KY/ER--15

DE93 012077

Environmental Restoration Program
Portsmouth Environmental Restoration Program

Evaluation of the Proposed Pilot Groundwater Pump and Treat Demonstration for the Paducah Gaseous Diffusion Plant

G. W. Bodenstein
R. R. Bonczek
T. O. Early
T. B. Hale
D. D. Huff
M. D. Nickelson
C. T. Rightmire

Date Issued—November 1992

Prepared for
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
under budget and reporting code EW 20

PADUCAH GASEOUS DIFFUSION PLANT
Paducah, Kentucky 42001
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

Author Affiliations

G. W. Bodenstein (chairman), R. R. Bonczek, T. O. Early, T. B. Hale, D. D. Huff, M. D. Nickelson, and C. T. Rightmire are members of the Groundwater Corrective Action Review Team. S. N. Davis (University of Arizona) and G. Reed (University of Tennessee) acted as consultants for this report.

CONTENTS

TABLES

FIGURES

ACRONYMS

ACL	alternate concentration limit
ACO	Administrative Order by Consent
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL	dense, nonaqueous-phase liquid
DOE	U.S. Department of Energy
DOE-OR	DOE Oak Ridge Field Office
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
HSWA	Hazardous and Solid Waste Amendments
KPDES	Kentucky Pollutant Discharge Elimination System
KYDEP	Kentucky Department for Environmental Protection
NEPA	National Environmental Policy Act
PGDP	Paducah Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RGA	Regional Gravel Aquifer
SAIC	Science Applications International Corporation
SGS	shallow groundwater system
SVOC	semivolatile organic compound
TCE	trichloroethylene
TVA	Tennessee Valley Authority
UV	ultraviolet
VOC	volatile organic compound
WMU	waste management unit

PREFACE

On March 19, 1992, the U.S. Department of Energy Oak Ridge Field Office (DOE-OR) and the Central Environmental Restoration (ER) Program held a review of the ER Program at the Paducah Gaseous Diffusion Plant (PGDP). Questions arose during this review about the desirability of conducting a planned pilot groundwater pump-and-treat demonstration on an off-site plume (known as the Northwest plume) that contains both trichloroethylene and ^{99}Tc. A Groundwater Corrective Actions Review Team was assembled at the request of R.C. Sleeman (DOE-OR) on March 23 and directed to evaluate the technical merit of the proposed demonstration project. A charter (see Appendix A) was developed and approved that established the guidelines for the evaluation. The charter directed the review team to prepare a written report to "...include a summary of key issues, an evaluation of technical merit of the proposed plan, an analysis of regulatory and public relations drivers, and, if appropriate, recommendations for added actions or modifications to the plan or schedule."

On March 25 the review team met with representatives of the PGDP DOE site office, the PGDP ER Program, and Science Applications International Corporation (who prepared the demonstration work plan) for a briefing about the proposed project and the factors that were considered during its development. Following this meeting, the review team requested clarification from PGDP personnel on a prioritization of objectives that guided their decision to propose the pilot project (see Appendix B for copies of pertinent correspondence). Table 1 was prepared from information provided by D. G. Cope (PGDP ER Program) and is an edited restatement of the objectives appearing in the referenced letter, prioritized by a high (H), medium (M), and low (L) ranking system.

From the start of its evaluation, the review team recognized that it was necessary to make a clear distinction between corrective actions aimed at source control and those intended to address plume remediation. It was concluded that the proposed demonstration is mainly a source-control activity. Although data obtained during this demonstration also might apply to plume remediation, that is not the primary benefit of conducting the demonstration. Consequently, the review team has approached this evaluation from the perspective that it is an assessment of the appropriateness of a proposed source-control remedy for the Northwest plume. Conclusions reached in this specific evaluation might not be applicable to other sources of contamination at the site and their associated plumes.

This report is subdivided into five sections. Section 1 presents background information about the site and the groundwater contamination, a brief description of the proposed pilot project, and a summary of the regulatory framework that provides the context for corrective actions. Section 2 presents background information about the hydrogeology of the site, risk assessment resulting from known groundwater contamination, and a summary of remedial alternatives that Paducah has considered. Section 3 provides a technical evaluation of the proposed demonstration project, and Sect. 4 reviews conclusions and recommendations of the review team. The appendixes provide supplementary information.

Table 1. Restatement of objectives by priority

Objective	Ranking
Establish an interim corrective measure to control the source of the Northwest plume contamination, consistent with regulatory guidance.	H
Comply with the National Contingency Plan for future risk to human health and the environment by reducing exposure from an "off-site" groundwater pathway.	H
Gather necessary technical and cost data for groundwater pump-and-treat to support a final decision for groundwater remediation.	H
Maintain favorable public (and regulatory) perception of the plant program by being proactive.	H
Compare technologies for ^{99}Tc removal by treatment.	M-H
Maintain an action bias to avoid being directed by others.	M
Keep commitments already made by plant management: "Groundwater will be cleaned up."	M-L

EXECUTIVE SUMMARY

This report contains the evaluation and recommendations of a Groundwater Corrective Actions Review Team that was assembled at the request of R.C. Sleeman, U.S. Department of Energy Oak Ridge Field Office (DOE-OR), on March 23, 1992. The primary goal of the review team is to evaluate the technical merit of and the need to implement a proposed groundwater pump-and-treat demonstration project for the Northwest contaminant plume at Paducah, Kentucky. A key distinction recognized by the review team is that the proposed project is intended to be a full-scale hydraulic containment of contaminants migrating from the sources of the plume, not plume remediation.

A decision tree was constructed as a framework for evaluating the various available options and the proposed plan. The key questions incorporated into this tree are whether (1) dense, nonaqueous-phase liquids (DNAPLs) are present in the Regional Gravel Aquifer (RGA) at the source of the plume and (2) ^{99}Tc removal must be included as part of any groundwater treatment process. The first question cannot be answered until the contaminant sources are better defined; the second question requires further risk assessment and/or a policy decision by DOE.

The regulatory status of any remedial activity at the Paducah Gaseous Diffusion Plant (PGDP) is that the U.S. Environmental Protection Agency administrator has authority under the Hazardous and Solid Waste Amendments Permit to require submission of a work plan and to make interim decisions on actions to be taken. Permit requirements dictate that the plan be submitted no later than June 29, 1992; although DOE-OR promised a deadline of May 22, 1992.

As formulated, the current work plan could be implemented. However, independent estimates suggest that the anticipated $7 million cost is low by at least a factor of 2. Further, if ^{99}Tc removal is required, an intermediate-scale (i.e., single well at 10 gpm) pilot test of the treatment technology is recommended. Without such a test, there is significant risk that costly design changes will be required.

The estimated health risk to affected residents under present conditions does not include benefits from the alternate supply of domestic water being provided. Further, there has been no determination of how contaminant concentrations will change as a result of the proposed demonstration, so there is no basis for estimating how long the source-control measure will be required.

Technical evaluation by the review team suggests that the recommended course of action be to modify the proposed work plan to include accurate identification of the sources of contaminants and vertical distribution of contaminants within the Northwest plume ***before*** a decision is made on the preferred source-control option. If DNAPLs are not present in the RGA, removal or containment of the sources is recommended. If DNAPLs are present, then hydraulic containment will be required. Finally, the review team recognizes that it is necessary to initiate a more comprehensive analysis of sitewide remediation needs to create links between action taken for the Northwest plume and action taken for other contamination sites at PGPD.

