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Engineering Evaluation/Conceptual Plan for the 200-ZP-1 Operable Unit Interim Remedial Measure

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1.0 INTRODUCTION

This report presents an engineering evaluation and conceptual plan for an Interim Remedial Measure (IRM) to address the organic contamination groundwater plume [primarily carbon tetrachloride (CCl_4)] in the 200 West Area of the Hanford Site. This report provides the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) with information regarding the need, and potentially achievable objectives and goals for an IRM, and evaluates alternatives to reduce the mobility, toxicity, and/or volume of CCl_4 and other organics in the groundwater. This report is intended to aid EPA and Ecology in selecting a preferred alternative for implementing an IRM.

The proposed purpose of an IRM would be to prevent, or at least minimize, further migration of organic contamination in 200 West Area groundwater. To achieve this purpose, the IRM must stabilize and reduce contaminant concentrations in the high-concentration zone ("hot-spot") of the 200 West organic contaminant plume. An associated goal would be to contain the contaminants within the high concentration zone. These objectives and goals are consistent with EPA guidance and with the *Hanford Sitewide Groundwater Remediation Strategy* document (DOE-RL 1994).

2.0 SITE CHARACTERIZATION

2.1 Background

The 200 Areas of the Hanford Site are included on the EPA National Priorities List (NPL) under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). The Hanford Site, established in 1943, was originally designed, built, and operated to produce plutonium for nuclear weapons using production reactors and chemical reprocessing plants. Operations in the 200 Areas involved mainly separation of special nuclear materials from irradiated nuclear fuel and related chemical and fuel processing and waste management.

In general, chemical and low-level radioactive liquid wastes associated with these operations were disposed to the ground via infiltration structures such as cribs, ponds, ditches, and injection wells resulting in soil and groundwater contamination.

An aggregate area management study program was implemented under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement, Ecology et al. 1989) to assess soil and groundwater contamination in the 200 Areas. Based on the findings of the studies, an overall remedial action strategy for the 200 Areas was developed for potential interim remedial actions to expedite the cleanup process. The 200 West Groundwater Aggregate Area Management Study Report (AAMSR) (DOE-RL 1992) summarized information about groundwater contaminants beneath the 200 West Area and provided recommendations for prioritizing, investigating, and remediating various contaminants and plumes. The 200 West Groundwater AAMSR provided a detailed description of the organic contaminant plumes in the 200 West Area, including CCl_4, chloroform, and trichloroethylene (TCE). This engineering evaluation report evaluates alternatives for taking interim remedial actions to address the organic contaminant plume.

2.2 Extent of Contamination

Approximately 3.4 million gallons of wastewater, including 1 to 2 million pounds of liquid CCl_4 from plutonium refining operations, were discharged to the soil column between 1955 and 1973 from four known sources. The areal extent of the CCl_4 groundwater plume (Figure 1) currently covers 4.2 mi^2 and contains at least 9,700 lb of dissolved CCl_4. The areal extent of the smaller plumes of organic contamination of TCE and chloroform are 0.25 mi^2 and 1.2 mi^2, respectively (Figures 2 and 3). Estimated quantities of TCE and chloroform in the groundwater are 68 lb and 0.3 lb (DOE-RL 1994).

Subsurface observations coupled with computer simulations of the major source of CCl_4 (216-Z-9 Trench) suggest that a major fraction of the residual and/or free phase CCl_4 is retained in the soil column above the water table, and that slow but continuous drainage persists from the soil column or vadose zone into the groundwater.

A combination of this long-term drainage and/or dissolution of a residual liquid CCl_4 phase in the saturated zone are postulated to be the major contributors to a continuing source of groundwater contamination. Alternative sources include preferential pathways involving older, unsealed wells and interaction of gas phase CCl_4 with the groundwater.

The portion of CCl_4 dissolved in groundwater spreads radially due to the location of the source(s) near the center of a major groundwater mound system beneath the 200 West Area. The "apparent" time-averaged rate of movement of the CCl_4 plume is about 1 ft/day. The rate of movement in the future should be slower due to declining hydraulic gradients as discharges to the adjacent soil column cease.

Figure 1. Concentration Isopleths for the Carbon Tetrachloride Plume in the 200 West Area. The Hashured Zone is the High-Concentration Area (>2,000 ppb).

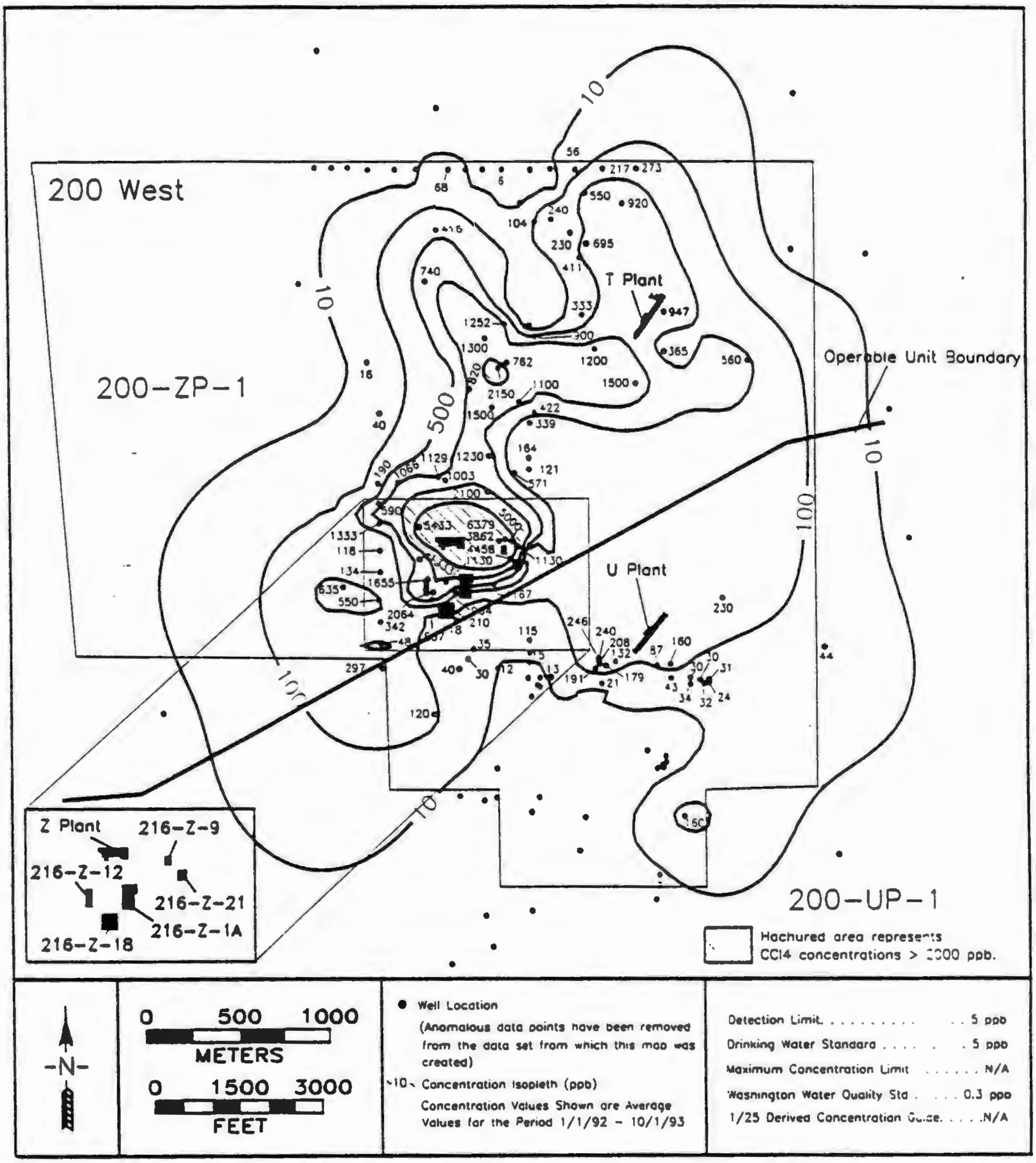


Figure 2. Concentration Isopleths for the Trichloroethylene Plume in the 200 West Area.

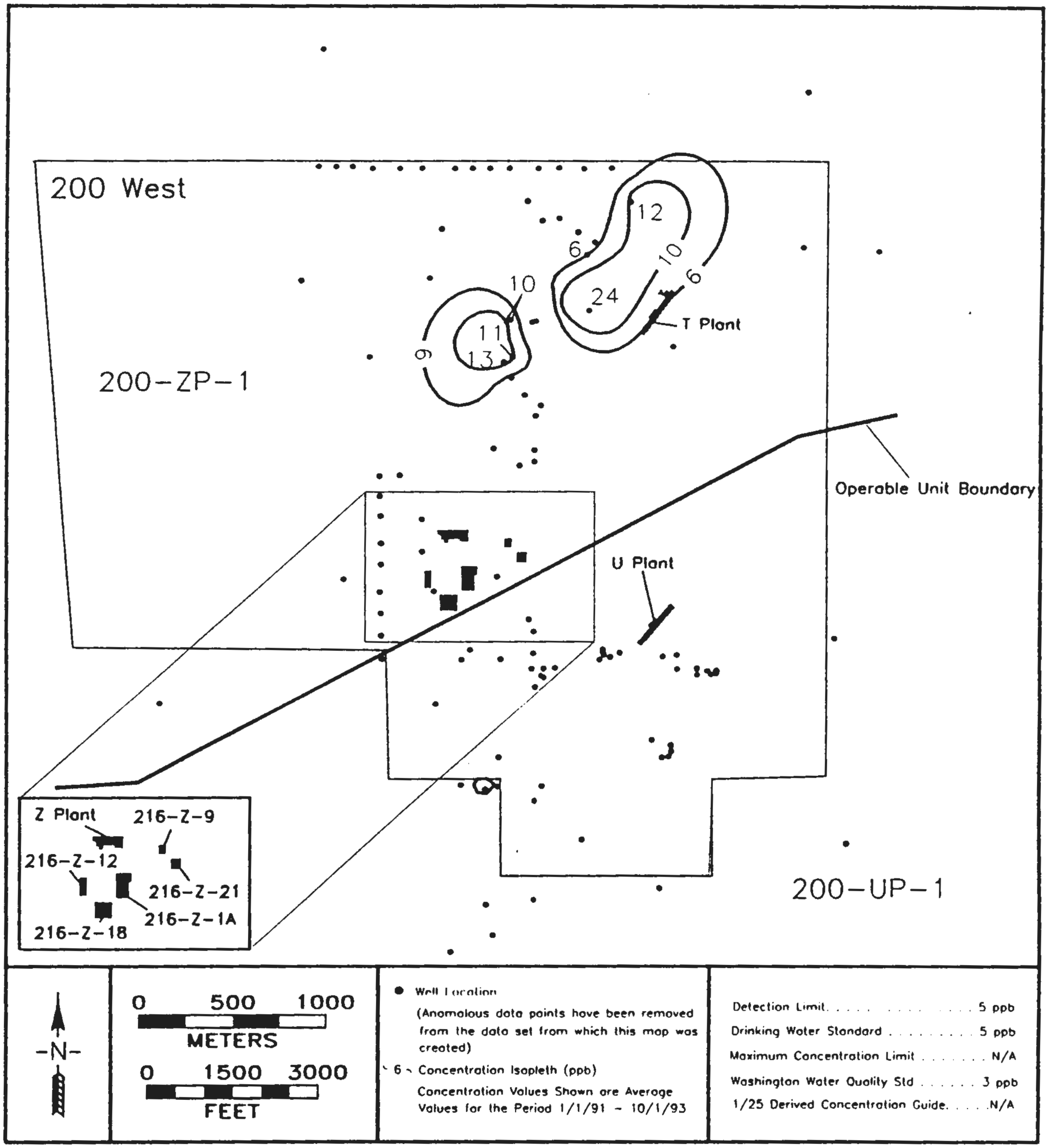
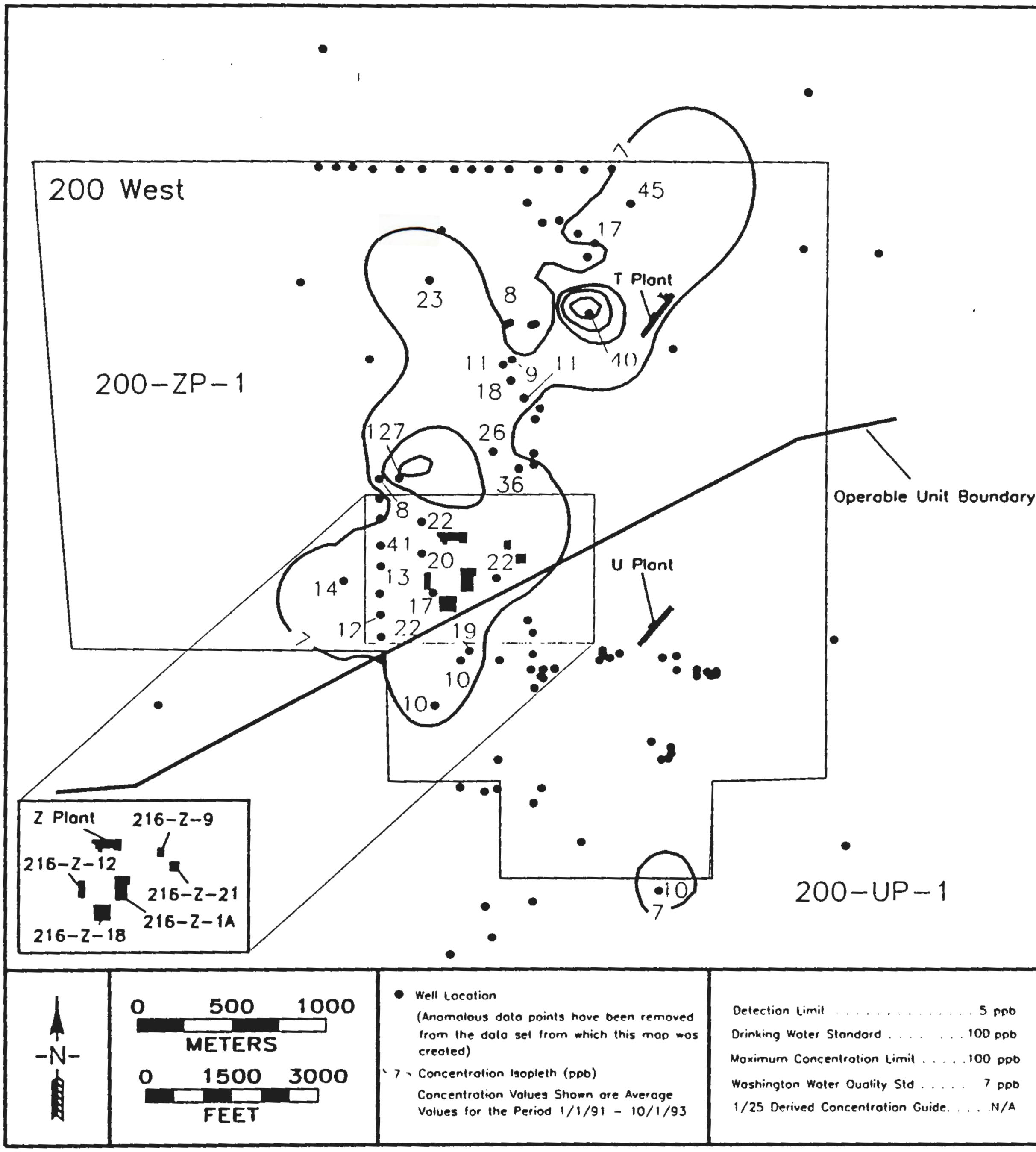


