	5.46E-06	N/A	1.48E-05	N/A
BeO	2.98E-07	N/A	8.06E-07	N/A
Cr_2O_3	3.52E-06	N/A	9.51E-06	N/A
Li_2O	2.11E-08	N/A	5.71E-08	N/A
MoO_3	1.77E-05	N/A	4.79E-05	N/A
Na_2O	2.66E-01	N/A	7.19E-01	N/A
NpO_2	5.33E-08	N/A	1.44E-07	N/A
V_2O_5	2.27E-07	N/A	6.13E-07	N/A
WO_2	1.22E-10	N/A	3.29E-10	N/A
WO_3	3.66E-06	N/A	9.89E-06	N/A

Notes
N/A = Not Applicable
Source: Jacobs 1996

Table F.3.11.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for Each Alternative

Constituent	Alternative	Drinking Water Standards	Maximum concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Carbon-14	No Action	2,000 pCi/L (4.49E-7 mg/L)	1.55E-05*	4.57E-06*	2.13E-09	3.18E-11	0.00
	Long-Term Management		3.15E-06*	3.96E-06*	2.13E-09	3.18E-11	0.00
	In Situ Fill and Cap		0.0	0.0	1.40E-12	2.99 E-07	1.93E-08
	In Situ Vitrification		0.0	0.0	0.0	0.0	0.0
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.00	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ No Separations		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Extensive Separations-Tank Sources[1]		0.0	0.0	3.42E-10	6.80E-09	2.00E-13
	Ex Situ Extensive Separations-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination-Tank Sources[1]		0.0	0.0	2.30E-10	5.89E-08	1.45E-09
	Ex Situ/In Situ Combination-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Phased Implementation		0.0	0.0	0.0	0.0	0.0

Notes:

[1] Maximum concentrations from the tanks source and LAW vaults additive, but not on a one-to-one basis because the source locations are not coincident and the time of release is not the same.

* Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.

Source: Jacobs 1996

9613409.1609

Table F.3.11.1 Comparison of Maximum Contaminant Concentrations Calculated for Each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Iodine-129	No Action	1 pCi/L (5.68E-06 mg/L)	2.50E-03*	3.21E-04*	6.51E-07	1.31E-08	1.10E-12
	Long-Term Management		4.09E-04*	3.21E-04*	6.51E-07	1.31E-08	1.10E-12
	In Situ Fill and Cap		0.0	0.0	9.82E-11	4.75E-05*	1.46E-05*
	In Situ Vitrification		0.0	0.0	0.0	0.0	0.0
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ No Separations		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Extensive Separations-Tank Sources[1]		0.0	0.0	5.32E-08	2.01E-06	1.32E-10
	Ex Situ Extensive Separations-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Ex Situ/In Situ Combination-Tank Source[1]		0.0	0.0	3.91E-08	2.17E-05*	1.07E-06
	Ex Situ/In Situ Combination-LAW Vaults[1]		0.0	0.0	0.0	0.0	0.0
	Phased Implementation		0.0	0.0	0.0	0.0	0.0

Notes:

[1] Maximum concentrations from the tank source and LAW vaults are additive, but not on a one-to-one basis because the source locations are not coincident and the time of release is not the same.

*Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.

Source: Jacobs 1996

Table F.3.11.1 Comparison of Maximum Containment Contaminant Calculated in Groundwater for Each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Technetium-99	No Action	900 pCi/L (5.33E-05 mg/L)	1.87E-02*	7.45E-03*	8.02E-06	1.58E-07	1.34E-11
	Long-Term Management		5.40E-03*	6.48E-03*	8.44E-06	1.71E-07	1.45E-11
	In Situ Fill and Cap		0.0	0.0	2.72E-09	8.70E-04*	1.03E-04*
	In Situ Vitrification		0.0	0.0	0.0	1.72E-06	2.21E-06
	Ex Situ Intermediate Separations Ex Situ Tank Sources[1]		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	4.56E-06	1.23E-05
	Ex Situ No Separations		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Extensive Separations - Tank Sources[1]		0.0	0.0	3.78E-07	1.50E-05	1.55E-09
	Ex Situ Extensive Separations - LAW Vaults[1]		0.0	0.0	0.0	3.36E-08	9.05E-08
	Ex Situ/In Situ Combination-Tank Sources[1]		0.0	0.0	2.78E-07	1.65E-04*	7.49E-06
	Ex Situ/In Situ Combination-LAW Vaults[1]		0.0	0.0	0.0	2.34E-06	6.30E-06
	Phased Implementation		0.0	0.0	0.0	0.0	0.0