1. INTRODUCTION

1.1 SITE BACKGROUND

In July 1988, the Purchase District Health Department sampled several residential wells north of the Paducah Gaseous Diffusion Plant (PGDP) in response to questions from a citizen concerning the quality of his water. Upon analysis of these samples, elevated gross beta levels indicative of the presence of radionuclide contamination were discovered. On August 9, 1988, these results were reported to PGDP, and plant personnel sampled private groundwater wells around the plant on the following day. Upon analysis, some of these samples were found to contain elevated levels of both trichloroethylene (TCE) and ^{99}Tc. An alternative source of potable water for household use was immediately provided to the five affected residences, and in November 1988 each of these households was connected to a municipal water supply at PGDP expense. DOE established the policy that if detectable levels of either TCE or ^{99}Tc are discovered in groundwater from wells that supply private residences and it is determined that PGDP is the likely source of the contamination, the homeowner will be offered connection to a municipal water system at PGDP expense. As of May 1, 1992, seven residences have been supplied with municipal water. An aggressive program of analysis of private well water in the vicinity of known off-site contamination continues to ensure that new occurrences of contamination will be identified rapidly and that an alternate source of water will be supplied.

Subsequent investigations at PGDP demonstrate that TCE and ^{99}Tc are the primary contaminants in off-site groundwater. Other contaminants identified in some monitoring wells that sample off-site groundwater generally occur at low concentrations and are of lesser environmental concern. These include selected volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), inorganic elements, and radionuclides.[1]

TCE has been used as a cleaning solvent at PGDP since its construction. Process piping and equipment used in the cascade system and in the electrical switchyards have been cleaned routinely with TCE. In addition, in 1986 TCE was discovered to have been directly discharged to soils from a leak in a sump pump in a degreaser area in the C-400 Building.

Technetium-99 is considered to have originated as a waste product from uranium enrichment processes used at PGDP. From 1953 until 1977, a feed plant (the C-410 Building) was in operation at PGDP. This feed plant converted both natural uranium and uranium reactor tailings to the uranium hexafluoride feed used in the cascade processes. Natural uranium ores do not contain ^{99}Tc; however, the reactor tailings, which came from plutonium production reactors at DOE sites Hanford, Washington, and Savannah River, South Carolina, were known to be contaminated with transuranic elements and fission products such as ^{99}Tc. Some of these contaminants are suspected to have escaped to the environment during the

[1] Dr. Stanley Davis, one of the consultants to the review team, noted that for some groundwater samples there is a poor balance between the amounts of total beta activity and the activity from ^{99}Tc. Before any final decisions are made on treatment technology, the presence or absence of other man-made beta emitters in the Northwest plume should be verified (see Appendix C).

cleaning of process equipment. No other sources of transuranics or ^{99}Tc are known to have existed at PGDP.

On November 23, 1988, DOE and the U.S. Environmental Protection Agency (EPA) entered into an Administrative Consent Order (ACO) under Sects. 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the off-site contamination. To achieve the ACO objectives, PGDP instituted a two-phase project. Phase I, which began in the summer of 1989 and concluded in March 1991, involved evaluating the nature and extent of off-site contamination originating from the plant (CH2M Hill 1991); Phase II began in November 1990 and concluded in October 1991 and involved evaluating the location of on-site sources of off-site contamination and developing an initial list of remedial alternatives (CH2M Hill 1992). A public health and ecological assessment is included as part of the Phase II report (Volume 6), and a formal evaluation of remedial alternatives also was prepared (SAIC 1991).

In September 1991, a consultant to PGDP, Dr. Bernard Kueper, was asked to evaluate the potential for dense nonaqueous-phase liquids (DNAPLs) to exist at the site. Available evidence of the observed concentrations of TCE in groundwater around the C-400 Building and near the northwest corner of the site suggests that it is prudent to assume that until proven otherwise, pure-phase DNAPL is present in the subsurface to the base of the Regional Gravel Aquifer (RGA), the most important shallow aquifer in the vicinity of PGDP. PGDP was cautioned that with existing technology, remediation of DNAPL sources is not a practical option and attempts to remediate actually may exacerbate the problem by causing unpredictable redistribution of DNAPLs (Kueper 1991). If this assumption is correct, then for the hydrogeologic setting at PGDP, far-field hydraulic containment of the DNAPL source using a pump-and-treat methodology may be the only safe alternative available for controlling further migration of TCE from the source.

Based on these assumptions and the results of a screening of remedial alternatives, PGDP decided upon a strategy of hydraulic containment of the source of a major off-site plume (Northwest plume) by groundwater pumping and treatment. This containment study will provide key technical information that will be applicable to expanded remediation efforts for other areas of off-site contamination.

1.2 DESCRIPTION OF THE PROPOSED PILOT PUMP-AND-TREAT DEMONSTRATION

The ER Program at PGDP proposes to construct and operate a pump-and-treat system to completely capture contaminated groundwater released from the source(s) of the Northwest plume and demonstrate treatment technologies (SAIC 1992). Contaminated water will be collected from a well field consisting of five or more 8-in. diam., high-capacity pumping wells fitted with submersible pumps. Contaminated water will be pumped to a central treatment area where various processes will be used to remove contaminants from the groundwater. The design-basis flow rate for the treatment facility is 250 gpm, and the central treatment area will include the following processes.

- Inlet and discharge tanks to provide adequate capacity to stabilize flow to the treatment facility.

- An inlet filter and iron filter to remove particulates so that process equipment is protected and water quality is improved.
- Reverse osmosis, ion exchange, and iron treatment units to evaluate effectiveness in removing ^{99}Tc
- An air stripper for removing TCE and TCE degradation products.

Treated water from the facility will be discharged by pipeline to the existing north-south diversion ditch through Kentucky Pollutant Discharge Elimination System (KPDES) outfall 018. A heated and ventilated building will be provided to house all of the process equipment except for the air stripper. The building will also house a laboratory.

A work plan for the proposed action was scheduled to be submitted to EPA Region IV by May 22, 1992. The design for the facility, to be performed by EBASCO, is scheduled to be completed by November 1992. The facility will be constructed by MK Ferguson and will be completed by April 1994. Operation/evaluation of the pilot facility is planned for 1 year's duration beginning in May 1994 and ending by May 1995.

1.3 REGULATORY FRAMEWORK

This section summarizes the regulatory issues associated with off-site contamination of groundwater at PGDP and the proposed interim corrective measure. A more detailed analysis is presented in Appendix D.

On July 16, 1991, a Hazardous and Solid Waste Amendments (HSWA) Permit was issued to PGDP. DOE was cited as the owner/operator and Martin Marietta Energy Systems, Inc., as the co-operator of the facility. The effective date of this permit is August 19, 1991. This permit, in conjunction with the Hazardous Waste Management Permit issued by the Commonwealth of Kentucky, constitutes the Resource Conservation and Recovery Act (RCRA) Permit, for PGDP. The HSWA Permit requires PGDP to investigate any releases of hazardous waste or hazardous constituents pursuant to this permit at PGDP, regardless of the time at which the waste was placed in such unit, and to take appropriate corrective action for any releases [Sect. 3004(u) of RCRA], including corrective actions beyond the facility boundary [Sect. 3004(v) of RCRA]. This permit also stipulates that PGDP must comply with all terms and conditions of the ACO under CERCLA Sects. 104 and 106.

The ACO was signed by DOE and EPA and approved by the Department of Justice. The effective date is November 23, 1988. Section II of this ACO, "Statement of Purpose," stipulates these items:

"In entering this Consent Order, the mutual objectives of EPA and DOE include the following:

- to determine fully the nature and extent of the threat to human health or welfare and the environment caused by the off-site contamination of the groundwater from the PGDP;

- to ensure that the environmental effects associated with the releases described herein are thoroughly investigated and appropriate action is taken as necessary to protect the public health, welfare, and the environment;
- to establish a work plan and schedule(s) for developing, implementing, and monitoring any necessary response actions at the site in accordance with CERCLA; and,
- to facilitate the cooperation, exchange of information, and participation of the parties in such action."

As noted in Sect. 1.1., the ACO resulted in two phases of site investigation by PGDP. The Phase I report (CH2M Hill 1991), which was to investigate the contamination of groundwater and surface water from PGDP, both on- and off-site, was finalized and approved by EPA in July 1991. The Phase II report (CH2M Hill 1992), which was to fill in data gaps from Phase I and identify contaminant sources, was finalized and forwarded to EPA in April 1992. As of April 16, 1992, the Phase II report has not been approved. The summary of remedial alternatives for PGDP (SAIC, 1991) was prepared and forwarded in draft to EPA in December 1991. Comments were due from EPA in May 1992.