Figure 3. Concentration Isopleths for the Chloroform Plume in the 200 West Area.



Adsorption, or the extent of interaction between CCl_4 dissolved in groundwater and the aquifer sediments, will have a significant influence on the total quantity of organic contaminant stored or present in the aquifer and the time needed to remediate the aquifer. While very little site-specific data exist, there is some indication that CCl_4 is slightly adsorbed by Hanford sediments (Rohay 1994).

2.3 Related Actions

Other related actions are occurring or have been proposed at or near the 200-ZP-1 Operable Unit to address the presence of organic contamination in the soil and groundwater.

Pursuant to an Action Memorandum issued by EPA and Ecology in 1992, an expedited response action is being undertaken at the 200-ZP-2 Operable Unit to remove vapor phase CCl_4 from 200 West Area soils by means of a soil vapor extraction system (SVE). The stated purpose of this SVE action is to mitigate the threat to site workers, public health, and the environment caused by the migration of CCl_4 vapors through the soil column and into the groundwater. It is expected that CCl_4 removed by the SVE system would then notbe available for transport to groundwater. The SVE system is expected to continue operation until a final remedy is selected. In addition, innovative technologies are being tested in the 200-ZP-2 Operable Unit to determine efficacy in mitigating CCl_4 contamination.

A pilot-scale pump-and-treat system is currently operating at 200-ZP-1 as a treatability test under authority of the Tri-Party Agreement (change control form M-13-93-03). The scope and purpose of this treatability test were set forth in the treatability test plan (DOE/RL-94-12), which is available in the administrative record. This test is evaluating treatment of contaminated groundwater in the 200 West Area with liquid phase granular activated carbon (GAC).

Several additional tasks have been proposed to mitigate contaminant plume migration, prevent additional portions of the aquifer from being contaminated, and provide baseline chemistry data for evaluating the effects of remedial operations at the operable units. These tasks will include the following:

- Eliminating as many surface discharges as possible to the soil column. Reducing discharges will decrease or eliminate downward hydraulic forces that may facilitate transport of existing contamination through the vadose zone to the water table (particularly for discharges near the 216-Z-9 Trench).

- Conducting an assessment of the integrity of existing wells and identifying wells that may be fostering vertical movement of contamination. At least three deep wells have already been identified that may fit into this category: 299-W14-9, 299-W15-5, and 299-W15-6 (Johnson 1993). An efficient use of resources would be to remediate these wells to serve as monitoring points in support of remedial operations.

- Continue monitoring plume concentrations, trends, and horizontal distribution of contaminants in accordance with the current groundwater sampling program. At this time, the number of deep wells suitable for evaluating the vertical distribution of contamination is limited.

3.0 IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES

Under EPA guidance, appropriate objectives for interim actions include site stabilization, prevention of further degradation, and significant rapid risk reduction (Interim Final Guidance on Preparing Superfund Decision Documents, OSWER Directive 9355.3-02, June 1989). For 200-ZP-1, the proposed site-specific interim remedial objectives are to minimize the migration of groundwater beyond the high-concentration areas of the plume near the Z Cribs and to remove CCl_4 from the unconfined aquifer. It is estimated that greater than 50% of the CCl_4 dissolved in the groundwater is located in the vicinity of the Z Cribs (DOE-RL 1994). Minimizing migration of this highly contaminated groundwater will help stabilize the site, prevent further degradation of groundwater quality outside of the source area, and mitigate future risks to human health and the environment. Specific interim remedial objectives include the following:

- Stabilizing the migration of CCl_4 downgradient from the Z Cribs source area
- Removing CCl_4 contamination and reducing concentrations in the unconfined aquifer
- Evaluating the source(s) of CCl_4 in the 216-Z-9 Crib area
- Optimizing cost effectiveness
- Providing data and information needed to select a final remedy for this operable unit.

These proposed remedial objectives are consistent with the proposed overall strategy for groundwater remediation at the Hanford Site (DOE-RL 1994) and with the recommendations of the *200 West Groundwater Aggregate Area Management Study Report* (DOE-RL 1993). The *Hanford Sitewide Groundwater Remediation Strategy* (DOE-RL 1994) for the 200 Areas states that the primary groundwater remedial action should be directed at controlling migration of contaminants in groundwater beyond the central plateau. Specifically, for CCl_4, these actions should focus on the highly contaminated portions of the plume and source areas.

4.0 IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

The 200 West Groundwater AAMSR provided an initial feasibility study that screened technologies for groundwater remediation in the 200 West Area and developed preliminary action alternatives. For interim actions regarding the CCl_4 plume, these alternatives include no action, institutional control, treatment at the point of use or discharge, physical containment, in situ treatment, and pump and treat.

The no action alternative is retained for further evaluation as required by the National Contingency Plan (NCP) [40 CFR 300-68(f)(l)(v)]. The alternatives of institutional control and treatment at the point of use or discharge are not retained for further evaluation because they would not meet the interim remedial objectives of preventing further degradation of 200 Area groundwater or removing contamination from the aquifer.

The alternative of physical containment is not retained for further evaluation because it is not considered implementable in the 200 West Area due to the great depth to groundwater (180 to 425 ft below ground surface). In addition, this alternative is not retained because it would not provide any removal of contamination from the aquifer, would be difficult to maintain, and would be very expensive.

The in situ treatment option is not retained for further evaluation at this time as an interim measure because the implementability is uncertain. In situ technologies are currently in the development stage and their success is dependent on geologic conditions and site-specific chemical and biological background conditions. Extensive information regarding subsurface mixing, effects of background conditions, hazards associated with byproduct production, and other failure/success modes is needed before in situ technology can be recommended and implemented successfully. The effectiveness and implementability of in situ technologies to the range of chemicals and site conditions at the Hanford Site are currently the subject of research and development through innovative technology development programs. The use of in situ technology may be considered for use at 200-ZP-1 in the future.

The alternative of pump and treat is retained for further evaluation because it is considered to be readily implementable, and may be able to achieve the interim remedial objectives of containment of the concentrated plume and removal and treatment of contaminated groundwater. Several options are possible for disposal of treated effluent water including reinjection within the plume near wells 699-39-79 and 699-40-80 to the west, discharging to a trench in the same area as the proposed injection wells, or going to a permitted surface disposal facility such as the Project W-049H pond. The presence of residual sources of contaminants such as chemicals contained in the vapor phase within the vadose zone or inaccessible pools of DNAPLs can also impede the success of groundwater pump-and-treat operations. Even with these limitations, pump-and-treat technologies are considered the primary proven technology available to contain, remove, and treat contaminants in groundwater.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

CERCLA requires remedial alternatives to be evaluated against nine criteria: (1) overall protection of human health and the environment; (2) compliance with federal and state regulations; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume through treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptance; and (9) community acceptance. Based on the preliminary screening of alternatives in Section 4.0, only the no action and the pump-and-treat alternatives are retained for detailed evaluation. EPA guidance contemplates that such a limited number of alternatives may be considered for purposes of taking interim actions. (EPA 1989)

5.1 Overall Protection

This criteria evaluates whether the alternative achieves adequate overall elimination, reduction, or control of risks to human health and the environment posed by each pathway. It is a summary check that takes into account the other criteria and includes an evaluation of short-term and cross-media impacts.

The no action alternative does not change the overall protection of human health and the environment. The pump-and-treat alternative would remove contaminant mass from the aquifer and contain the high-concentration area of the plumes. Therefore, it will improve overall protection of human health and the environment.

5.2 Compliance with Regulations

Applicable or relevant and appropriate requirements (ARARs) in federal or state law must be met or waived for remedial actions. Potential ARARs were identified in the AAMSR. The major requirements pertinent to this operable unit are drinking water standards (maximum contaminant levels or MCLs), state effluent discharge standards, solid and hazardous waste designation and management standards, hazardous waste treatment system design standards, and air emission standards.

Simplified numerical predictions indicate that under the no-action alternative, concentrations of CCl_4 might exceed 3,000 ppb if and when the plume reaches the river bank, and up to 4,500 ppb could occur when the plume passes through Gable Gap in the vicinity of a proposed 200 Area compliance boundary. Travel time to the river is estimated to be more than 100 years (Golder 1991). Numerous assumptions are incorporated into these predictions that remain to be verified.

The primary ARAR issue associated with the pump-and-treat alternative would involve the return of treated groundwater to the aquifer. It is anticipated that this effluent may contain constituents above the MCLs. Additionally, the effluent would be considered a hazardous waste pursuant to the *Resource Conservation and Recovery Act* (RCRA) due to the presence of CCl_4 from a hazardous waste source listed in 40 Code of Federal Regulations (CFR) 261.31 and Washington Administrative Code (WAC) 173-303-9904 as well as the potential presence of hazardous constituents (including CCl_4) at concentrations in excess of the hazardous waste toxicity characteristic limits of 40 CFR 261.24 and WAC 173-303-090(9). Other significant regulatory issues concern design and operating standards for the pump-and-treat system and compliance with air emission standards.

5.2.1 Effluent Discharges

Three discharge options were considered for treated effluent for the pump-and-treat alternative: (1) discharge into an injection well located in the 200-ZP-1 contaminated plume; (2) discharge into a trench located above the 200-ZP-1 contaminated plume; or (3) discharge into the Treated Effluent Disposal Facility (TEDF) associated with the W-049 project.

5.2.1.1 Discharge Into an Injection Well Within the Contaminated Plume. For non-CERCLA activities, discharge of hazardous or radioactive waste into injection wells is prohibited by both Federal law pursuant to Section 3020(a) of RCRA and 40 CFR 144.13(a). At CERCLA sites, however, RCRA Section 3020(b) allows such discharge *provided* that the reinjection: (1) is done pursuant to CERCLA or RCRA corrective action authority; (2) includes treatment of contaminated water to substantially reduce hazardous constituents prior to reinjection; and (3) the CERCLA or RCRA effort will, upon completion, be sufficient to protect human health and the environment. Based upon regulator concurrence, reinjection of treated effluent via a well within the 200-ZP-1 contaminated plume would be allowable pursuant to RCRA Section 3020(b). In a similar manner, and notwithstanding the general prohibition of 40 CFR 144.13(a), 40 CFR 144.13(c) allows injection of treated groundwater into the same formation from which it was drawn when such actions are done pursuant to CERCLA or RCRA authority.

State underground injection control standards are promulgated at WAC 173-218. Unlike the Federal counterpart, the state regulation provides no exemption for hazardous or radioactive waste discharges during from CERCLA actions. The pump-and-treat alternative may not meet the state discharge standard (WAC 173-218). This alternative, however, is being evaluated as an interim action, and will become part of a total remedial action that will attain federal and state ARARs.