Notes:
[1] Maximum concentrations from the tank source and LAW vaults are additive, but not on a one-to-one basis because the source locations are not coincident and the time of release is not the same.
* Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.
Source: Jacobs 1996

Table F.3.11.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentrations Observed in groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Uranium-238	No Action	0.02 mg/L (Total)	1.23E+02*	1.42E+01*	5.04E-03	1.02E-04	0.0
	Long-Term Management		1.83E+01*	1.42E+01*	7.50E-04	1.51E-05	9.00E-09
	In Situ Fill and Cap		0.0	0.0	3.00E-06	2.40E+00*	2.44E-01*
	In Situ Vitrification		0.0	0.0	0.0	1.84E-03	2.37E-03
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.0	0.0	0.0	3.08E-04	8.35E-04
	Ex Situ No Separations		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Extensive Separations - Tank Sources[1]		0.0	0.0	1.11E-03	8.90E-02*	1.02E-06
	Ex Situ Extensive Separations - LAW Vaults[1]		0.0	0.0	0.00	1.13E-06	3.06E-06
	Ex Situ/In Situ Combination-Tank Sources[1]		0.0	0.0	4.99E-04	3.11E-04	1.99E-02
	Ex Situ/In Situ Combination-LAW Vaults[1]		0.0	0.0	0.0	01.58E-04	4.28E-04
	Phased Implementation		0.0	0.0	0.0	0.0	0.0

Notes:
[1] Maximum concentrations from the tank source and LAW vaults LAW vaults are additive, but not on a one-to-one basis because the source locations are not coincident and the time of release in not the same.
* Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.
Source: Jacobs 1996

9613409.1610

Table F.3.11.1 Comparison of Maximum Contaminant Concentrations Calculated in Groundwater for each Alternative (cont'd)

Constituent	Alternative	Drinking Water Standards	Maximum Concentration Observed in Groundwater at the Specified Time				
			300 Years (mg/L)	500 Years (mg/L)	2,500 Years (mg/L)	5,000 Years (mg/L)	10,000 Years (mg/L)
Nitrate	No Action	45 mg/L	6.62E+03*	8.22E+02*	1.21E+00	2.43-02	2.90E-06
	Long-Term Management		1.05E+03*	8.21E+02*	1.21E+00	2.44E-02	2.10E-06
	In Situ Fill and Cap		0.00	0.00	3.17E-05	1.27E+02*	2.68E+01
	In Situ Vitrification		0.00	0.00	0.00	0.00	0.00
	Ex Situ Intermediate Separations Ex Situ-Tank Sources[1]		0.00	0.00	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Intermediate Separations Ex Situ-LAW Vaults[1]		0.00	0.00	0.00	0.00	0.00
	Ex Situ No Separations		0.00	0.00	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Extensive Separations - Tank Sources[1]		0.00	0.00	2.19E-02	5.13E+00	2.44E-04
	Ex Situ Extensive Separations - LAW Vaults[1]		0.00	0.00	0.00	0.00	0.00
	Ex Situ/In Situ Combination-Tank Sources[1]		0.0	0.0	1.11E-02	7.85E+01*	9.19E+00
	Ex Situ/In Situ Combination-LAW Vaults[1]		0.00	0.00	0.00	0.00	0.00
	Phased Implementation		0.00	0.00	0.00	0.00	0.00

Notes:

[1] Maximum concentrations from the tank source and LAW vaults are additive, but not on a one-to-one basis because the source locations are not coincident and the time of release is not the same.