On March 31, 1992, EPA and the Kentucky Department for Environmental Protection (KYDEP) jointly issued a letter directing DOE: "pursuant to Condition II.E.1.a. of the EPA RCRA Permit and Condition IV.E.1.a. of the state RCRA Permit, to carry out interim corrective measures for the off-site releases associated with sources contributing to these off-site releases." This March 31, 1992, letter references DOE's two corrective measures activities that were described in the DOE letter of February 27, 1992, to EPA. The two identified measures were these:

> "First, we plan to pursue a groundwater Pump and Treat Pilot system. The goal of this is to prevent further migration of contaminated groundwater."
>
> "Additionally, we will be pursuing Institutional Controls as an Interim Measure for Outfalls, Creeks, and Lagoons....signs warning against consumption of fish from the creeks and outfalls, and against recreational use would be posted to minimize the risks from direct contact with contaminated sediments and ingestion of contaminated fish. Fences would be installed along outfall 011 and Little Bayou Creek to McCaw Road and along the North-South Diversion Ditch (outfall 003) to Ogden Landing Road. Fences would be extended around waste management unit (WMU) 18 to limit access to humans and some migratory wildlife (deer)."

Interim measures may encompass a broad range of possible actions. For example, a facility that has contaminated a public drinking water supply may be required to make alternate drinking water available or initiate a groundwater pump-and-treat system to control further migration of the plume. Section II.E.1.b. of the HSWA Permit states that interim measures are designed to mitigate any current or potential threat(s) to human health or the environment and are consistent with and integrated into any long-range solution at the facility.

The March 31, 1992, letter from EPA and KYDEP stipulates that a work plan to carry out interim corrective measures for the off-site releases associated with sources contributing to these off-site releases should be forwarded to EPA by May 22, 1992, per DOE's letter of February 27, 1992. However, Condition II.E.1.a. of the HSWA Permit states that the work

plan shall be submitted within 90 days of notification by the regional administrator. This notification was the March 31, 1992, letter from EPA and KYDEP. Thus, the latest due date for submission of this work plan should be June 29, 1992, according to the requirements of the HSWA Permit.

The evaluation of alternatives for remediation of groundwater at PGDP included consideration of pump-and-treat technology to intercept and remove TCE and ^{99}Tc from the groundwater and prevent the continued spread of contamination downgradient of PGDP. The pilot demonstration work plan describes a treatment facility to remove contaminants from groundwater and provides data needed to select among treatment options for scaling up. The work plan is consistent with the intent of Sect. II.E.1.a. of the HSWA Permit for an Interim Measures work plan.

On September 1, 1991, DOE and Energy Systems forwarded comments during the public comment period on the draft RCRA permits from EPA and KYDEP. Comment 17 requested to expand the dispute resolution clause to include all sections under Part II (corrective action) of the RCRA HSWA Permits. DOE and Energy Systems were concerned about the impact of revisions of RCRA Facility Investigation (RFI) work plans and other plans by the regional administrator and the impacts that these changes may have on the schedules and available resources for implementation of the plan or on other work under the HSWA Permit.

EPA responded that it too was concerned about the impact to schedules and resources resulting from revisions of RFI work plans and other plans required by EPA. Such concerns have been expressed previously in the Administrative Order Denying Review of a HSWA Permit issued to United Technology Corporation/Pratt & Whitney Group (RCRA Appeal No. 88-34, dated February 12, 1990). Under that appeal, the petitioner argued that the permit improperly made no provisions for an administrative appeal (or dispute resolution) of certain interim decisions and approvals by the regional EPA office during the corrective action process. These interim decisions and approvals generally involve reviews of various work plans, schedules, and even interim measures.

The administrator decided that allowing an administrative appeal from such interim decisions and approvals would lead to unnecessary and undesirable delays in the corrective action process. Should the petitioner be dissatisfied with an interim decision by the regional EPA office, the petitioner is free to pursue any available opportunities for judicial review. The administrator also declared that the permit properly gives final authority to the regional EPA office to make various interim decisions during the corrective action process; the ultimate corrective measures are to be added to the permit through a major modification. DOE and Energy Systems did not choose to appeal this permit on the basis of the conditions of a no-dispute-resolution clause in Sect. II.

2. BACKGROUND

2.1 HYDROGEOLOGY

2.1.1 Geology

PGDP lies near the northern margin of the Mississippi Embayment: a large north-south trending, sediment-filled trough that existed during Cretaceous and Tertiary time. The sedimentary sequence found in the vicinity of PGDP consists primarily of fine- to medium-grained clastic materials including (from oldest to youngest) a basal gravel (Tuscaloosa Formation), the McNairy Formation, the Porters Creek Clay, and undifferentiated Eocene sands. These units dip gently to the southwest toward the axis of the embayment.

Following deposition, uplift occurred and an erosional surface developed, truncating the sediments. Subsequently, during late Tertiary and Quaternary time a formation designated as the Continental Deposits was deposited in the region, and an angular unconformity with the underlying sediments resulted. Pleistocene loess, originating as wind-blown, glacial-derived material, was deposited immediately overlying the Continental Deposits.

The Continental Deposits can be subdivided into two facies: a lower gravel or sandy gravel unit, the Gravel Facies, that is reported to vary in thickness from 0 to 106 ft and an upper clay-sand unit, the Clay Facies, with a comparable range of thickness.

The Gravel Facies appears to be continuous from the southern part of PGDP, where it abuts against a buried fluvial terrace known as the Porters Creek Terrace, northward to the Ohio River. Stratigraphic correlation suggests that the Gravel Facies is present at the edge of the terrace escarpment at a thickness of less than 10 ft and that it thickens rapidly to the north. Near the Ohio River the Gravel Facies thins again. The Gravel Facies does not appear to correlate with the thin gravels observed on the top of the Porters Creek Terrace.

The Clay Facies of the Continental Deposits is believed to consist of discontinuous, fine sand lenses enclosed by the dominant clay. The lack of continuity of the interbedded sands has not been verified, but based on the interpretation of depositional environment, it is a logical assumption. Studies to date in the PGDP area continue to emphasize the vertical and lateral heterogeneity of the Clay Facies deposits. Vertical transmissivity within the Clay Facies is dependent on the interconnection of numerous lenticular sand bodies. Undoubtedly, any vertical migration path in this setting will be tortuous and unpredictable.

2.1.2 Hydrogeology

The Gravel Facies is commonly referred to as the RGA in the vicinity of PGDP and is a major aquifer within western McCracken County. It is saturated over most of its areal extent near PGDP, and wells completed in it are reportedly capable of producing yields as high as 1000 gpm. Insufficient data are available to define detailed flowpaths for the RGA near PGDP. However, potentiometric surface interpretations reported in the Phase I and Phase II reports (CH2M Hill 1991, 1992) and developed by PGDP hydrogeologists indicate that groundwater flow is generally northward from PGDP to the Ohio River. The known configuration of contaminant plumes within the RGA generally reinforces this interpretation.

The sand intervals in the Clay Facies make up the shallow groundwater system (SGS). Although potentiometric data have been obtained from the SGS, uncertainties about the continuity of the lenses cast doubt on the validity of available potentiometric maps.

In the vicinity of the Northwest plume, the RGA is a 30-ft thick heterogeneous sandy gravel with apparent anisotropic permeability. Apparently, it is at least semiconfined by the overlying Clay Facies. Based on several methods of investigation, hydraulic conductivity of the RGA in the vicinity of PGDP ranges over several orders of magnitude.

- Pumping tests yield values ranging from 1.8×10^{-4} to 7.8×10^{-2} cm/s (53 to 218 ft/d).
- Slug tests yield values ranging from 1.2×10^{-4} to 6.4×10^{-2} cm/s (0.34 to 181 ft/d).
- Model analyses suggest hydraulic conductivities as high as 0.25 cm/s (725 ft/d).