Irrespective of hazardous or radioactive waste considerations, Federal regulations at 40 CFR 144.12(a) prohibit discharge of any fluid into an injection well if such injection could cause an underground source of drinking water (USDW) to exceed any of the MCLs. As noted previously, the 200-ZP-1 treated effluent is expected to exceed the MCLs. Additionally, the receiving aquifer meets the definition of an USDW. However, reinjection of the treated effluent is not viewed as a discharge that is prohibited pursuant to 40 CFR 144.12(a) so long as the action is undertaken as a part of a continuing groundwater remediation effort. In discussing compliance with ARARs in the preamble to the CERCLA NCP, EPA acknowledged that "chemical-specific ARARs used as remediation goals, such as MCLs as ARARs for ground water remediation, cannot be attained during implementation." (See 55 *Federal Register* 8755.) In such cases, EPA "recognizes that ARARs that are used to determine final remediation levels apply only at the completion of the action." This evaluation is relevant to the 200-ZP-1 pump-and-treat effort. Inasmuch as this action is an ongoing remediation effort, cleanup standards such as MCLs are considered ARARs to be met at completion of the activity. Based on this analysis, ongoing discharge of treated effluent into the 200-ZP-1 contaminated plume during the course of the remediation activity is acceptable, even if the discharge contains contaminants in concentrations in excess of the MCLs.

5.2.1.2 Discharge into a Trench Above the Plume. Absent CERCLA waivers, use of a trench to discharge hazardous waste would be prohibited by a variety of ARARs. Unlined liquid disposal trenches do not fit into any category of RCRA units. RCRA Section 3004(o) prohibits use of unlined trenches in the manner under consideration. 40 CFR 268.30 would prohibit such discharge unless the fluid has been treated such that the concentration of CCl_4 does not exceed the 0.057 mg/L limit established by the land disposal restriction regulations. From a State perspective, discharge of hazardous waste into an unlined trench would be prohibited pursuant to WAC 173-303-650 and -140. Even in the absence of a hazardous waste, effluent discharge into a trench would be prohibited by WAC 173-216 unless the solution had been subjected to "all known, available, and reasonable methods of prevention, control, and treatment." Additional considerations that make the trench disposal option untenable include issues relating to the determination that such a discharge would be protective of human health and the environment. Included in this category would be regulatory concerns regarding possible air emissions resulting from volatilization of organic constituents and the potential for mobilizing hazardous constituents currently held in the soil column. For these reasons, this discharge option is not retained for further consideration at this time.

5.2.1.3 Discharge into the Treated Effluent Disposal Facility (TEDF). As currently planned, the TEDF is intended to receive discharges of liquid effluents generated via operations occurring in U.S. Department of Energy facilities in the 200 Areas. These effluents will consist primarily of relatively clean process streams such as cooling water and steam condensate. Based upon evaluations to date, these streams are not designated as hazardous waste pursuant to RCRA.

The TEDF will be located east of B Pond in the 200 East Area. The B Pond area has been designated a "RCRA Past Practice" (RPP) area in the Tri-Party Agreement; however, the actual TEDF location is outside the boundary of an operable unit with a discharge that is well outside the 200 West Area CCl_4 groundwater plume. These factors make discharge of the treated effluent to TEDF infeasible because disposal of the 200-ZP-1 effluent to TEDF would constitute an offsite CERCLA action. Offsite CERCLA actions must comply with all applicable standards; CERCLA waivers cannot be used for offsite actions. Effluent disposal via the TEDF poses the same regulatory concerns as discharge into a trench located above the 200-ZP-1 plume (discussed above) with the added issue of discharge of contaminated effluent outside the contaminated plume. For these reasons, this discharge option is not retained for further consideration at this time.

5.2.2 System Design and Operating Standards

The pump-and-treat alternative will treat a RCRA hazardous waste. Therefore, substantive RCRA and WAC 173-303 standards will apply to design and operation of the system.

40 CFR 264 Subpart J and WAC 173-303-640 require secondary containment systems for tanks and ancillary equipment (e.g., pumps, piping, valves). As currently configured, the proposed pump-and-treat system does not meet these provisions. In lieu of the 40 CFR 264 Subpart J/WAC 173-303-640 standards, the temporary units (TU) provisions of 40 CFR 264.553/WAC 173-303-646(7) may be applied to the pump-and-treat system for the initial year of operation. Following the initial year of operation, the TU provisions may be invoked for a second year provided that (1) continued operation will not pose a threat to human health and the environment and (2) continued operation is necessary to ensure timely and efficient implementation of remedial actions.

The TU regulations were created to allow tank systems or containers used in remediation activities to comply with alternative design, operating, or closure standards that are protective of human health and the environment. In the proposed rule the EPA stated that, due to the shorter duration of operation, TUs may not need to comply with the secondary containment requirements applicable to typical RCRA treatment, storage, or disposal tank systems. TUs must be located within the facility boundary and may only be used for remediation wastes. When secondary containment is not provided, the pump-and-treat system would need to meet these TU criteria, or the secondary containment requirement would have to be waived.

5.2.3 Air Emissions

Under 40 CFR Part 61, Subpart H and WAC 246-247, radionuclide airborne emissions from all combined operations at the Hanford Site may not exceed 10 mrem/year effective dose equivalent to the hypothetical offsite maximally exposed individual. WAC 173-460 establishes acceptable source impact levels for more than 500 carcinogenic and acutely toxic air pollutants.

The no action alternative would not be subject to air emission requirements. The radionuclide emission requirements would apply to all fugitive, diffuse, and point source air emissions of radionuclides generated by the pump-and-treat alternative. If the pump-and-treat alternative generated an increase of toxic air pollutants to the atmosphere above the small quantity emission rates, implementation of Best Available Control Technology for Toxics (T-BACT) would be required. If radionuclides exist in the groundwater and emissions do not exceed small quantity emission rates, Reasonably Available Control Technology would be required at a minimum. The pump-and-treat alternative proposes to use GAC to treat the air stream. The GAC should adequately control the expected emissions from the treatment system, and would therefore be considered T-BACT for the proposed operation.

5.3 Long-Term Effectiveness

The long-term effectiveness and permanence criteria assesses whether the alternatives leave a risk after the conclusion of remedial activities. The no-action alternative would effectively reduce risk in the very long term through natural attenuation; however, the time necessary to achieve this risk reduction is many hundreds of years. Until natural attenuation is achieved, the risk to human health and the environment would likely increase as the plume migrated out from the central area. The pump-and-treat alternative would not, by itself, achieve long-term effectiveness and permanence for the entire plume. However, removal of contaminants would provide some long-term and permanent reduction in risk.

Containment of the concentrated plume will prevent increased risks from plume migration. Pump and treat is also consistent with potential final remedies and could improve the potential for final remedies to achieve long-term effectiveness and permanence.

5.4 Reduction of Toxicity, Mobility, or Volume

The reduction of toxicity, mobility, or volume through treatment criteria assesses whether the alternatives permanently and significantly reduce the hazard posed by the site by destroying contaminants, reducing the quantity of contaminants, or irreversibly reducing the mobility of the contaminants. The no action alternative provides no immediate reduction of toxicity, mobility, or volume through treatment; such reduction would only occur over a very long period of time through natural attenuation. The pump-and-treat alternative would provide immediate reduction of the volume of contaminants in the aquifer and would treat the extracted groundwater to remove such contaminants, thereby reducing the toxicity of the groundwater in the vicinity of the concentrated plume.

5.5 Short-Term Effectiveness

The short-term effectiveness criteria assesses whether the alternative provides adequate protection to human health and the environment during the remedial action, and how long it will take for the action to achieve the established objectives. Because the groundwater in the 200 West Area is not currently used as a source of drinking water, there is no immediate risk to human health. However, under the no action alternative, the plume will continue to migrate, creating a threat to human health and the environment. The time for the no action alternative to achieve restoration of the aquifer to acceptable levels is extremely long. The pump-and-treat alternative would not present a current risk to human health and the environment because it would be implemented in a manner that would be protective of workers and the environment. The pump-and-treat alternative would provide short-term benefits in limiting the migration of the concentrated portion of the plume and potentially shortening the time needed to restore the aquifer to acceptable levels.

5.6 Implementability

The implementability criteria assesses whether the alternatives are technically and administratively feasible. The no action alternative is implementable. A pump-and-treat system could be implemented without administrative difficulty using available technology. It is not certain that the remedial objectives of containment could be achieved; however, screening-level modeling indicates that it is feasible.

5.7 Cost

The cost criteria evaluates whether the alternatives are cost effective. The no action alternative would involve no additional cost.

Cost estimates for the pump-and-treat alternative were prepared based on budget and planning costs, vendor information, and conventional cost-estimating guides. The assumptions for the cost estimates are summarized in Section 6.6 according to fiscal year (FY) and are built on FY 1995 dollars. The total estimated costs for the pump-and-treat alternative through FY 2000 are $23,100,000.

5.8 State Acceptance

The state acceptance criteria evaluates whether the technical and administrative concerns of the state have been addressed. The no action alternative does not meet the concern expressed by the state regarding the continued migration of contaminants in groundwater at the Hanford Site. The pump-and-treat alternative is supported by the State of Washington.

5.9 Community Acceptance

The community acceptance criteria evaluates whether the alternatives address the concerns of the local community. The local community has expressed concern regarding the continued migration of contaminants in groundwater at the Hanford Site. The no action alternative would not address these expressed concerns. The pump-and-treat alternative was first proposed as part of the Fourth Amendment to the Tri-Party Agreement and received favorable public comments. Final community acceptance of the alternative will be evaluated after the public comment period on the 200-ZP-1 Proposed Plan ends.

6.0 PREFERRED INTERIM REMEDIAL ALTERNATIVE

Based on implementability, effectiveness and cost, the preferred interim alternative is to pump and treat the concentrated portion of the plume in a phased manner while evaluating the effectiveness of the method for containment, mass removal, reductions of contaminant concentrations, and the permanence of the remediation. In addition to the phased pump-and-treat system, site investigation and other field activities would be conducted during the IRM to optimize the remedial action and provide data for the final remedy selection.

Three phases of operation are proposed: Phase I consists of a nominal 50 gal/min pilot-scale pump-and-treat system; Phase II involves expansion of the hydraulic and treatment system to 150 gal/min; and a final Phase III entails expansion to a 150 gal/min to 500 gal/min system depending on the effectiveness of the other phases in containing and reducing contaminant mass in the plume. Treated groundwater would be returned to the aquifer within the contaminant plume via injection wells in the western portion of 200 West Area.

The increase in capacity from the 150 gal/min system to the 500 gal/min system would be tied directly to the results of the periodic performance evaluation which will determine the effectiveness and efficiency of the systems. This approach is expected to result in significantly reducing migration of highly contaminated groundwater from the vicinity of the source area (Z Cribs) to the less contaminated portions of the plume.

A secondary objective of this approach will be the removal of CCl_4 from groundwater, reducing the total mass of CCl_4 in the saturated portion of the aquifer. Concentrations may not decrease, however, if a residual dense nonaqueous-phase liquid (DNAPL) source is present. Groundwater extracted from the containment zone would be treated for CCl_4 and other volatile organics using air-stripping technology and vapor-phase GAC. Use of liquid-phase GAC for treating groundwater from the 50 gal/min system is being tested in the treatability test. Use of air stripping and vapor-phase GAC is proposed for the remedial action because it is more cost effective than liquid-phase GAC for this application.

The following sections present the technical basis for the preferred alternative, conceptualization of the wellfield, a description of the treatment system, evaluation of the capture zone, criteria for technical evaluation of performance of the pump-and-treat systems, and additional proposed activities.

6.1 Technical Basis for the Preferred Alternative

The preferred alternative would create a hydraulic containment zone in the area of highest dissolved CCl_4 contamination (greater than the 2,000 ppb isopleth), which is an elliptically shaped area around the sources of CCl_4 contamination (the Z Cribs) (Figure 1). This area is proposed because it is the major source of dissolved contamination to the aquifer, is limited in areal extent, and therefore provides the best opportunity to control local plume migration and reduce contaminant mass. This proposal addresses primarily CCl_4 contamination; however, other organic contaminants are known to be present (i.e., TCE and chloroform). Although this IRM concentrates on CCl_4, any TCE and chloroform removed as incidental contaminants will be treated by the treatment system.

Containment and mass reduction of the entire CCl_4 plume is impracticable with current or next-generation technology. Table 1 illustrates two remedial scenarios: one for the entire plume and a second for the much smaller concentrated portion of the plume. The concentrated portion of the plume is the area where concentrations are greater than 2,000 ppb, and that contains about 50% of the total inventory of dissolved CCl_4 beneath the 200 West Area but only 6% of the total plume area (Rohay and Johnson 1991).

As shown in Table 1, containment and treatment of the concentrated portion requires from 2 to 48 years depending on treatment rate and geochemical adsorption assumptions. Based on a total pumping rate of 100 gal/min, about 10 years would be required for a 90% reduction of currently dissolved CCl_4 in the concentrated portion of the plume. [Although at a total pumping rate of 500 gal/min, this time theoretically could be as short as 2 years, if even a small amount of sorption is assumed (K_d = 0.2), the 100 gal/min pumping time increases to 48 years.]

Remediation time for the concentrated plume stands in stark contrast to remediation time for the entire plume. Estimated remediation times for the entire plume range from a minimum of 35 years (at 500 gal/min) to a maximum of 800 years (at 100 gal/min and assuming the 0.2 retardation factor).

As demonstrated by these two scenarios, even a small retardation factor or change in contaminant distribution can significantly increase the time for remediation. Additionally, these estimations do not consider continuing source(s) of contamination, which could dramatically extend or nullify remediation efforts. Remediation times would change in a linear fashion if the input parameters for the calculation are varied. Table 2 is included to demonstrate that doubling the porosity and the thickness of the contaminated interval will quadruple the remediation time. This illustration points to the need for additional, accurate field data for more reliable estimates of remediation times.