* Calculated value exceeds drinking water standard (40 CFR 141.16) based on a calculated dose equivalent to 4 millirem/year to an internal organ.

Source: Jacobs 1996

9613409.1611

Table F.4.4.1 Estimated Mass of Selected Contaminants Released During Retrieval and as Residual for the Ex Situ Alternatives

Contaminant	Mass Released for Nominal Case Retrieval Scenario (g)	Mass Released for Lower Bounding Retrieval Scenario (g)	Mass Released as Residual Remaining in all Tanks (g)
Iodine-129	1.97E+03	3.94E+02	9.08E+02
Carbon-14	2.26E+01	4.52E+00	1.20E+01
Technetium-99	1.37E+04	2.74E+03	1.93E+04
Uranium-238	7.63E+08	1.53E+07	1.43E+07
Nitrate	8.12E+08	1.62E+08	1.03E+09

Source: Jacobs Engineering Group Inc. 1995

Table F.4.5.1 Estimated Past Practice and Projected Future Waste Disposed Quantities Compared to Tank Waste Quantity

Waste Source / Contaminant	Tc-99 (Ci)	I-129 (Ci)	C-14 (Ci)	Uranium [3] (Ci)	Nitrate (Metric tons)
Waste Tanks (177)	32,700	16	5,330	480	103,500
Estimated Past Practice Liquid Disposal [1]	960	9	[2]	137	50,000
Estimated Past Practice Solid Waste Disposal [1]	[2]	[2]	6,300	560	[2]
Projected Low-Level Waste Disposal in 200 West Burial Grounds [4]	0.0025 [5] 1.6 [6]	0.014 [5] 0.17 [6]	1.3E-04 [5] 5.26 [6]	3.6E-04 [5] 206 [6]	[2]
Projected Low-Level Waste Disposal in ERDF [7] Burial Grounds	0.2	3.0E-05	118.7	115 [9]	[2]
Projected Low-Level Waste Disposal in US Ecology Burial Grounds [8]	65.5	5.77	3880.7	10,938	

Notes:
[1] Source: Wodrich 1991
[2] Indicates contaminant not provided in inventory
[3] Isotopic distribution of uranium is unknown and assumed to consist of U-238
[4] Source: Wood et al. 1995
[5] Waste disposed of as a Category 1 waste. Disposal does not include a cap.
[6] Waste disposed of as a Category 3 waste. Disposal includes a cap.
[7] Source: Wood et al. 1995a
[8] Source: Jacobs 1996
[9] Reported in Wood et al. 1995a as uranium. Assumed here to be U-238.

Table F.4.5.2 Potential Maximum Groundwater Contaminant Concentrations Associated with Solid Waste Disposal in the Central Plateau

Contaminant/ Waste Source	Tc-99 mg/L (pCi/L)	I-129 mg/L (pCi/L)	C-14 mg/L (pCi/L)	Uranium [3] mg/L (pCi/L)
Estimated Past Practice Solid Waste Disposal [1]	[2]	[2]	1.42E-06 (6,300)	1.67E+00 (560)
Projected Low-Level Waste Disposal in 200 West Burial Grounds [4]	1.54E-07 [5] 9.98E-05 [6] (2.6 [5] 1686 [6])	3.86E-07 [5] 4.72E-06 [6] (0.068 [5] 0.83 [6])	1.91E-11 [5] 7.62E-07 [6] (0.085 [5] 3392 [6])	6.25E-07 [5] 3.39E-01 [6] (2.1E-04 [5] 114 [6])
Projected Low-Level Waste Disposal in ERDF [7] Burial Grounds	4.37E-07 (7.38)	5.56E-09 (9.78E-04)	5.01E-08 (223)	5.06E-04 (0.17 [9])
Projected Low-Level Waste Disposal in US Ecology Burial Grounds [8]	1.95E-07 (3.3)	3.83E-08 (6.74E-03)	1.22E-09 (5.41)	1.01E-03 (3.4E-01)