Slug testing for other pertinent formations yields the following ranges of hydraulic conductivity.

- SGS from 2.1×10^{-7} to 4.9×10^{-3} cm/s (5.9×10^{-4} to 13.9 ft/d).
- Porters Creek Clay from 2.0×10^{-7} to 2.4×10^{-4} (5.7×10^{-4} to 0.68 ft/d).
- McNairy Formation from 2.9×10^{-7} to 2.4×10^{-4} cm/s (8.2×10^{-4} to 0.68 ft/d).

Mean flow velocities for the RGA reportedly ranged from 3.6×10^{-2} to 0.76 m/d (0.12–2.24 ft/d). The velocities were based on pumping test data assuming porosity of 0.20 and a gradient of 0.0006. Alternatively, if one assumes that the release occurred in 1954, was instantaneous to the RGA, experienced no retardation, and had a gradient of 0.0006 and porosity of 0.20, the calculated flow velocity of the Northwest plume is 0.30 m/d (0.99 ft/d).

The review team was told during its evaluation that PGDP has considered the possibility that contaminated groundwater migrating off site potentially could flow under the Ohio River. Our hydrogeology consultant, Dr. S. N. Davis, has evaluated this possibility (see Appendix C) and suggests that if contamination is restricted to the RGA, such a scenario is unlikely. However, if contamination from PGDP has migrated into the Mississippian limestones that underlie the site at the depth of about 300 ft, one could not rule out underflow based on existing data. Dr. Davis suggests that PGDP should consider obtaining additional characterization data to address this possibility. Investigations to address entry of DNAPLs into the McNairy Formation should deal with this possibility.

2.1.3 Contaminant Distribution

The Northwest plume as currently configured has its upgradient end in the RGA in the vicinity of monitoring well (MW)-66, located near the northwest corner of the plant area (Fig. 1). TCE concentrations as high as 6200 µg/L have been observed in samples from MW-66. Dissolved ^{99}Tc has been detected in that well at concentrations as high as 3700 pCi/L. The plume extends to the north-northwest for at least 10,800 ft in an arcuate shape. Portion A of Fig. 1 illustrates the configuration of the plume for TCE; a similar plume map results when ^{99}Tc contamination in plotted (Portion B of Fig. 1). The plume appears to be relatively narrow in the vicinity of Ogden Landing Road where it is ~2500 ft wide; this is the region that has been chosen tentatively as the site for the proposed pumping wells. However, the plume width will become progressively narrower as the source is approached.

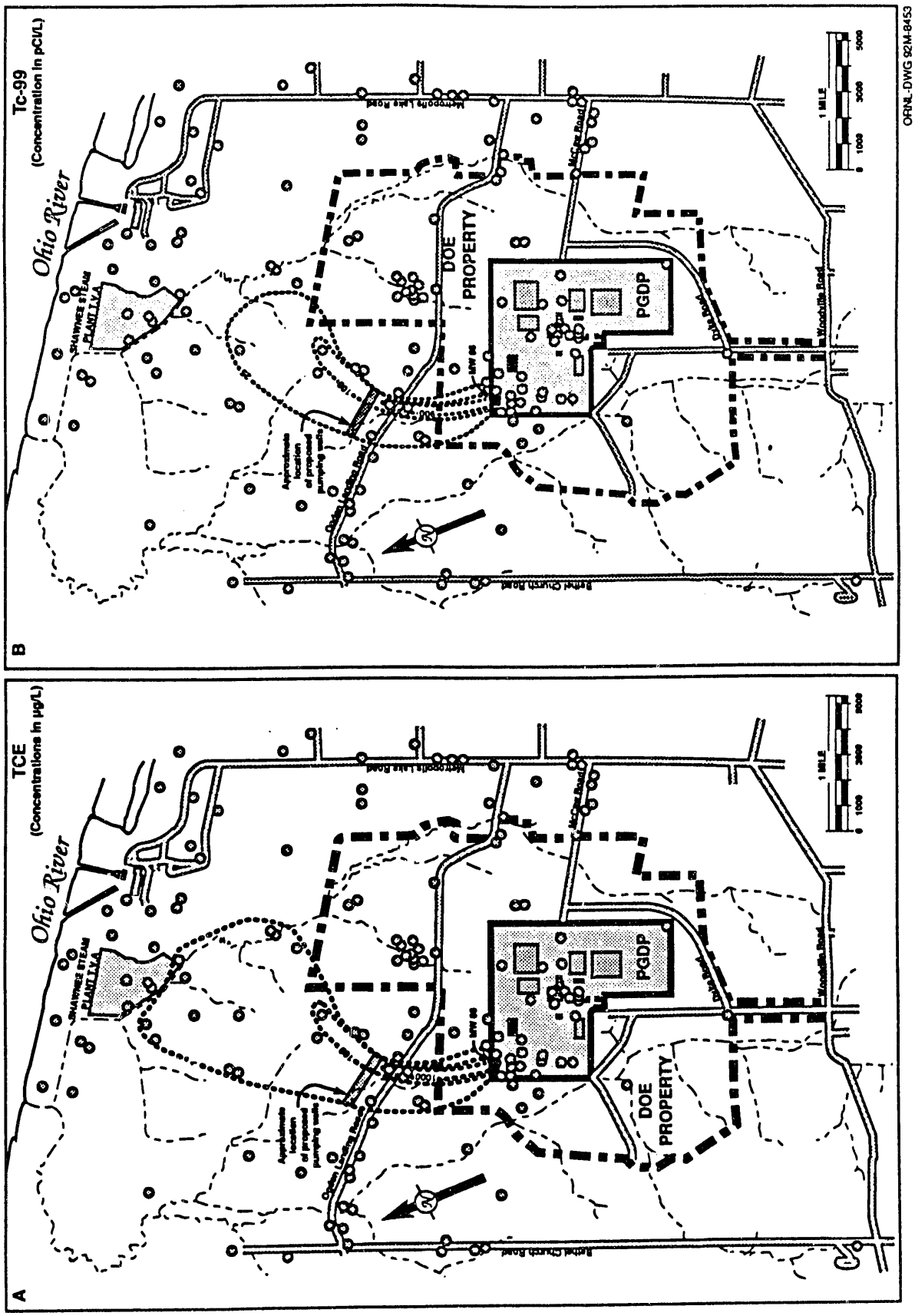

Fig. 1. Map for PGDP illustrating the location of the Northwest plume with respect to TCE (1A) and ^{99}Tc (1B) contamination.

Little is presently known about the vertical distribution of either TCE or ^{99}Tc within the RGA or, for that matter, about the distribution of aquifer hydraulic properties within that unit.

Although the areal configuration of the plume is defined within the constraints of existing well control and sample data, little is known of the actual source of the plume. Because of the potential for tortuous vertical migration pathways in the SGS, the actual source location may not be truly identified in three dimensions by the presence of TCE contamination in the wells in the RGA. The approach taken to contain the source will differ according to the location of the source in the vertical dimension and the pathway taken by contaminants from the source to the RGA.

2.2 CHARACTERIZATION OF RISK FROM USE OF GROUNDWATER OFF SITE

Risk from household use of groundwater drawn from wells near PGDP was determined in the Phase I and Phase II reports (CH2M Hill 1991, 1992). In this section, the results reported in these studies will be summarized with attention focused on the following:

- Methods and data used to characterize the risk in the Phase I and Phase II reports and
- Uncertainties in these risk calculations which affect their use as drivers in the construction of the proposed pump-and-treat project.

2.2.1 The Phase I Report

The purpose of the Phase I investigation (CH2M Hill 1991) was to evaluate the nature and extent of off-site contaminants originating from PGDP. Tables 6-2 and 6-10 in that report present a listing of contaminants detected in wells in the vicinity of PGDP during Phase I (see Appendix E). Risk characterization reported in that document did not result from a full and complete baseline risk assessment (BRA). Methods used in the report focused on the creation of a "snapshot" of the health risks that may arise from the level of contamination identified in Phase I of the site investigation. Of greatest importance was the fact that no attempt was made to model or project changes in contaminant concentration over time.