The volumetric calculations in the tables also do not consider the number of wells needed to extract the contaminated groundwater. For example, it would take over 50 wells to intercept just the eastern portion of the 4.2-mi^2 plume, assuming a 300-ft well spacing. For the partial plume, it is estimated that about 10 wells will be needed to contain the concentrated plume (also assuming 300-ft well spacings).

6.2 Wellfield Conceptualization

A treatability test is currently being conducted using two existing wells: one extraction well (299-W18-1) and one injection well (299-W18-4). Initial withdrawal rates at the extraction well are about 35 gal/min. Contaminated groundwater is treated with liquid-phase GAC and then reinjected inside the plume

Table 1. Estimated Time to Remove CCl_4 Contaminated Water
Porosity = 10%, Contaminated Thickness = 50 ft

Options*	Plume Area (ft2)	Quantity Treated (gal)	Estimated Time for 90% Reduction (years)	Estimated No. Wells
Full Plume				
-No Retardation	1.1E+08	9.1E+09	**175 @ 100 gpm** 35 @ 500 gpm	>50
-Retardation	1.1E+08	4.2E+10	**800 @ 100 gpm** 160 @ 500 gpm	
Partial Plume				
-No Retardation	6.5E+06	5.5E+08	**10 @ 100 gpm** 2 @ 500 gpm	10
-Retardation	6.5E+06	2.5E+09	**48 @ 100 gpm** 10 @ 500 gpm	

*Table Assumptions:
1. No CCl4 source continues to contribute to the dissolved plume;
2. 2.3 pore volumes are needed for 90% mass reduction;
3. Number of wells depends on capture zone size, assumed a 300 ft radius;
4. Wells assumed to produce 50 gpm;
5. A retardation factor of 0.2 is assumed (see Appendix A);
6. Adsorption factor is 4.6 times the pore volume;

Note: Partial Plume is 6% of total plume area, but contains about 50% of mass.

Table 2. Estimated Time to Remove CCl_4 Contaminated Water
Porosity = 20%, Contaminated Thickness = 100 ft

Options*	Plume Area (ft2)	Quantity Treated (gal)	Estimated Time for 90% Reduction (years)	Estimated No. Wells
Full Plume				
-No Retardation	1.1E+08	3.6E+10	**700 @ 100 gpm** 140 @ 500 gpm	N/D
-Retardation	1.1E+08	1.7E+11	**3,200 @ 100 gpm** 640 @ 500 gpm	
Partial Plume				
-No Retardation	6.5E+06	2.2E+09	**40 @ 100 gpm** 8 @ 500 gpm	N/D
-Retardation	6.5E+06	1.0E+10	**192 @ 100 gpm** 40 @ 500 gpm	

*Table Assumptions:
1. No CCl4 source continues to contribute to the dissolved plume;
2. 2.3 pore volumes are needed for 90% mass reduction;
3. Number of wells depends on capture zone size, assumed a 300 ft radius;
4. Wells assumed to produce 50 gpm;
5. A retardation factor of 0.2 is assumed (see Appendix A);
6. Adsorption factor is 4.6 times the pore volume;

Note: Partial Plume is 6% of total plume area, but contains about 50% of mass.

about 433 ft upgradient from the extraction well. This system will operate for approximately 6 months as a treatability test from the starting date of August 29, 1994. The system, if effective, may continue to operate as Phase I of the IRM while the results of the treatability test are evaluated and additional or new treatment equipment is procured. These operations are to the southwestof the high-concentration area of the plume. Preliminary results from these test activities indicate successful treatment of extracted groundwater to concentrations below MCLs and near or below detection limits.

Phase II of the conceptual plan would consist of expanding operations by installing two extraction wells and one injection well. Existing or remediated wells will be used initially as monitoring wells. The extraction wells will be installed in the eastern portion of highest plume concentrations (between the 2,000 to 3,000 ppb CCl_4 concentration isopleth, Figure 1). The combined discharge rate will be about 150 gal/min. Contaminated groundwater will be treated at ground surface by air stripping to remove volatiles from the extracted groundwater. GAC will be used to treat the air stream to meet applicable emission standards prior to release to the environment.

The injection well is proposed to be located within the CCl_4 plume about 3,000 ft west of the extraction wells (near wells 699-39-79 and 699-40-80). The well(s) should be capable of injecting at a maximum rate of about 150 gal/min.

Engineering data also will be collected during installation of the monitoring wells (or from the remediated wells noted above) for designing the 150 gal/min treatment system and later the 500 gal/min system. Monitoring wells may be drilled to the top of the lower mud unit (or deeper if warranted) to determine the vertical distribution of contamination and to test for preferred pathways of contaminant migration (i.e., higher hydraulic conductivity zones). This information will be used to determine well screen intervals, well spacings for additional extraction and monitoring wells, and capture zone analysis.

Monitoring wells may be either multiple-level completions or cluster sites capable of collecting three-dimensional hydraulic head and contaminant concentration data during the operation of the extraction system. These data are critical for evaluating whether containment is being achieved and whether contaminant concentrations are being reduced.

In Phase III, the expanded treatment system may operate anywhere from 150 gal/min to 500 gal/min, depending on the results of the periodic performance evaluation of the 150 gal/min system. If full scale-up is warranted, four extraction wells, two injection wells, and two monitoring wells may be added to the pump-and-treat system in FY 1996 and another set again in FY 1997. The total hydraulic containment system would then consist of 10 extraction wells, 5 injection wells, and at least 4 multi-level monitoring wells (or however many wells the hydrogeologic conditions warrant in order to meet remedial goals). The estimation of 10 extraction wells at 300-ft spacings is supported by the capture zone analysis presented below.

Extraction wells are proposed to be added to the wellfield in an arc extending to the northwest (Figure 4). The exact spacing of the wells and screen lengths will be determined from engineering data collected during drilling of the monitoring wells (spacings are currently estimated at 300 ft) and the results of the performance evaluation. Expansion of the wellfield will be predicated on the likelihood of achieving the remedial action objectives and goals at an increased operating rate.

Each of the five injection wells should be capable of handling an injection rate of about 100 gal/min. The monitoring wells may be drilled to the top of the lower mud unit (or deeper as warranted) to collect engineering data, and again will be used to estimate the shape of the capture zone, the three-dimensional hydraulic head distribution, and changes in contaminant concentrations during system operation.

An evaluation of aquifer response and treatment system performance will be used to optimize the pump-and-treat operating parameters. Pumping rates and schedules will be modified as system (wellfield and treatment) performance evaluations dictate. For example, even though pumping rates of 150 and 500 gal/min are given, these could be increased or decreased to better meet the remedial goal of containment. In like manner, pumping schedules may be adjusted anywhere from continuous 24-hour operation to any of various "ON-OFF-ON-Again" scenarios to optimize containment and mass reduction. Operational costs will also play a role in this evaluation. An optimization model will be used during operation of the pump-and-treat system to help maximize system efficiency.

6.3 Treatment System Conceptualization

Both air stripping and GAC adsorption are existing and proven technologies for removal of CCl_4. Liquid-phase GAC is being tested for removal of CCl_4 during treatability test operations (50 gal/min system). During Phases II and III of the IRM, CCl_4 is proposed to be removed from the incoming groundwater by air stripping. The resulting CCl_4-enriched air stream will be treated to meet applicable air-emission standards as it passes through the GAC. The GAC will then be handled as a solid hazardous waste.

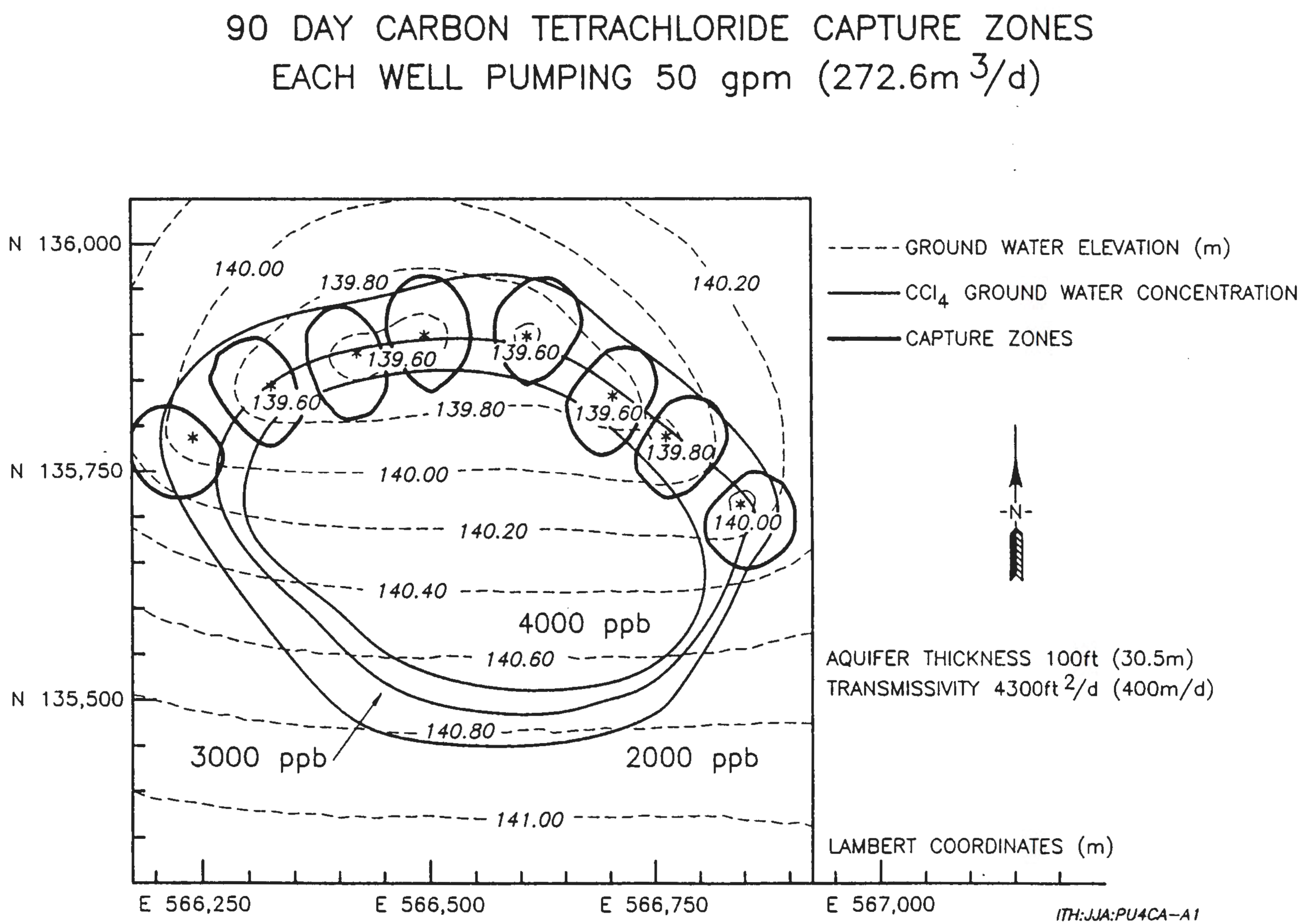


Figure 4. Capture Zone Analysis for Eight-Well Scenario.

The treatment system capacity may be increased in two or three stages or modules during Phases II and III. Each module would contain an air-stripping unit, a GAC treatment unit, associated piping, instrumentation, and controls. The air stripper is proposed to remove a minimum of 90% of the inlet CCl_4 at a designed flow rate of 200 gal/min. The vapor-phase GAC will be designed to remove CCl_4 to meet applicable air-emission standards. Treatment capacity for Phase II may be increased in two steps. Step 1 would involve installation of the first treatment module, two extraction wells, and one injection well. Step 2 would involve installation of a second treatment module, four extraction wells, two injection wells, and two monitoring wells.

Each module is proposed to be operated at a flow rate of 150 gal/min (300 gal/min total for both modules). The effectiveness of treatment during Step I will be evaluated relative to the remedial action objectives and goals. If treatment is effective and additional capacity is warranted, the second 150 gal/min module will be added.

Following analysis of the effectiveness of the two-module operation, system capacity may be increased by another 150 gal/min in Phase III. Phase III would involve installation of a third treatment module, four extraction wells, two injection wells, and two monitoring wells.

Phase III would increase the total treatment capacity to 500 gal/min (i.e., a 167 gal/min planned operational rate per module; 200 gal/min designed flow rate per module). Results of the periodic performance evaluation will be used to optimize system operation during all phases and steps of operation.

Although the 200-ZP-1 pump-and-treat system may be operated as a TU without meeting all the substantive requirements for standard RCRA tank systems, the U.S. Department of Energy, Richland Operations Office will institute appropriate measures to ensure protection of human health and the environment. These measures include provision of some simpler forms of secondary containment coupled with daily inspections during operations, overflow protection devices, and spill containment equipment. Additionally, the pump-and-treat system will be designed to accommodate future upgrading, if necessary, to comply with 40 CFR 264 Subpart J/WAC 173-303-640 tank system standards.