Notes:
[1] Source: Wodrich 1991
[2] Indicates not provided in inventory.
[3] Isotopic distribution of uranium is unknown and assumed to consist of U-238.
[4] Source: Wood et al. 1995
[5] Waste disposed of as a Category 1 waste. Disposal does not include a cap.
[6] Waste disposed of as a Category 3 waste. Disposal includes a cap.
[7] Source: Wood et al. 1995a
[8] Source: Jacobs 1996
[9] Reported in Wood et al 1995a as uranium. Assumed here to be U-238.

9613409.1612

APPENDIX F
REFERENCES

40 CFR 141. National Primary Drinking Water Regulations. U.S. Environmental Protection Agency. Code of Federal Regulations, as amended. 1995.

DOE 1994h. Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility. DOE/RL-93-99, Rev. 1. U.S. Department of Energy. Richland, Washington. October 1994.

DOE 1993a. 200 East Groundwater Aggregate Area Management Study Report. DOE/RL-92-19, Rev. 0. U.S. Department of Energy. Richland, Washington. 1993.

DOE 1993b. 200 West Groundwater Aggregate Area Management Study Report. DOE/RL-92-16, Rev. 0. U.S. Department of Energy. Richland, Washington. 1993.

DOE 1987. Final Environmental Impact Statement. Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes Hanford Site Richland, Washington. DOE/EIS-0113. U.S. Department of Energy. Washington, D.C. December 1987.

Domenico 1985. Domenico, P.A. and G.A. Robbins. A New Method of Contaminant Plume Analysis. Groundwater, Vol. 23. No. 4. 1985

Dresel et al. 1995. Dresel, P. E., and P. D. Thorne, S.P. Luttrell, B.M. Gillespie, W.D. Webber, J. K. Merz, J. T. Rieger, M.A. Chamness, S.K. Wurstner, and B.E. Optiz. Hanford Site Groundwater Monitoring for 1994. PNL-10698. Pacific Northwest National Laboratory. August 1995.

Dresel et al. 1994. Dresel, P.E., S.P. Luttrell, J.C. Evans, W.D. Webber, P.D. Thorne, M.A. Chamnes, B.M. Gillespie, B.E. Opitz, J.T. Rieger, and J.K. Merz. Hanford Site Groundwater Monitoring for 1993. PNL-10082. Pacific Northwest National Laboratory, Richland Washington. 1994.

Droppo et al. 1991. Droppo, J.G., Jr., J.W. Buck, J.S. Wilbur,. D.L. Strenge, M.D. Freshley. Single-Shell Tank Constituent Rankings for Use in Preparing Waste Characterization Plans. Pacific Northwest National Laboratory. Richland, Washington. June 1991.

Ecology et al. 1994. Hanford Federal Facility Agreement and Consent Order, as amended. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. Olympia, Washington. January 1994.

Fetter 1994. Fetter, C.B., Applied Hydrogeology, Third ed. Section 5.14, Steady Flow in an Unconfined Aquifer. MacMillan Publishing Company. 1994.

Freeze-Cherry 1979. Freeze, R.A. and John A. Cherry. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 1979.

Gee et al. 1992. Gee, G.W., M.L. Rockhold, M.J. Fayer, and M.D. Campbell. Variations in Recharge at the Hanford Site. Northwest Science, Vol. 66, No. 4. 1992.

Gee 1987. Gee, G.W., Recharge at the Hanford Site: Status Report. PNL-6403. Pacific Northwest National Laboratory. Richland, Washington. November 1987.

Huyakorn et al. 1991. Huyakorn, P.S., J.B. Kool, and Y.S. Wu. VAM2D - Variably Saturated Analysis Model in Two Dimensions, version 5.2 With Hysteresis and Chained Decay Transport, Documentation and User's Guide (NUREG/CR-5352). HydroGeoLogic, Inc. Herndon, Virginia. October 1991.