2.2.1.1 Risk characterization in Phase I report

Risk was characterized using methods described in EPA's *Guidelines for Health Risk Assessments of Chemical Mixtures* (EPA 1986a) and *Guidelines for Carcinogenic Risk Assessment* (EPA 1986b); risk was calculated for both average and reasonable maximum exposure. Risk characterization is summarized in Tables 6-36 through 6-39 and 6-53 of the Phase I report (see Appendix E). In calculations of risk under average exposure conditions, average concentration of contaminants was used, and exposure factors were average values. In calculations of risk under reasonable maximum exposure conditions, the maximum concentration of contaminants was used, and exposure factors were 90th percentile values. Under average exposure assumptions, the total lifetime excess cancer risk from exposure to chemicals in groundwater drawn from residential, monitoring, and Tennessee Valley Authority (TVA) monitoring wells associated with the nearby Shawnee Steam Plant was determined to be 4×10^{-5}, 1.5×10^{-5}, and 1.2×10^{-6}, respectively. The contaminants driving risk under these assumptions were TCE and arsenic for residential wells; arsenic, bis(2-ethylhexyl)phthalate, and TCE for monitoring wells; and TCE for TVA wells. Under reasonable maximum exposure

assumptions, the total lifetime excess cancer risk from exposure to samples drawn from residential, monitoring, and TVA wells was determined to be 6×10^{-4}, 1.8×10^{-4}, and 7.5×10^{-4}, respectively. The contaminants driving risk under these assumptions were TCE, arsenic, and bis(2-ethylhexyl)phthalate for residential wells; bis(2-ethylhexyl)phthalate, TCE, and arsenic for monitoring wells; and arsenic for TVA wells.

Under average exposure assumptions, the total lifetime excess cancer risk from exposure to radionuclides in groundwater drawn from residential, monitoring, and TVA wells was determined to be 4.4×10^{-6}, 2.8×10^{-6}, and 9.8×10^{-6}, respectively. The contaminants driving risk under these assumptions were ^{234}U, ^{238}U, and ^{99}Tc for residential wells; ^{234}U, ^{238}U, and ^{99}Tc for monitoring wells; and ^{234}U, ^{235}U, ^{238}U, and ^{99}Tc for TVA wells. Under reasonable maximum exposure assumptions, the total lifetime excess cancer risk from exposure to samples drawn from residential, monitoring, and TVA wells was determined to be 5.4×10^{-5}, 4.9×10^{-5}, and 3.2×10^{-4}, respectively. The contaminants driving risk under these assumptions were ^{99}Tc, ^{234}U, and ^{238}U for residential wells; ^{234}U, ^{238}U, and ^{99}Tc for monitoring wells; and ^{234}U, ^{235}U, and ^{238}U for TVA wells.

Under average exposure assumptions, the hazard indexes (measures of systemic toxicity) from exposure to chemicals in groundwater drawn from residential, monitoring, and TVA wells were determined to be 0.9, 1.1, and 0.5, respectively. The contaminants driving risk under these assumptions were carbon tetrachloride, cadmium, and bis(2-ethylhexyl)phthalate for residential wells; chromium, manganese, cadmium, silver, and bis(2-ethylhexyl)phthalate for monitoring wells; and manganese, chromium, and barium for TVA wells. Under reasonable maximum exposure assumptions, the hazard indexes from exposure to samples drawn from residential, monitoring, and TVA wells were determined to be 2.7, 3.9, and 1.7, respectively. The contaminants driving risk under these assumptions were chromium, carbon tetrachloride, manganese, and bis(2-ethylhexyl)phthalate for residential wells; chromium, manganese, bis(2-ethylhexyl)phthalate, and barium for monitoring wells; and manganese, chromium, and barium for TVA wells.

2.2.1.2 Pertinent uncertainties in the Phase I risk calculations

Uncertainties in the Phase I risk assessment and their effects on the determination of risk are presented in Table 6-66 of the Phase I report (CH2M Hill 1991). Most uncertainties found in this table are common to all risk assessments (e.g., uncertainties related to cancer potency factors, toxicity values, effect of absorption, magnitude of exposure factors, assumption of additive effects, etc.); several uncertainties unique to this assessment are listed below.

- Not all possible exposure routes were quantified. Dermal contact with groundwater was not assessed quantitatively in this assessment. Although this pathway tends to contribute little to cumulative risk in risk assessments, not assessing this pathway reduces the estimated cumulative risk.

- For the inhalation pathway, not all possible routes of exposure were considered. Because the area around PGDP is rural, use of groundwater by residents for agricultural purposes is likely (e.g., irrigation of crops). Because water droplets in air are likely to be created during spray irrigation, risk from inhalation of contaminants in groundwater may be greater than presented because of underestimation of exposure frequency, exposure

duration, and rate of intake of contaminants. Similarly, risk from dermal exposure becomes more important under an assumption of widespread irrigation.

- Current concentrations are used to determine future risk. Because the source of contamination was not determined before the Phase I assessment was performed, it was not possible to determine the magnitude of increase or decrease of contaminant concentrations that may occur in the future. This uncertainty may lead to an underestimate or overestimate of risk.

- Level of risk was not determined for specific areas. Although wells were categorized as residential, monitoring, or TVA, no determination of plume-specific risk was performed. Because off-site risk under average conditions was determined using contaminant concentrations averaged over all detected concentrations, the risk calculated under the average-conditions exposure scenario may have underestimated or overestimated the risk posed by contamination in the Northwest plume.

2.2.2 The Phase II Report

The purpose of the Phase II investigation (CH2M Hill 1992) was to further evaluate the nature and extent of any risk arising from off-site contamination originating from PGDP, to determine and characterize the on-site units, and to identify contaminant migration pathways that may contribute to off-site contamination. Tables 2-1 and 2-2 from that report present a listing of contaminants detected in wells in the vicinity of PGDP during Phase II (see Appendix E).

During this investigation of groundwater contaminati... additional well clusters were installed, and both the newly installed and existing monit... ng wells and some residential groundwater wells were sampled. As with the Phase I report, the sampling program was extensive; 333 locations were sampled.

Risk characterization reported in the Phase II document did result from a BRA. Methods used in the Phase II report focused on the risk posed by contaminants migrating in groundwater from selected waste units. As with the Phase I report, no attempt was made to model or project changes in contaminant concentration over time.

Because the purpose of this report is to address off-site contamination as it relates to the Northwest contaminant plume, only cumulative off-site risk and risk from potential use of water drawn from monitoring wells MW-134 and MW-200 is summarized below (see Fig. 4 for the location of MW-134 and MW-200).

2.2.2.1 Risk characterization in Phase II BRA

Risk was characterized using methods described in EPA's *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A* (EPA 1989). In addition, cumulative risk from multiple exposure pathways and chemicals was determined using methods described in *Guidelines for the Health Risk Assessment of Chemical Mixtures* (EPA 1986a) and *Guidelines for Carcinogen Risk Assessments* (EPA 1986b).

Risk characterization is summarized in the Phase II report in Table 3-13 (see Appendix E). The total lifetime excess cancer risk from exposure to chemicals in groundwater

drawn from residential, off-site monitoring, and TVA wells and MW-134 and MW-200 was determined to be 7×10^{-4}, 5×10^{-4}, 3×10^{-3}, 6×10^{-5}, and 5×10^{-4}, respectively. The contaminants driving risk were TCE, arsenic, and beryllium for all well categories.

The total lifetime excess cancer risk from exposure to radionuclides in groundwater drawn from residential, monitoring, and TVA wells and MW-134 and MW-200 was determined to be 3×10^{-5}, 2×10^{-5}, 6×10^{-5}, 7×10^{-6}, and 6×10^{-6}, respectively. The contaminants driving risk were ^{99}Tc, ^{234}U, ^{238}U, and ^{237}Np for residential wells; ^{234}U, ^{238}U, and ^{239}Pu for off-site monitoring wells; ^{238}U and ^{234}U for TVA wells; ^{99}Tc, ^{234}U, and ^{238}U for MW-134; and ^{99}Tc and ^{238}U for MW-200.