6.4 Capture Zone Evaluation

A simple scoping-level model was run to test the likelihood of developing a capture zone that would contain the plume in the high-concentration area and to estimate the number of wells and well spacings that would be required. An analytical model called CAPZONE was used to create the initial hydraulic flow field for the analysis

(Figure 5). Capture zones were then generated for 90 days of continuous operation (24-hour pumping) using the software program GWPATH. In the analysis it was assumed that the aquifer thickness and vertical extent of contamination was 100 ft, the pumping rate was 50 gal/min, and the hydraulic conductivity was 43 ft/d (geometric mean for the 200 West Area).

The scoping model results indicate that the initial estimate of 10 wells at spacings of 300 ft is reasonable for establishing hydraulic containment in the high-concentration area (the model itself only required eight wells to achieve this). As shown in Figure 4, a line (arc) sink is established across the entire high-concentration area (note water-level contours), thereby achieving hydraulic containment. [Even though full coverage of the capture zones is not readily apparent on the plot, it is in fact occurring as suggested by the equipotential lines (this is a shortcoming of the model).]

Plots of the model results are shown in Figures 4 through 6. Figure 5 shows the flow field and concentration contours prior to pumping (the initial groundwater flow direction is more or less toward the northeast). Five-well and eight-well configurations are shown in Figures 6 and 4, respectively. After 90 days of operation, the five-well system does not appear to capture the entire area of the plume in the area of the wells, whereas the eight-well system does. The average spacings between wells for the five- and eight-well systems are slightly more than 500 ft and 300 ft, respectively.

6.5 Performance Evaluation

Quantifiable interim remedial goals for 200-ZP-1 can be based on parameters that are directly measurable from remediation data. These goals will be used to assess the effectiveness of the action and judge whether the remedial objectives are being fulfilled.

Quantifiable goals include the following:

- Maintain hydraulic control and containment with overlapping cones of depression in the area of the extraction wells
- Prevent CCl_4 concentrations from increasing immediately downgradient from the containment zone
- Remove a minimum of 90% of CCl_4 from the extracted groundwater using the surface treatment system.

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90 DAY CARBON TETRACHLORIDE CAPTURE ZONES
EACH WELL PUMPING 50 gpm (272.6m ^{3}/d)

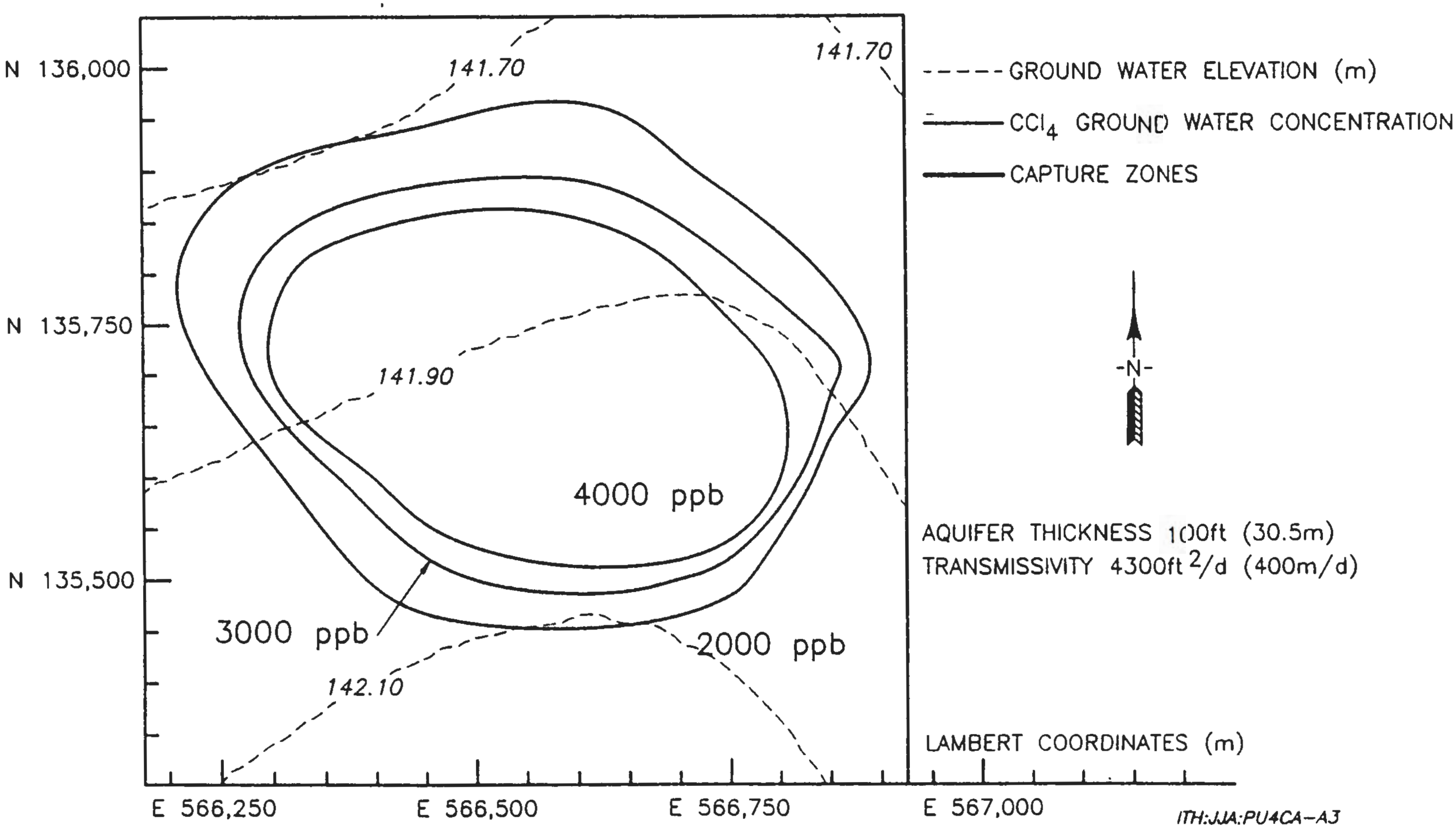

Figure 5. Base Hydraulic Conditions Prior to Capture Zone Analysis.

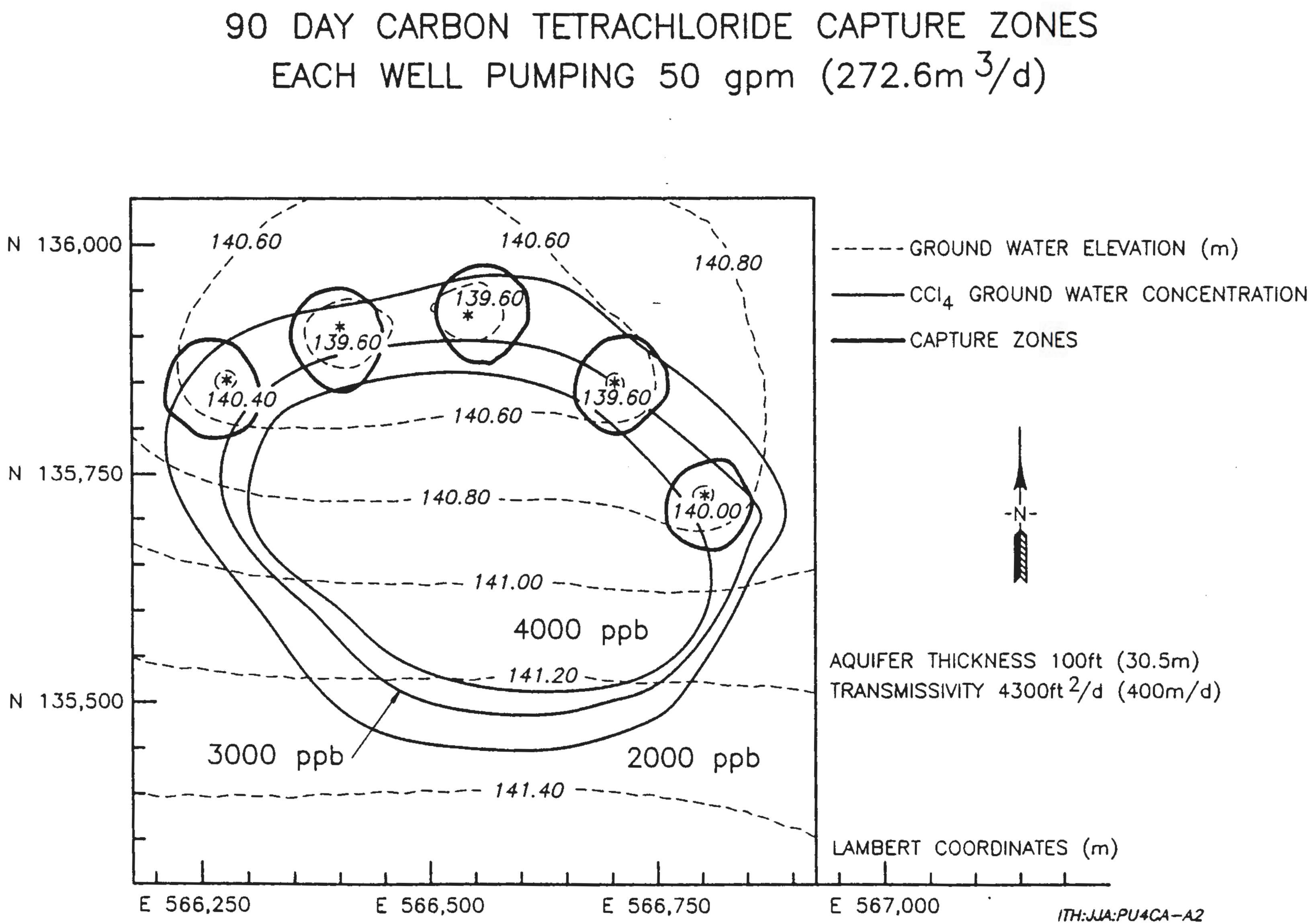

Figure 6. Capture Zone Analysis for Five-Well Scenario.

A technically successful interim remedy would result in (1) hydraulically containing the highly contaminated portion of the plume; (2) extracting significant contaminant mass and reducing contaminant concentrations; and (3) eliminating or reducing CCl_4 sources that continue to contribute to groundwater contamination (well remediations, etc.). Therefore, to evaluate the technical success of the preferred alternative during operation and prior to each stage of expansion, a periodic performance evaluation using the observational approach will be conducted. Several specific technical criteria will be addressed in the evaluation.

- Criteria 1

  Is the wellfield hydraulically containing and/or intercepting the CCl_4 plume in the area of the extraction wells? This evaluation will require estimating the extent of the three-dimensional capture zone. Field measurements to support this evaluation will consist of measurements of hydraulic head at the extraction and monitoring wells. If this criterion is met, the action will have achieved the overall interim goal of containment.

  These data will be used to design next-phase extraction well locations, spacings, screen lengths, pumping rates, and pumping schedules (in conjunction with other field results).

- Criteria 2

  Have contaminant concentrations downgradient of the containment zone been stabilized? Field activities will consist of collecting groundwater samples at monitoring wells and extraction wells prior to treating the groundwater. Analysis results will be used to plot contaminant concentrations versus time and to evaluate the effectiveness of pumping.

  These data will be used for a qualitative judgement on whether the plume concentrations can be reduced to acceptable levels in the time frame of cleanup of the Hanford Site (for example). Other contextual factors that will be considered are the total costs to achieve these concentrations and current regulatory requirements.

- Criteria 3

  Is mass removal occurring at a rate that will remove the dissolved contamination in a reasonable period of time and at a reasonable cost? Field and laboratory measurements will include contaminant concentration changes over time in the extraction and monitoring wells and evaluation of treatment system effectiveness/efficiency. Specifically, the rate of mass removal will be measured (grams per unit time; grams per unit volume; cost per unit gram), and the amount of mass removed will be compared to the estimated total dissolved mass for the partial plume and the entire plume.

Efforts to reduce contaminant mass and concentrations may not be successful if substantial CCl_4 sources (e.g., residual CCl_4 or CCl_4 pools) continue to contribute to the dissolved plume.

In conclusion, the remedial objectives and goals will be achieved if the high-concentration plume is hydraulically contained; contaminant mass is removed in a reasonable timeframe and at a reasonable cost; and specific potential sources of continuing contamination are eliminated or reduced, thus stabilizing the plume in this area. In addition, the remedial activities and related actions will provide valuable information for the final remedy selection.

6.6 Basis for Cost Estimate

The cost estimates for the preferred alternative were prepared based on budget and planning costs, vendor information, and conventional cost-estimating guidelines. Table 3 provides a summarized listing of the costs themselves.

The FY 1995 costs included the following items: (1) operations and maintenance for the 50 gal/min pilot-scale system for 6 months (starting August 29, 1994); (2) capital costs for the design, procurement, and installation of a 150 gal/min air stripping pump-and-treat system; (3) installation of three wells (two extraction and one injection well); (4) sampling and analysis, and monitoring costs; and (5) the DNAPL investigation (including deepening two wells).