Huyakorn et al. 1985. Huyakorn, P.S., J.W. Mercer, and D.S. Ward. Finite Element Matrix and Mass Balance Computational Schemes for Transport in Variably Saturated Porous Media. Water Resources Res. Vol. 21, No. 3: 346-358. 1985.

Huyakorn et al. 1984. Huyakorn, P.S., S.D. Thomas, and B.M. Thompson. Techniques For Making Finite Elements Competitive in Modeling Flow in Variably Saturated Porous Media. Water Resources Res. Vol 20, No. 8: 1099-1115. 1984.

Jacobs 1996. Engineering Calculations for the Tank Waste Remediation System Environmental Impact Statement. Jacobs Engineering Group Inc. Kennewick, Washington. April 1996.

Kaplan et al. 1995. Kaplan D.J., R.J. Serne, and M.G. Piepho. Geochemical Factors Affecting Radionuclide Transport Through Near and Far Fields at a Low-Level Waste Disposal Site. PNL-10379. Pacific Northwest National Laboratory. Richland, Washington. March 1995.

Kaplan et al. 1994. Kaplan, D.J., R.J. Serne, and M.G. Piepho. Geochemical Factors Affecting Radionuclide Transport Through Near and Far Fields at a Low-Level Waste Disposal Site. Pacific Northwest National Laboratory. Richland, Washington. December 1994.

Kincaid et al. 1995. Kincaid, C.T., J.W. Shade, G.A. Whyatt, M.G. Piepho, K. Rhoads, J.A. Voogd, J.H. Westsik, Jr., M.D. Freshley, K.A. Blanchard, and B.G. Lauzon. Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford. WHC-SD-WM-EE-004, Rev. 1. Westinghouse Hanford Company. Richland, Washington. May 1995.

9613409.1613

Kincaid et al. 1993. Kincaid, C.T., J.W. Shade, G.A. Whyatt, M.G. Piepho, K. Rhoads, J.A. Voogd, J.H. Westsik, Jr., M.D. Freshley, K.A. Blanchard, and B.G. Lauzon. Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford. WHC-SD-WM-EE-004, Rev. 0. Westinghouse Hanford Company. Richland, Washington. October 1993.

Meyers 1978. Meyers, D.A. Environmental Monitoring Report on the Status of Groundwater Beneath the Hanford Site January-December 1977. PNL-2624. Pacific Northwest National Laboratory. Richland, Washington. April 1978.

NRC 1994. Branch Technical Position on Performance Assessment for Low-Level Waste Disposal Facilities (Draft). Low-Level Waste Management Branch. U.S. Nuclear Regulatory Commission. Washington D.C. January 1994.

National Research Council 1995. Technical Bases for Yucca Mountain Standards. National Research Council. National Academy Press. Washington, D.C. 1995.

Pelton-Davis 1995. M. Pelton and J. Davis. Database Manager and Health Physicist, Advanced Sciences Inc. Personal Communication. Richland, Washington. January 1995.

Reidel et al. 1992. Reidel, S.P., K. A. Lindsay, and K. R. Fecht. Field Trip Guide for the Hanford Site. WHC-MR-0495. Westinghouse Hanford Company. Richland, Washington. 1995.

Rockhold et al. 1990. Rockhold, M.L., M.J. Fayer, G.W. Gee, and M.J. Kanyid. Natural Groundwater Recharge and Water Balance at the Hanford Site. PNL-7215. Pacific Northwest National Laboratory. January 1990.

Schramke et al. 1994. Schramke, J.A., C.S. Glantz, and G.R. Holdren. Hanford Site Environmental Setting Data Developed for the Unit Risk Factor Methodology in Support of the Programmatic Environmental Impact Statement (PEIS). PNL-9801. Pacific Northwest National Laboratory. Richland, Washington. May 1994.