The hazard indexes (measures of systemic toxicity) from exposure to chemicals in groundwater drawn from residential, off-site monitoring, and TVA wells and MW-134 and MW-200 were determined to be 3.3, 2.6, 8.8, 0.3, and 3.2, respectively. The contaminants driving risk were carbon tetrachloride, antimony, and thallium for residential wells; silver, beryllium, and chromium for off-site monitoring wells; antimony, manganese, and arsenic for TVA wells; manganese, barium, and arsenic for MW-134; and chromium, vanadium, and beryllium for MW-200.

2.2.2.2 Pertinent uncertainties in the Phase II BRA

Uncertainties in the Phase II risk assessment and their effects on the determination of risk are presented in Table 3-33 of the Phase II BRA (CH2M Hill 1992). As with the Phase I report, most uncertainties found in this table are common to all risk assessments (e.g., uncertainties related to cancer potency factors, toxicity values, effect of absorption, magnitude of exposure factors, assumption of additive effects, etc.); however, several uncertainties are unique to this assessment and are similar to those listed in Sect. 2.2.1.2.

2.3 REMEDIAL ALTERNATIVES EVALUATION

2.3.1 General Information

The summary of remedial alternatives (SAIC 1991) is intended to be a summary of all potential remedial alternatives (preliminary screening summary under CERCLA) that could be used as the selected remedial alternative or corrective measure for contaminated sites at the plant. It is a sitewide document.

A portion of this document addresses the potential remedial alternatives that are applicable to groundwater contamination. The goal of the remedial alternative selected is to address groundwater contamination to reduce the toxicity and mobility and/or contain the area of contaminated groundwater as it relates to source control. An important factor in the selection of any remedial activity is the determination of the remedial activity goal as it relates to the EPA criteria that were considered for remediation.

As noted in Sect. 1.3, PGDP plans to install a combined pilot system for a groundwater pump-and-treat facility with a treatability study to determine the optimum methodology for addressing TCE and ^{99}Tc removal associated with the Northwest plume. As proposed, the system is also large enough to act as a hydraulic barrier to further migration of contamination from suspected sources but is not intended to capture all of the contaminated groundwater

in the Northwest plume. It is not currently known whether pure-phase DNAPLs are a factor in the formation of the dissolved contaminant plume. This uncertainty should be resolved before a preferred method of source control can be defined.

2.3.2 Initial Alternative Selection

2.3.2.1 Containment

During the initial alternative selection process, ten activities were selected for consideration under the containment response action. These were divided into six activities for the control of groundwater by vertical barriers and four for the control of groundwater by horizontal barriers. Of the ten response actions, only three survived the initial screening activity. The three response actions were all related to the same type of activity (i.e., the creation of an impermeable barrier in the form of a soil-bentonite slurry, a cement-bentonite slurry, or a grout curtain wall).

2.3.2.2 Removal

Under the removal response action, only two activities were initially selected: well construction and the installation of subsurface drains. Both survived the initial screening activity.

2.3.2.3 Treatment

Under the treatment response action, 25 treatment technologies were identified during the initial screening of alternatives. Of the 25 technologies identified, 18 were carried forward for the detailed analysis-of-alternatives phase.

2.3.3 Alternatives Selected After the Initial Screening

After the 12 initial technologies identified for the containment or removal of groundwater were screened, only 5 were further developed within the detailed evaluation of alternatives. The technologies that were carried forward represent two basic types: (1) the creation of a slurry wall or some other impenetrable barrier and (2) the pump-and-treat scenario. During the evaluation, the pump-and-treat system was not identified as a containment technology but as a removal technology. However, during the detailed discussion, the pump-and-treat system was defined as two systems: one designed as a remediation technology and the other as a containment technology.

3. TECHNICAL EVALUATION

3.1 EVALUATION STRATEGY

In the preparation of this report, the review team evaluated a broad range of technical data associated with the hydrogeology of the PGDP site as well as available remedial and treatment technologies. The team believes that there are two key questions that must be answered before final development of a comprehensive strategy for source control for the Northwest plume. First, are pure-phase DNAPLs that will act as a long-term source of dissolved TCE present in the RGA? Second, is removal of ^{99}Tc from groundwater a required part of the chosen treatment process? The first question cannot be answered without additional field work to better define the source(s) of the Northwest plume. The second question requires a decision, perhaps based upon a risk analysis, the determination of alternate concentration limits (ACLs), or established DOE policies. On the basis of these fundamental questions, it is possible to construct a decision tree to help guide PGDP in the development of a comprehensive work plan (Fig. 2).

The value of this tree is that it explicitly identifies categories of appropriate source-control alternatives as a consequence of the decision process and clearly illustrates how one justifies the choice among these alternatives.

3.2 TREATMENT EVALUATION

3.2.1 Pilot Plant Evaluation

In general, pilot plant studies are desirable whenever any of the following are true.

- The technical feasibility of the treatment is unknown or uncertain.
- The cost feasibility is uncertain.
- Process modifications or refinements may be beneficial.
- Bench-scale tests were performed on synthetic rather than actual contaminated water.
- Random, intermittent phenomena are present that cannot be adequately simulated.

At least two of these factors are true for the proposed pump-and-treat project. For the removal of ^{99}Tc, reverse osmosis and ion-exchange processes are being considered. Although these are appropriate choices, the bench-scale laboratory experiments on both technologies were terminated prior to establishment of good end-point and economic evaluations of the treatment processes. Additionally, only a synthetic groundwater was used to generate the laboratory information on reverse osmosis for ^{99}Tc removal. Furthermore, flat-plate equipment was used rather than tubular equipment, which is more common in full-scale operations. There is concern that the groundwater may contain constituents that may have detrimental long-term effects on membrane performance. Therefore, a pilot plant study would seem appropriate for this application.