Costs associated with FY 1996 work assume that the results of the performance evaluation recommend scaling up the hydraulic control and treatment systems. The following items are associated with this effort and ongoing operations: (1) capital costs to upgrade the 150 gal/min system to about a 300 gal/min system (200 gal/min design capacity for the air-stripping module) with a second treatment module (assumed to be the same as for the first module constructed in FY 1995); (2) installation of eight new wells at an average depth of 400 ft (two characterization wells at $1,600 per lineal foot, and standard wells at $800 per lineal foot); (3) operations and maintenance [3.5 full-time equivalents (FTEs) at $125,000 each, $5,000 per month for replacement of parts, and carbon replacement at $2.00 per pound. Carbon replacement was estimated using the EPA *Cost of Remediation Action* (CORA) model]; (4) sampling and analysis, and monitoring ($450,000 for groundwater sampling and $460,000 for treatment system sampling); (5) "other" (escalation at 2.3% per year); (6) markup of 80% on direct labor for support; and (7) markup of 22% on materials.

Table 3. Summary Table for Costs and Schedule for the 200-ZP-1 IRM from the Present through Fiscal Year 2000.

	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
Capital	860,000	750,000	750,000	0	0	0
Well Installation	900,000	2,700,000	2,700,000	0	0	0
Operations and Maintenance	1,140,000	980,000	980,000	980,000	980,000	980,000
Sampling, Analysis, and Monitoring	1,970,000	910,000	910,000	910,000	910,000	910,000
DNAPL Investigation[a]	990,000	0	0	0	0	0
Escalation	0	120,000	250,000	130,000	170,000	220,000
Total[b]	$5,860,000	$5,460,000	$5,590,000	$2,020,000	$2,060,000	$2,110,000

[a]Includes deepening two existing wells for use as IRM monitoring wells.
[b]No contingency included.

Costs associated with FY 1997 work assume that the results of the performance evaluation recommend scaling up the hydraulic control and treatment systems. The following items are associated with this effort and ongoing operations: (1) capital cost to upgrade the 300 gal/min system to about a 500 gal/min system (assumed to be the same as for the FY 1995 system, because modeling shows that 150 gal/min and 200 gal/min systems are the same size and costs should not vary); (2) installation of eight new wells at an average depth of 400 ft (two characterization wells at $1,600 per lineal foot, and standard wells at $800 per lineal foot); (3) operations and maintenance (3.5 FTEs at $125,000 each, $5,000 per month for replacement of parts, and carbon replacement at $2.00 per pound); (4) Sampling and analysis, and monitoring ($450,000 for groundwater sampling and $460,000 for treatment system sampling); (5) "other" (escalation at 2.3% per year); (6) markup of 80% on direct labor for support; and (7) markup of 22% on materials.

Costs after FY 1997 assume that performance evaluations demonstrate continued benefit from operation. These costs include operations and maintenance, sampling and analysis, escalation, and markup based on the same assumptions as prior years.

6.7 Additional Proposed Activities

In addition to the operation of the pump-and-treat systems, other work will be performed as part of the IRM that will also contribute to containment of the CCl_4 plume, help reduce the potential for further contamination of the aquifer, test innovative technology, and/or provide essential engineering data for system designs. These activities include more immediate tasks such as investigation of continuing sources of CCl_4 groundwater contamination, reduction in surface discharges, innovative technology demonstrations, well integrity assessments, and groundwater sampling; and longer-term tasks such as a DNAPL investigation and an ongoing assessment into the vertical extent of contamination. This information will be used to evaluate the performance of the extraction and treatment systems, optimize the remedial action, and help design each phase of wellfield expansion (as applicable), and will provide important technical input for the final remedy selection and record of decision. In addition, the treatment system may be used to treat groundwater extracted from other wells in the 200 West Area (e.g., for purposes of well sampling or other similar activities) and condensate from the SVE systems operating to remove CCl_4 from the vadose zone.

Several areas of data collection are considered critical for evaluating the performance of the Phase I and II pump-and-treat systems and for the longer term success of remediation. These data will be needed to determine if the remedial action goals and objectives are met and to support final remedy selection. Two areas of particular concern are three-dimensional hydraulic head distribution and occurrence of DNAPL. Knowing the hydraulic head distribution is essential for estimating the three-dimensional capture zone, and thus evaluating the extent of containment of the dissolved plume.

Understanding the physical states of CCl_4 in the subsurface and the vertical distribution of contamination are critical for proper wellfield design, implementation of the remedial action, establishing the probability of successful remediation, and selection of the final remedy. Vertical distribution of contamination will be explored in part during the installation of monitoring wells, but will be more fully addressed through a DNAPL investigation.

6.7.1 DNAPL Investigation

Volatile DNAPL such as CCl_4 presents unique and difficult problems with respect to characterization and remediation. Volatile DNAPL compounds can partition into several different physical states in the subsurface. The complex distribution of aqueous, vapor, solid, and liquid phases complicate design and implementation of remedial actions in the 200 West Area. In particular, the ability to achieve remedial objectives and goals will be strongly influenced by the presence of liquid-phase CCl_4 below the water table.

The objective of the 200-ZP-1 IRM is primarily based on hydraulic containment of the high-mass portion of the CCl_4 groundwater plume, with a secondary objective of mass reduction. Ascertaining the presence or absence of DNAPL CCl_4 is vital to the containment approach because the majority of CCl_4 below the water table may be located in the DNAPL zone. There are no known technically feasible methods for completely removing CCl_4 DNAPL from aquifers. Additionally, knowledge of DNAPL in the aquifer is extremely important to the design of the containment system. The design must effectively isolate the DNAPL zone from the aqueous-phase portion of the groundwater plume while minimizing any disturbance to the DNAPL zone that could remobilize or fragment the DNAPL. Finally, early determination of the presence and extent of DNAPL below the water table will aid in near-term decision making, final remedy selection, and technology development efforts directed at remediating DNAPL below the water table.

The DNAPL investigation will focus on the area near the 216-Z-9 Trench. This area is considered the most likely location of DNAPL below the water table for several reasons. Pore-volume column estimates indicate that liquid-phase CCl_4 wastes have saturated the vadose zone and reached the groundwater (DOE-RL 1991). In addition, drilling and sampling activities conducted near the trench have found relatively high CCl_4 vapor-phase concentrations near the water table and high aqueous-phase concentrations in the groundwater, which may be indicative of CCl_4 DNAPL in the capillary fringe and uppermost aquifer (Rohay et al. 1993).

A DNAPL investigation at the 216-Z-9 Trench is estimated to require 6 to 12 months. The preferred investigative approach is a partitioning interwell tracer test. This approach would require the deepening of at least two existing vadose zone wells to groundwater and refurbishment of existing well 299-W15-6. The tracer test would be conducted using the two deepened vadose zone wells. This test requires that a suite of tracers be injected into one well and hydraulically entrained through the suspected DNAPL zone by pumping from an extraction well. The tracers consist of various alcohols that partition into the DNAPL and a conservative tracer (such as lithium bromide) that does not react with the DNAPL. Groundwater withdrawn from the extraction well during the test is analyzed for the tracers to determine arrival times and attenuation. Arrival of all tracers at approximately the same time indicates no DNAPL was present between the injection and extraction points. Conversely, retardation of the alcohol tracers relative to the conservative tracer would indicate DNAPL was present between the injection and extraction points. The arrival time and attenuation data can also be used to estimate the volume of DNAPL present between the injection and extraction points.

7.0 REFERENCES

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APPENDIX A
CHLORINATED HYDROCARBON CONTAMINANTS IN THE 200 WEST AREA

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CHLORINATED HYDROCARBON CONTAMINANTS IN THE 200 WEST AREA

A1.1 Source Characteristics

The primary sources of CCl_4 in the 200 West Area include the cribs, trenches, and ditches (e.g., 216-Z-18, 216-Z-1A, 216-Z-9, and 216-T-19) used for disposal of liquid wastes associated with past operations within the Plutonium Finishing Plant (PFP) complex (see Figure A-1). Spent or degraded CCl_4 based solvent, used in the solvent extraction process to refine plutonium, was discharged to the ground as a separate liquid phase. This liquid phase was a mixture (85:15) of CCl_4 and complexing agent (e.g., tributyl phosphate or dibutyl butyl phosphonate) as well as 50:50 mixtures of CCl_4 and lard oil. These organic solutions made up only about 4 to 8% of the total volume of liquid waste discharged to the disposal facilities (Last and Rohay 1993). The aqueous waste consisted of acidic, high salt (sodium nitrate) wastewater containing the organic liquid as well as organics dissolved in the wastewater. Significant quantities of transuranics (primarily plutonium-239 and americium-241) may have also been carried in association with the organic liquid phase. Should a separate dense liquid phase of CCl_4 exist, it may also contain significant amounts of transuranic radionuclides as co-contaminants.

A1.1.1 Mass Distribution. Recent estimates suggest approximately 21% of the total inventory of CCl_4 was lost to the atmosphere due to gas phase transport and 12% was retained in the vadose zone, thus leaving 65% unaccounted for (Last and Rohay 1993). Less than 1% is observed in the dissolved phase in groundwater. The unaccounted fraction may be retained as "residual saturation" in the vadose zone or the aquifer. A residual or liquid phase would continue to migrate downward and to dissolve slowly over time. Alternatively, the liquid phase CCl_4 retained in the vadose zone may drain slowly over time down to the water table.

A1.1.2 Vertical Movement. Carbon tetrachloride in the subsurface exists as a gas phase, dissolved in water or as a separate liquid or free phase as illustrated in Figure A-2. In the gas phase it may be lost to the atmosphere due to soil venting from open wells or by diffusion to the surface through the soil column. It is also possible that CCl_4 as a gas phase can migrate downward because of its high vapor density or can be absorbed by downward percolating wastewater which eventually reaches groundwater as a dissolved phase (Johnson 1993a). The presence of several wastewater disposal sites adjacent to the major sources of CCl_4 make these possible secondary sources of groundwater contamination that may partly explain the apparent coincidence of high soil gas concentrations and the highest groundwater concentrations (Figure A-3).

Figure A-1. Contour Map Showing the Distribution of Carbon Tetrachloride Concentrations (ppb) in Groundwater in the Vicinity of the 200 West Area.

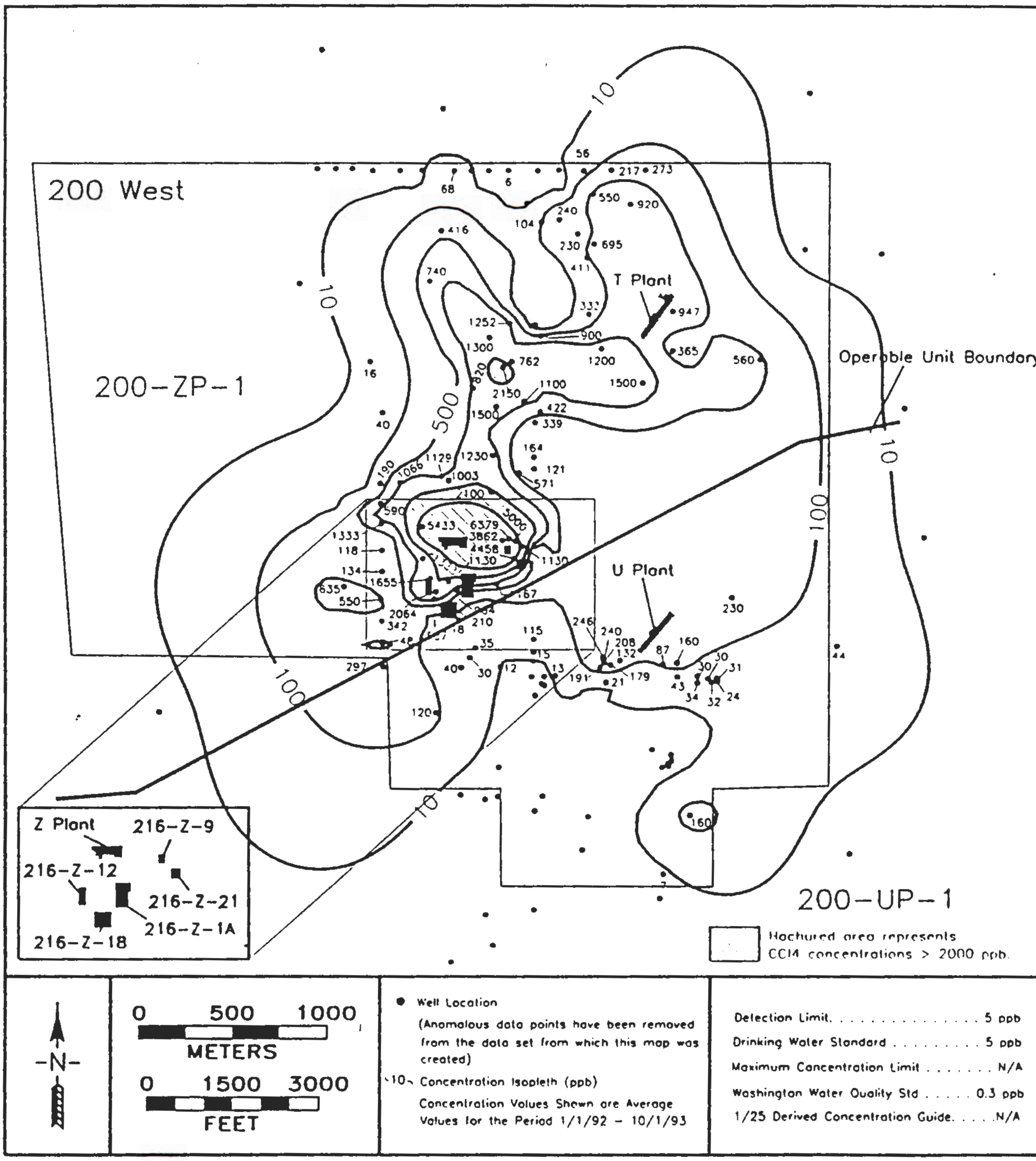


Figure A-2. Schematic Illustration of the Conceptual Model for Carbon Tetrachloride Disposal and Migration Beneath the 216-Z-9 Trench.