Serne-Wood 1990. Serne, R. J., and Wood, M. I. Hanford Waste-Form Release and Sediment Interaction: A Status Report with Rationale and Recommendations for Additional Studies. PNL-7927. Pacific Northwest National Laboratory. Richland, Washington. May 1990.

Shade et al. 1995. Shade, J.W., J.M. Conner, D.W. Hendrickson, W.J. Powell, and R.A. Watrous. Preliminary Low-Level Waste Feed Definition Guidance Low-Level Waste Pretreatment Interface. WHC-SD-WM-RD-052, Rev. 0. Westinghouse Hanford Company. February 1995.

Tallman et al. 1979. Tallman, A.M., K.R. Fecht, M.C. Marratt, and G.V. Last. Geology of the Separations Areas, Hanford Site, South-Central Washington. RHO-ST-23. Rockwell Hanford Operations. Richland, Washington. 1979.

Thorne-Chamness 1992. Thorne, P.D. and M.A. Chamness. Status Report on the Development of a Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System. PNL-8332. Pacific Northwest National Laboratory. Richland, Washington. 1992.

Thorne-Newcomer 1992. Thorne, P.D. and D.R. Newcomer. Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System. PNL-8337. Pacific Northwest National Laboratory. Richland, Washington. November 1992.

Walton 1985. Walton, W. C. Practical Aspects of Groundwater Modeling. National Water Well Association. Worthington, Ohio. 1985.

WHC 1995c. No Separations Data Package for the Tank Waste Remediation System Environmental Impact Statement. WHC-SD-WM-EV-103, Rev. 0. Westinghouse Hanford Company. Richland, Washington. July 1995.

WHC 1995j. Tri-Party Agreement Alternative Engineering Data Package for the Tank Waste Remediation System Environmental Impact Statement. Westinghouse Hanford Company. Tank Characterization Reference Guide. WHC-SD-WM-TI-648, Rev. 0. Westinghouse Hanford Company. Richland, Washington. September 1995.

WHC 1994f. Tank Characterization Reference Guide. WHC-SD-WM-TI-648, Rev. 0. Westinghouse Hanford Company. Richland, Washington. September 1994.

Whelan 1994. Unit Environmental Transport Assessment of Contaminants from Hanford's Past-Practice Waste Sites. Pacific Northwest National Laboratory. Richland, Washington. June 1994.

Wodrich 1991. Wodrich, D. Historical Perspective of Radioactivity Contaminated Liquid and Solid Wastes Discharged or Buried in the Ground at Hanford. TRAC-0151-VA. Westinghouse Hanford Company. Richland, Washington. April 1991.

Wood et al. 1995. Wood, M.I., R.K. Khaleel, P.D. Rittman, A.H. Lu, S. Finfrock, R.J. Serne, and K.J. Cantrell. Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds. WHC-EP-0645. Westinghouse Hanford Company. Richland, Washington. June 1995.

Wood et al. 1995a. Wood, M.I., R.K. Khaleel, P.D. Rittmann, A.H. Lu, S.H. Finfrock, and T.H. DeLorenzo. Environmental Restoration Disposal Facility Performance Assessment. BHI-00169, Rev. 00. Bechtel Hanford, Inc. Richland, Washington. August 1995.

Woodruff-Hanf 1993. Woodruff, R.K., and R.W. Hanf. Hanford Site Environmental Report for Calendar Year 1992. PNL-8682. Pacific Northwest National Laboratory. Richland, Washington. June 1993.

9613409.1614

Wurstner-Devary 1993. Wurstner, S.K. and J.L. Devary. Hanford Site Ground-Water Model: Geographic Information System Linkages and Model Enhancements, FY 1993. PNL-8991. Pacific Northwest National Laboratory. Richland, Washington. December 1993.

van Genuchten-Leij 1989. van Genuchten, M. Th, F.J. Leij, and L.J. Lund, editors. Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils. Proceedings of the International Workshop on Indirect Methods for Estimating the Hydraulic Properties of Unsaturated Soils. University of California. Riverside, California. October 11-13, 1989.

This page intentionally left blank.