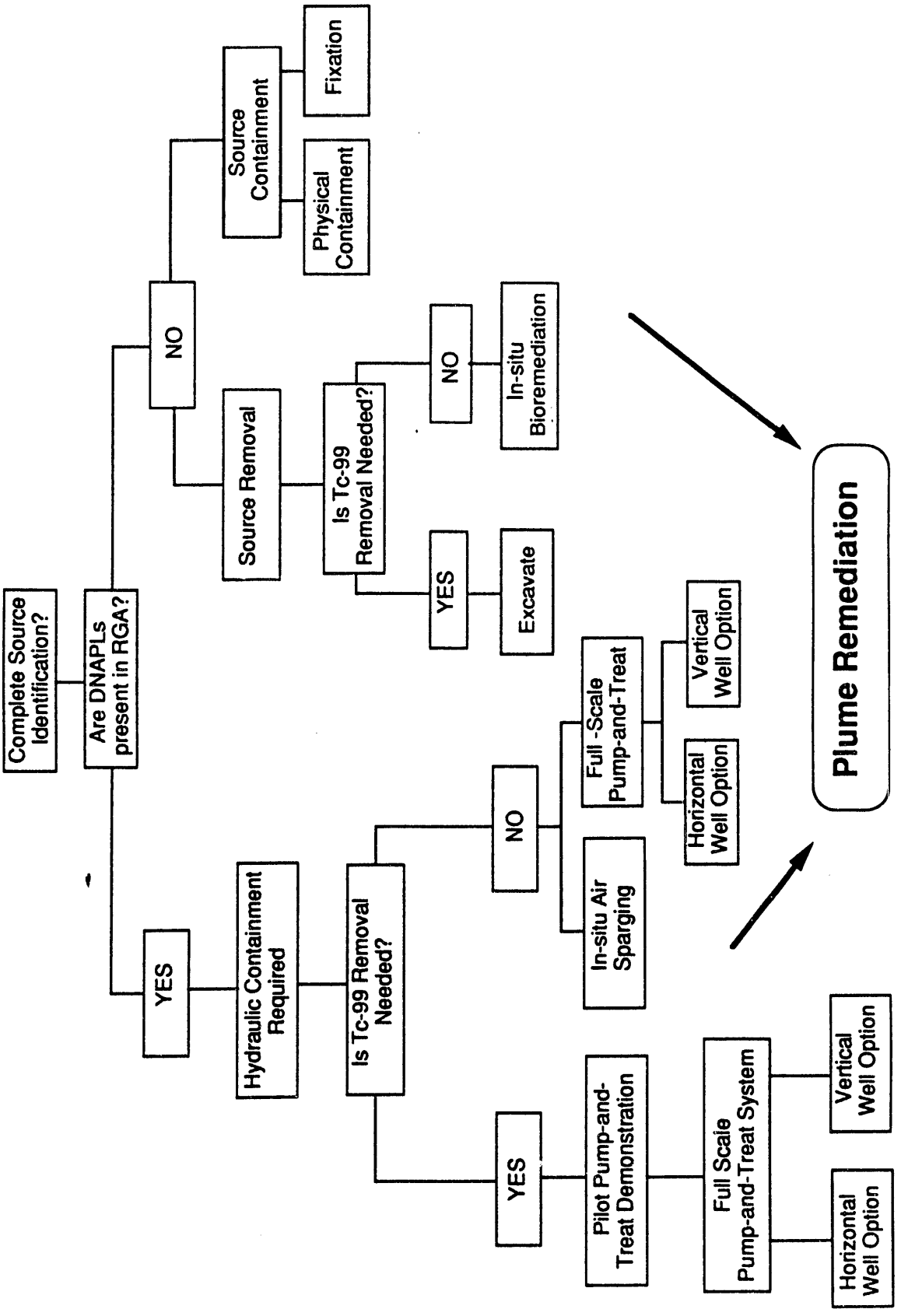

Fig. 2. Decision tree for source control of the Northwest plume.

Pilot plants are usually in the range of 10 gpm. The 250-gpm flow rate proposed for the pilot study indicates that other objectives (e.g., hydraulic containment) exist for the project. Appropriate scale-up information on the technologies at the 10-gpm loading level could reduce the potential for later design modifications. Therefore, it is recommended that a smaller-scale pilot study be conducted before finalizing the design for the full-scale facility. The pilot plant should be configured using the laboratory data and run long enough to go through three or more cycles to test operational and long-term loading criteria (i.e., to what extent deterioration will occur over time).

The draft treatability test work plan (SAIC 1992) includes several objectives in Sect. 3 for this pilot-scale facility. The criteria specified in this section, with the addition of the cost of waste treatment and disposal, appear to be appropriate. This cost could be significantly different for the options being considered for ^{99}Tc treatment.

From a risk assessment perspective, the need for treatment of ^{99}Tc is questioned by the review team. Should it be determined that ^{99}Tc treatment is not required and only TCE and degradation products must be treated, there would not be a strong driver to implement a pilot-scale facility prior to full-scale operation. TCE and other volatile organics are very common groundwater contaminants. Air stripping, as is proposed for the PGDP pump-and-treat pilot-scale facility, is used frequently for remediation of groundwater with volatile organic contamination. A comprehensive literature search and possibly small-scale bench test is recommended, but the technological risk of implementing a full-scale facility without first performing pilot-scale studies for air stripping is fairly low.

In summary, it is appropriate to perform a pilot plant study for this project (assuming ^{99}Tc treatment is necessary), but it should be at a smaller scale than proposed to evaluate the treatment technologies. The processes selected are appropriate, and the treatment objectives are good. The pilot-scale evaluation should also include an evaluation of waste-treatment and disposal costs. The pilot plant should be run long enough to provide long-term operational and loading information.

3.2.2 Cost Assessment

The cost of the proposed project is estimated in the work plan to be ~$7 million. The cost estimate [Sect. 15 in the treatability test work plan for PGDP (SAIC 1992)] provides some detail of the items costed for this project. However, there are several items missing from the estimate that will have significant impact on the total estimated cost for the project.

Cost Items

- The cost of the building is underestimated at $8/ft^2; it should be a factor of 3 higher. It appears that allowances were not made for the slab and foundation.
- The allowance for lighting appears to be low, and there is little mention of any other electrical requirements for this facility. The electrical cost for such a facility could be as much as a factor of 10 higher.
- The heating ventilation air conditioning allowance appears to be low by a factor of 4.
- Site development costs are not included.
- The workhours for the installation of the high-density polyethylene pipe are not included.

- Fire protection requirements are not addressed.
- Sidewalks, platforms, and handrails for accessing the equipment were not included.
- Costs to extend utilities to the facility are not included.
- An equalization tank for incoming wastewater and a holding tank for treated wastewater are sized to be ~2000 gal. On the basis of the incoming flow rate of 250 gpm assumed for this test, the tanks have only an 8-min capacity and are undersized.
- It cannot be determined from the description given in the referenced Work Breakdown Structure whether the wells are appropriately priced.

General Cost Factors

- The cost to design the facility was not included. For this type of project, design costs would be ~20–25% of the construction costs.
- Construction management costs, usually 20–25% of the fixed price construction costs, were not included.
- No consideration was given to Paducah general and administrative and general plant services overhead rates.
- Escalation rates are not included.
- Contingency costs, usually about 20%, were not included.

The operating costs are based on the facility operating for 1 year only. As an interim measure, it is questionable whether the facility operation can be discontinued after 1 year. Therefore, the operating costs beyond 1 year of operation also should be considered. Items included in the cost estimate addressing operating costs include laboratory analysis of samples, technician labor, and data management. However, personnel training and physicals and the costs to treat and dispose of operational waste streams were not included.

In summary, a refined and more complete cost estimate should be prepared for this project which addresses, at a minimum, the items listed above. Based on this initial assessment, the cost of the project potentially could increase by a factor of 2 or more.

The pilot plant evaluation leads to a recommendation that a smaller scale facility, 10 gpm, be considered instead of one of 250 gpm. Obviously, the costs of a smaller scale facility would be less. A common "rule of thumb" used in arriving at ratios for the costs of various scales of facilities is to divide the proposed capacity (10 gpm) by the baseline capacity (250 gpm), raise it to the 0.6 power, and multiply by baseline costs. When this formula is applied, the estimated cost of the 10-gpm pilot-scale facility is projected to be ~15% of the estimated costs of the 250 gpm facility. However, before proceeding with a project that includes a 10-gpm flow rate facility, it is recommended that a complete cost estimate be prepared.

3.3 HYDROGEOLOGIC EVALUATION

3.3.1 Overview

From a hydrogeologic perspective, the acceptability of the proposed pilot pump-and-treat project depends on the specific objectives of the activity. There are no hydrogeologic reasons for conducting the test as a demonstration that adequate quantities of water can be extracted from the RGA; this has been proved adequately through several pumping tests performed by PGDP. However, if the objective is hydraulic containment of sources contributing to the Northwest plume, the approach is appropriate pending adequate characterization of the source. Likewise, if the objective of the demonstration is remediation of the Northwest plume, then it will be partially effective. However, the proposed location of the pumping well system upgradient of the midpoint of the plume will allow a significant portion of the plume to migrate further off site, probably to the Ohio River. This may or may not be acceptable pending the establishment of some performance standard or residual levels of contaminants that will be allowed to remain in the RGA.

It is appropriate to inquire as to what extent available data provide information about the location of the source of the Northwest plume and the presence or absence of pure-phase DNAPLs in the RGA.

The review team believes that existing hydrochemical data from groundwater samples collected from the vicinity of the Northwest plume indicate that the source(s) of this plume is near the northwest corner of the plant (see Fig. 1). Only limited hydrochemical data exist for the SGS, but data tend to indicate that little lateral migration occurs within this unit. It is uncertain if this observation reflects a lack of continuity of the sand intervals that make up the SGS or results from a relatively low hydraulic conductivity for the unit.