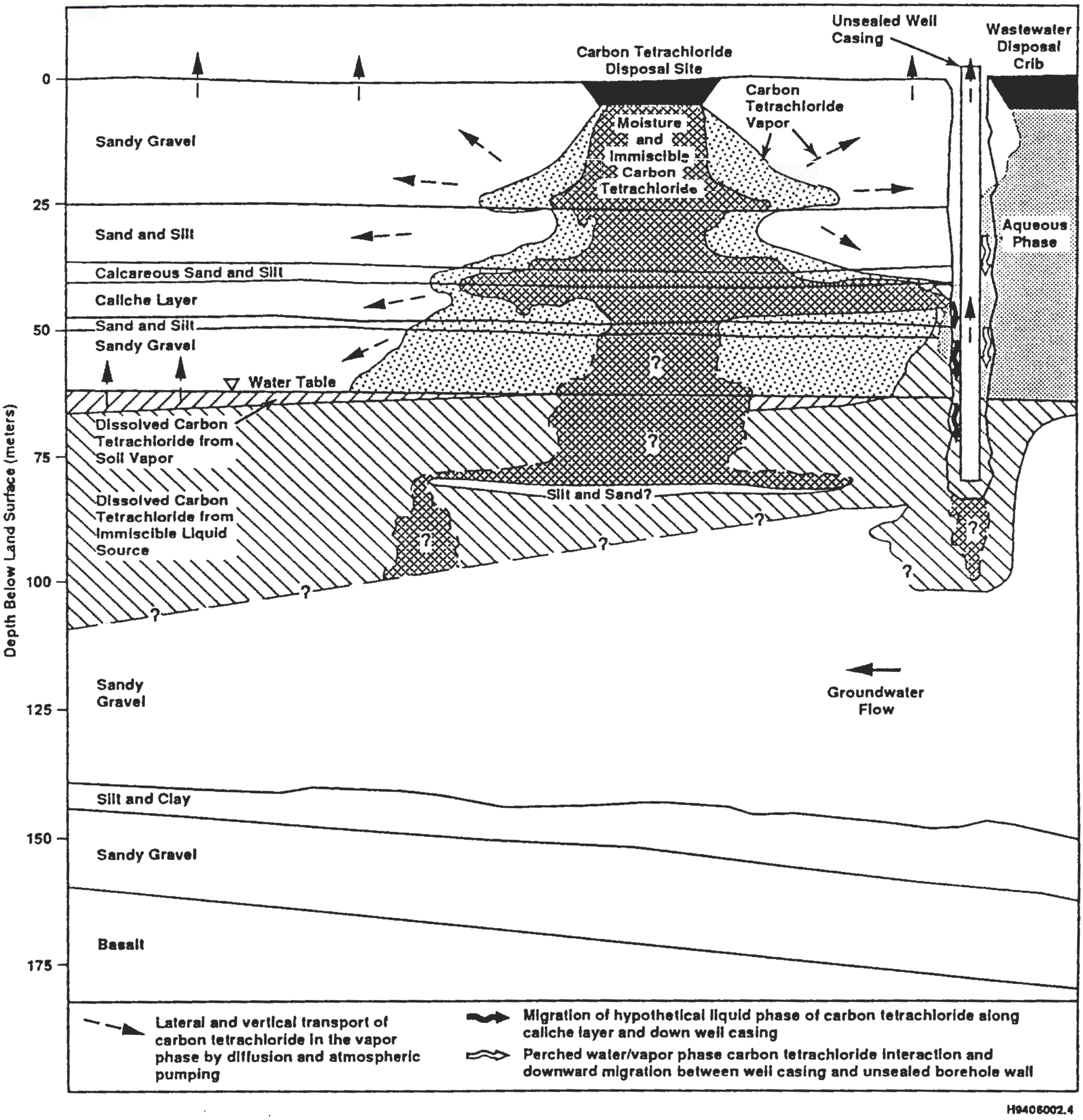
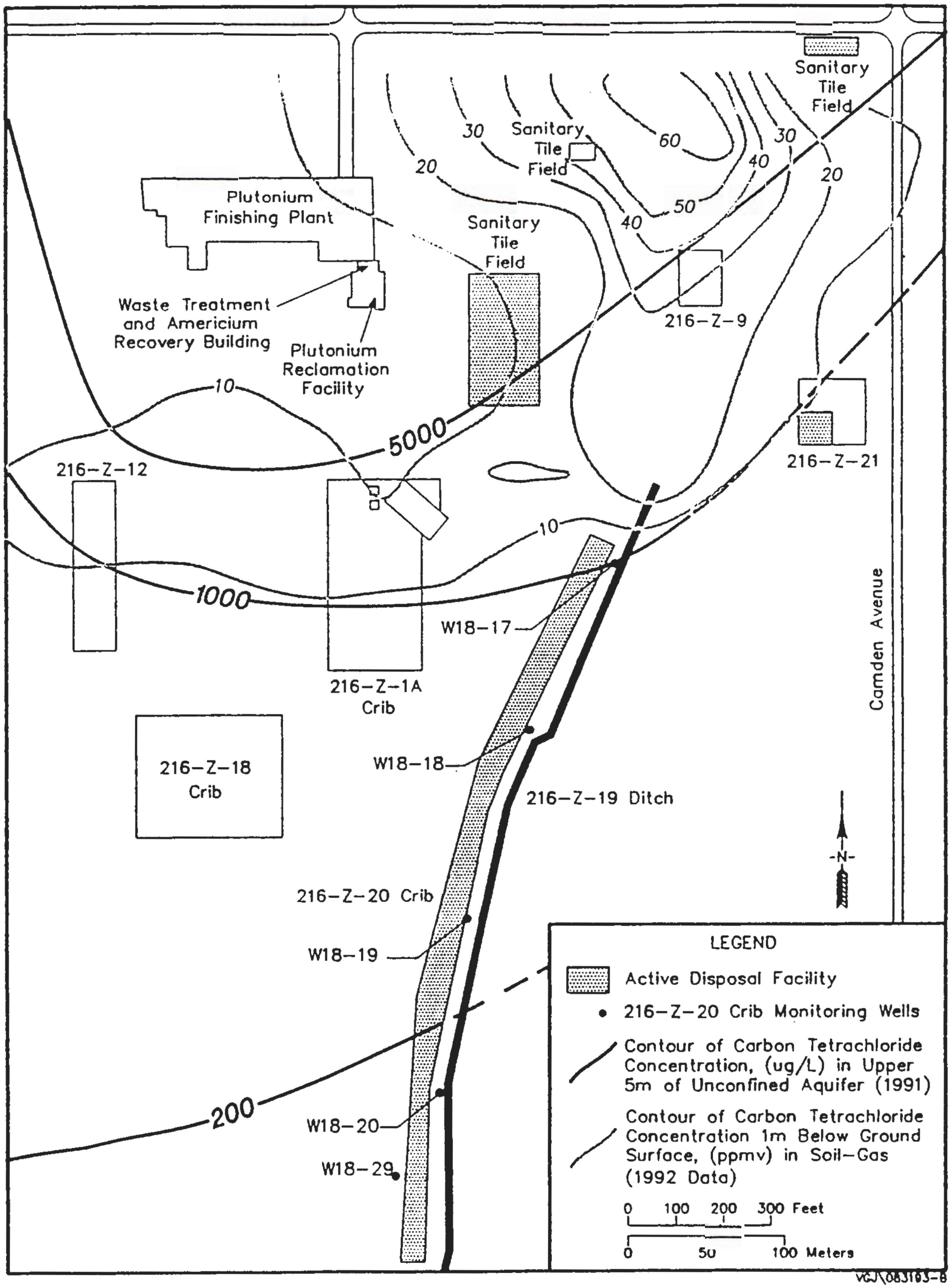


Figure A-3. Contour Map Showing Carbon Tetrachloride Concentrations in Soil Gas (ppmv) and Groundwater (ppb) in Relation to Active Waste Water Disposal Sites in the Vicinity of the Plutonium Finishing Plant (PFP).



Estimates of theoretical water retention capacity of the soil column beneath the three major disposal sites suggest that only the 216-Z-9 Trench received sufficient volumes of waste to reach the water table (Last and Rohay 1993). Accordingly, computer simulations of liquid phase CCl_4 transport have focused on the 216-Z-9 Trench.

A1.1.3 Model Predictions. Initial simulations of a dissolved and liquid phase beneath the 216-Z-9 Trench (Johnson 1993a) suggested that a liquid or free phase may reach the water table and extend to the bottom of the unconfined aquifer. However, when a modest hydraulic gradient was introduced, the liquid phase appeared to completely dissolve in the groundwater by the time it reached the bottom of the aquifer. Other modeling efforts have lead to the conclusion that it is probable that a liquid phase has reached the water table, at least beneath the 216-Z-9 Trench (Last and Rohay 1993). Due to many simplifying assumptions and the lack of site-specific chemical and hydraulic property values, the modeling results thus far remain inconclusive. However, they do suggest the possibility of long-term drainage of a liquid phase through the vadose zone and into the groundwater beneath the 216-Z-9 Trench. An adequate understanding of this potential continuing source is fundamental to development of a remediation strategy.

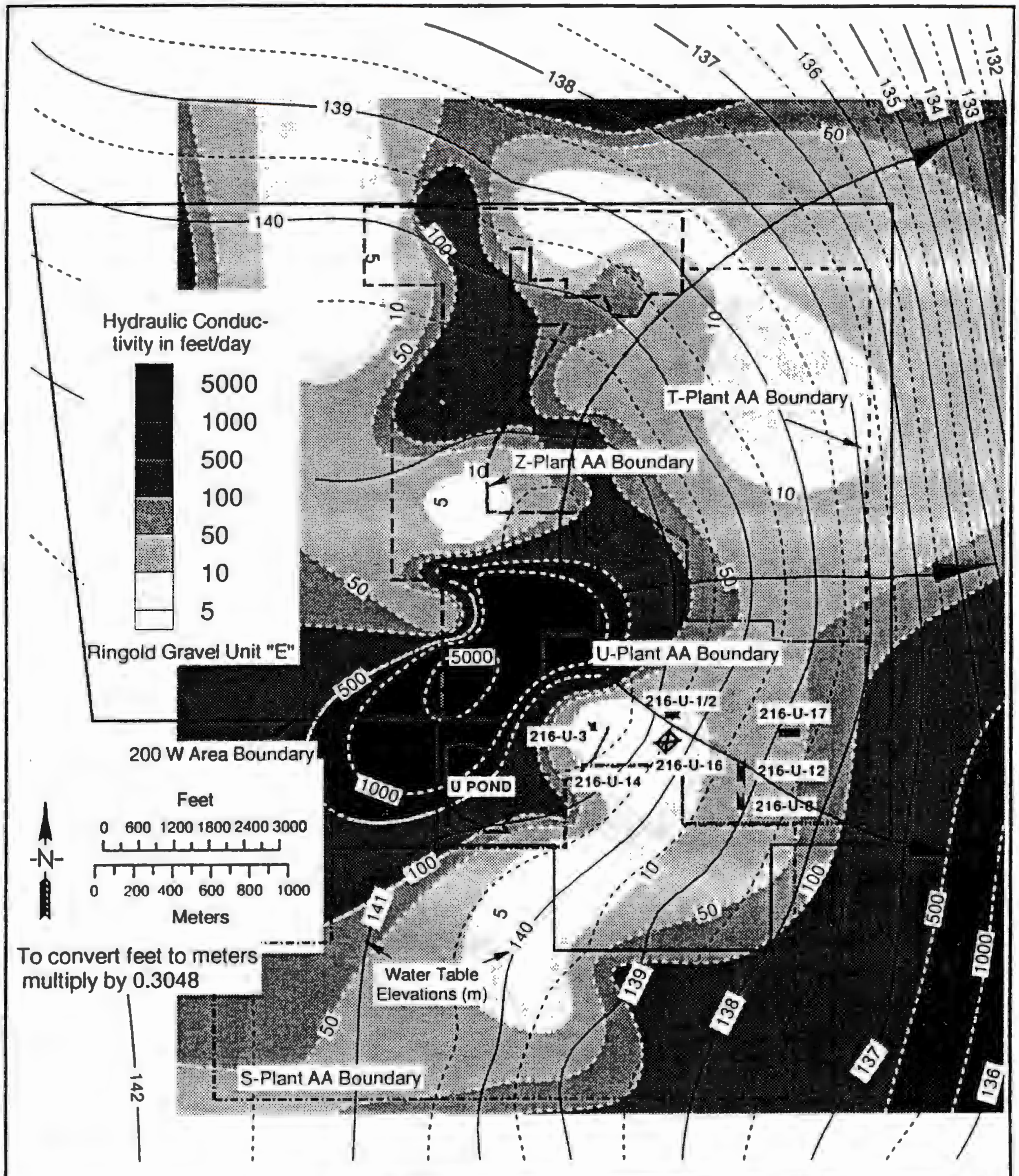
A1.1.4 Observed Vertical Distribution. The limited depth distribution data suggest that CCl_4 dissolved in groundwater exists at varying depths and locations. In some locations it has been found to depths of up to at least 24 m (80 ft) below the water table surface. However, six wells completed at the bottom of the unconfined aquifer in the 200 West Area did not contain CCl_4. The few hints of deeply distributed CCl_4 that do exist are consistent with the one model prediction of a long-term, deep drainage of a liquid phase through the aquifer that dissolves while settling and thus results in deeply distributed groundwater contamination. More confirmatory sampling is needed to assess this possibility. A deeply distributed source would significantly impact estimates of volume and the strategy for recovery of water to be treated or contained.

A1.1.4.1 Unsealed Wells as Vertical Pathways. Unsealed wells adjacent to the major CCl_4 disposal sites may have acted as preferential pathways for either a dissolved or free liquid phase to reach groundwater (Johnson 1993) and as illustrated in Figure A-2. Several older unsealed wells exist around each disposal site. Perhaps the most significant of these is the existence of a well (299-W15-5) located approximately 150 m (500 ft) south of the 216-Z-9 Trench. This well is completed in the uppermost basalt (confined) aquifer. The well was installed in 1957 without any seal between the casing and the formation and is essentially "open" between the uppermost confined aquifer and the overlying unconfined aquifer. The casing was perforated at various depths beginning at near the water table elevation and filled with "pea" gravel through both the confined and unconfined aquifers. The water table elevation has been approximately 9 m (30 ft) greater than the hydraulic head for the confined aquifer with which it is in communication. Thus the potential for downward flow of contaminated groundwater via this well has existed for the last 37 years. It has been estimated that over 4 X 10^7 L (10^7 gal) of groundwater contaminated with CCl_4 may have flowed into the deeper aquifer system via this preferential pathway. Elimination of all such pathways and the timing of potential remediation of the confined aquifer must be considered as part of the overall 200 West Area groundwater strategy.

A1.1.5 Areal Distribution. The plume distribution pattern (see Figure A-1) suggests that a continuing source of groundwater contamination exists in the vicinity of the 216-Z-9 Trench. Other sources are also possible. It is currently unknown if this is due to the secondary vapor phase/wastewater interaction process described above, and or due to a slow but continuous dissolution of a liquid phase in the saturated zone, or a slow migration from the residual contained in the vadose zone. The sources of wastewater in the vicinity of the Z Cribs will be eliminated by 1995 and thus any pathway involving absorption of vapor phase CCl_4 by wastewater will no longer exist. The significance of a liquid CCl_4 phase in either the vadose zone or the saturated zone is that any attempt to remediate the zones of highest groundwater contamination will be futile without containment or elimination of the source(s). The relatively high CCl_4 concentrations in groundwater near the 216-Z-9 Trench (up to ca. 6,000 ppb), taken together with observations made elsewhere and the observed plume pattern and model predictions suggest a free liquid phase currently exists in the vadose and saturated zones beneath or in the vicinity of the 216-Z-9 Trench.

A1.1.5.1 Rate of Movement and Mechanisms. The spread of the CCl_4 groundwater plume that emanates from the vicinity of the PFP complex is controlled primarily by the hydraulic gradient (change in water table elevation with direction and distance), and the variations in hydraulic conductivity of the unconfined aquifer. Predictions based on these two primary controlling factors are shown in Figure A-4. While such predictions are in approximate agreement with observed CCl_4 movement or spreading, the observed rate appears to be somewhat slower than the rate estimated for groundwater. For example considering that the 216-Z-9 Trench, the primary source, began operation in ca. 1955, and assuming the 10 ppb contour interval represents the maximum travel distance, this contour line represents a "time contour" of approximately 35 years or approximately 3,050 m/35 yr = 88 m/yr (290 ft/yr) in the direction of greatest apparent travel distance to the north-northeast. Since the gradient in the water table elevation was greater in the past than today, this approximation represents an overall average for the last 35 years; the rate today, and projected into the future, would be slower due to the declining water table and hydraulic gradients in the 200 West Area. It should also be noted that shifts in the sources of wastewater disposal in the late 1950's may have complicated the dispersal pattern observed today. Nevertheless, the apparent rate of movement is generally consistent with but somewhat slower than other estimates of migration rate for the 200 West Area

Figure A-4. Contour Map Showing the Distribution of Hydraulic Conductivity (ft/day) and Water Table Elevation (m above mean sea level) in the 200 West Area. Arrows indicate groundwater flow directions.



(Freshley and Thorne 1992) based on observed contaminant plume movement rates. The apparent difference may be due to retardation of CCl_4 migration rate due to adsorption by aquifer sediments.

A1.1.5.2 Retardation Mechanism. Adsorption, or the extent of interaction between CCl_4 dissolved in groundwater and the aquifer sediments, will have a significant influence on the total quantity of organic contaminant stored or present in the aquifer and the time needed to remediate the aquifer. While very little site-specific data exists, there is some indication that CCl_4 is slightly adsorbed by Hanford sediments (Rohay 1994). The relationship between contaminant velocity (V_c) and water velocity (V_w) is often expressed in terms of the "retardation factor" as follows:

$$R_f = V_w/V_c = 1 + [\rho(1-\theta)/\theta]\ K_d$$

where ρ is the bulk density (g/cm^3) of the aquifer solids (taken as 2 g/cm^3), θ is the effective porosity of the aquifer solids and K_d is the distribution coefficient of the contaminant. The latter has the units of cm^3/g. The distribution coefficient used in the above manner implies that the adsorption of the contaminant on the aquifer solids is a reversible reaction.

Assuming an aquifer effective porosity of 0.1 for the 200 West Area and an average Kd of 0.2 cm^3/g (Rohay 1994) for the interaction of dissolved CCl_4 with typical Hanford Site soils or sediments, the estimated water velocity would be 4.6 times faster than the CCl_4 due to the slower rate of migration caused by adsorption and desorption on aquifer solids. In addition, the ratio (R) of CCl_4 adsorbed on aquifer sediments to that dissolved in groundwater within the pore spaces of the sediments can be estimated from the following relationship:

$$R = [K_d(1 - \theta)\rho]/\theta$$

Under the same assumptions used above for the retardation estimate, the corresponding ratio, R, of the quantity of CCl_4 adsorbed on the sediments in a cubic foot of aquifer to that quantity dissolved in the groundwater contained in the same cubic foot of material would be 3.6.

or

$$R = [0.2\ \text{cm}^3/\text{g}\ (1 - 0.1)\ 2\ \text{g/cm}^3]/0.1 = 3.6$$

Thus even a very small and seemingly insignificant distribution coefficient can result in an appreciable difference in contaminant migration rate and mass storage in the aquifer. Because of the potential significance of adsorption, additional determinations of the K_d for CCl_4 in representative 200 West Area aquifer sediments are warranted.

A1.1.6 Concentrations at the River. Another important reference point for considering remediation alternatives, is the expected maximum groundwater concentrations of CCl_4 that may exist if/when the existing plume arrives at the river. Recent estimates (Golder Associates 1991) of tritium travel time and concentration from a proposed crib near the northeastern edge of the 200 West Area can be applied to the CCl_4 case. For example the relative change in concentration (C/C_o) when multiplied by the maximum source area concentration of CCl_4 is shown in Figure A-5. The estimated maximum concentrations at two important arrival points, the hypothetical compliance boundary for the 200 Area Plateau and the river, provide an indication of the degree of cleanup needed to meet public expectations. This plot shows the relative concentration along the centerline of a hypothetical plume migrating from the 200 West Area to the river under continuous, steady-state input conditions. The corresponding travel time to the river is over 100 years (Golder Associates 1991). The relative change in centerline or maximum concentration implies maximum CCl_4 concentrations of approximately 3,000 ppb would eventually occur at the river bank and approximately 4,500 ppb where the plume crosses the 200 Area Plateau compliance boundary. Numerous assumptions are included in the preceding that remain to be evaluated. The potential impact of the movement of the 200 West CCl_4 plume points to the need for an improved conceptual and numerical model of solute transport.

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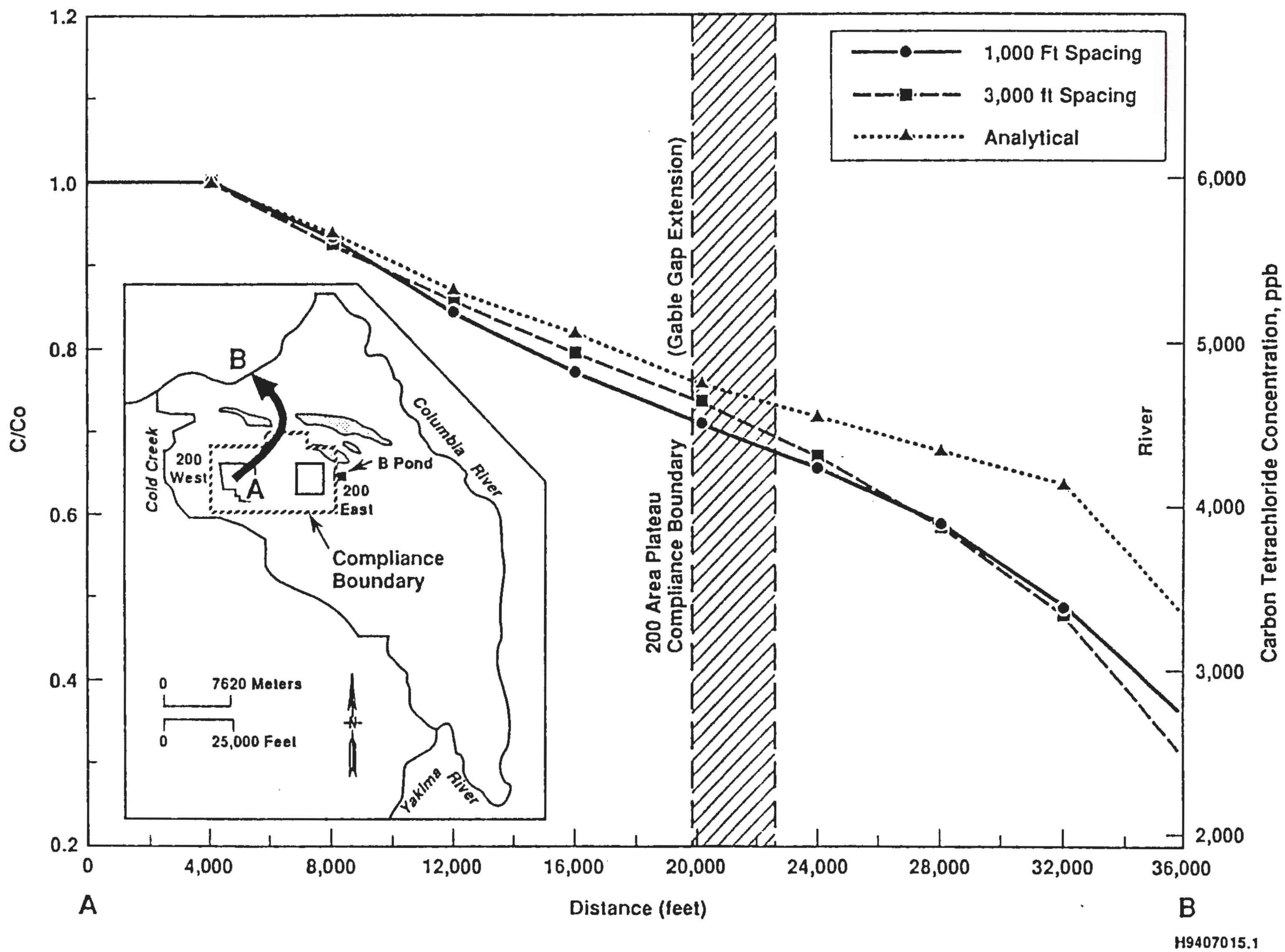
Figure A-5. Plot Showing Estimated Maximum Center Line Carbon Tetrachloride Concentrations Along a Flow Path from the 200 West Area to the Columbia River. Concentrations are Expressed in Both ppb and C/C_o, Where C is Plume Centerline Concentration and C_o is the Maximum Source Concentration.



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Current Five-Year Plan and Activity Data Sheets (Hanford Site Focus)

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MEC Expedited Response Action Engineering Evaluation/Cost Analysis

OK Expedited Response Action - Candidate Waste Sites

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Feasibility Study and Corrective Measures Study Phase II Reports

OK Hanford Ground Water Monitoring Reports (1987 - Present)

Hanford Operable Unit Reports (Hanf Site Waste Mgmt Units Reps)

Hearing Transcripts

Interim Response Action Proposals

Meeting Summaries (from TPA public meetings)

News Releases (information from the media, news releases, news conferences, public service announcements, editorial boards, and Hanford Site tours)

Newsletters (Hanford Update and others)

None Operations and Maintenance Plans

Permit applications

Preliminary Natural Resource Survey

Public Comments on Draft Documents and Comment Responses

Public Notices

RCRA Permits

RCRA Facility Assessment Reports

RCRA Permit Modifications

Records of Decision

* Remedial Investigation and RCRA Facility Investigation Phase II Reports

Remedial Investigation/Feasibility Study and RCRA Facility Investigation/Corrective Measures Study Work Plan

Remedial Design and Corrective Measures Design Reports

Remedial Action and Corrective Measures Implementation Work Plans

Response Summaries

TPA Milestone Summary Report (SMS Executive Summary Report)

TPA, amendments and changes

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OK = ALL ARE IN

TPA Chg Forms