The bulk of the groundwater data for the Northwest plume has been collected from the RGA. However, even for this unit, inadequate coverage exists. Figure 3 illustrates what is known about contaminant distributions and concentrations in the upper part of the RGA. Residential wells in the area have been included in the figure for reference. Because of uncertainties about their completion depth, it is inappropriate to include these wells in a discussion of vertical distribution of contaminants in the RGA. However, available information suggests that they are screened within the RGA, and observed levels of TCE and ^{99}Tc in groundwater from them are consistent with data obtained from the high-quality monitoring wells screened within the upper RGA illustrated in Fig. 3.[2]

In general, data obtained from the upper RGA indicate that the source of both TCE and ^{99}Tc contamination in the Northwest plume is from the vicinity of WMUs 7 and 30. Although there are gaps between MW-63 and MW-54, MW-52 and MW-53, and MW-169 and MW-173 through which a narrow plume from another source to the south could pass, the evidence suggests that the contaminant source probably is localized to the northwest corner of the plant.

---

[2] MW-20 is a private well that has been monitored by PGDP for many years. There is little information available regarding its construction.

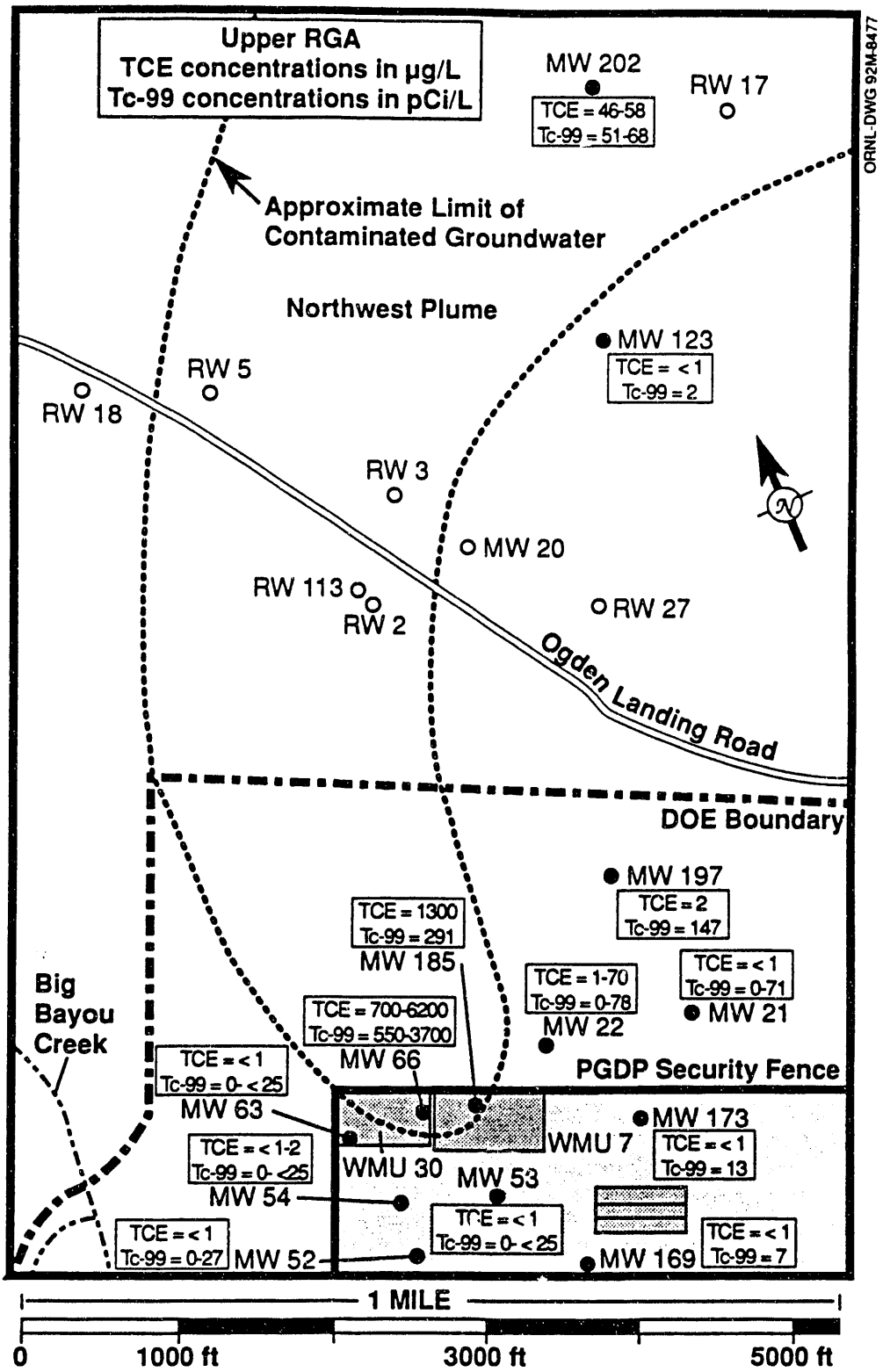

Fig. 3. TCE and ^{99}Tc concentrations in groundwater from the upper RGA in the vicinity of the Northwest plume.

Rather than install additional, permanent monitoring wells to delineate the source area, a one-time sampling strategy using a modified hydropunch method is recommended. To distinguish these installations from conventional monitoring wells, the hydropunch monitoring facilities will be referred to as sampling stations. Hydraulically pushing a detachable drive point with smooth, flush-threaded drill rods (where the point has been machined to the same diameter as the rods) through a zone contaminated with DNAPLs will prevent creation of a micro-annulus around the rods and avoid possible mobilization of free product. Groundwater can be sampled at any point during the installation process. At the completion of the sampling activity, the drill rod is extracted simultaneously with grout injection; the drive point remains at the bottom of the hole.

Using this technique, several additional sampling stations should be established to confirm the source location. Recommended locations for these stations are between MW-54 and MW-53 and ~500 ft east of MW-53. The stations should permit sampling both of the SGS and the RGA.

A second major concern in the current evaluation is whether or not a pure-phase DNAPL (TCE) exists in the source region of the plume. Given the high density of TCE (1.47 g/cc), if a sufficient quantity of free-phase material exists in this environment such that the entry pressures are exceeded, it will migrate downward under the influence of gravity. As it passes through successively deeper lithologic units, a portion of the pure phase will be left behind as residual droplets or ganglia. With a limited amount of pure phase, the supply of TCE eventually will be exhausted by formation of a trail of residuum. The residual material will become a long-term source of a dissolved plume as groundwater flows through the region of pure-phase contamination in the aquifer. Given this general picture of DNAPL migration, several alternative scenarios applicable to the Northwest plume are possible:

- Pure-phase TCE exists only in the disposal trench, and the dissolved plume is formed by dissolution of TCE and ^{99}Tc by infiltrating meteoric water.
- Pure-phase TCE has migrated downward under the influence of gravity and has reached the sandy unit that comprises the SGS.
- Pure-phase TCE extends into the clays and silts of the Upper Continental Deposits.
- Pure-phase TCE has reached the RGA but does not extend to the base of this unit.
- Pure-phase TCE extends to the base of the RGA.

At present there are insufficient characterization data to determine which of these scenarios applies to the source of the Northwest plume. Therefore, it is prudent to assume that each is equally likely until further studies are completed.

It is apparent why additional characterization data are required to differentiate among the scenarios listed above. If one can demonstrate that pure-phase DNAPLs, if present in the source area, have ***not*** migrated into the RGA, then a variety of source-containment options other than pumping and treating the RGA are possible. In contrast, if pure-phase TCE has migrated to the base of the RGA, a dissolved-phase plume will exist throughout the vertical extent of the aquifer. Therefore, confirmation of the existence of such a plume at the base of the RGA near the contaminant source area will be a strong indication that pure-phase DNAPLs have migrated at least to this depth.

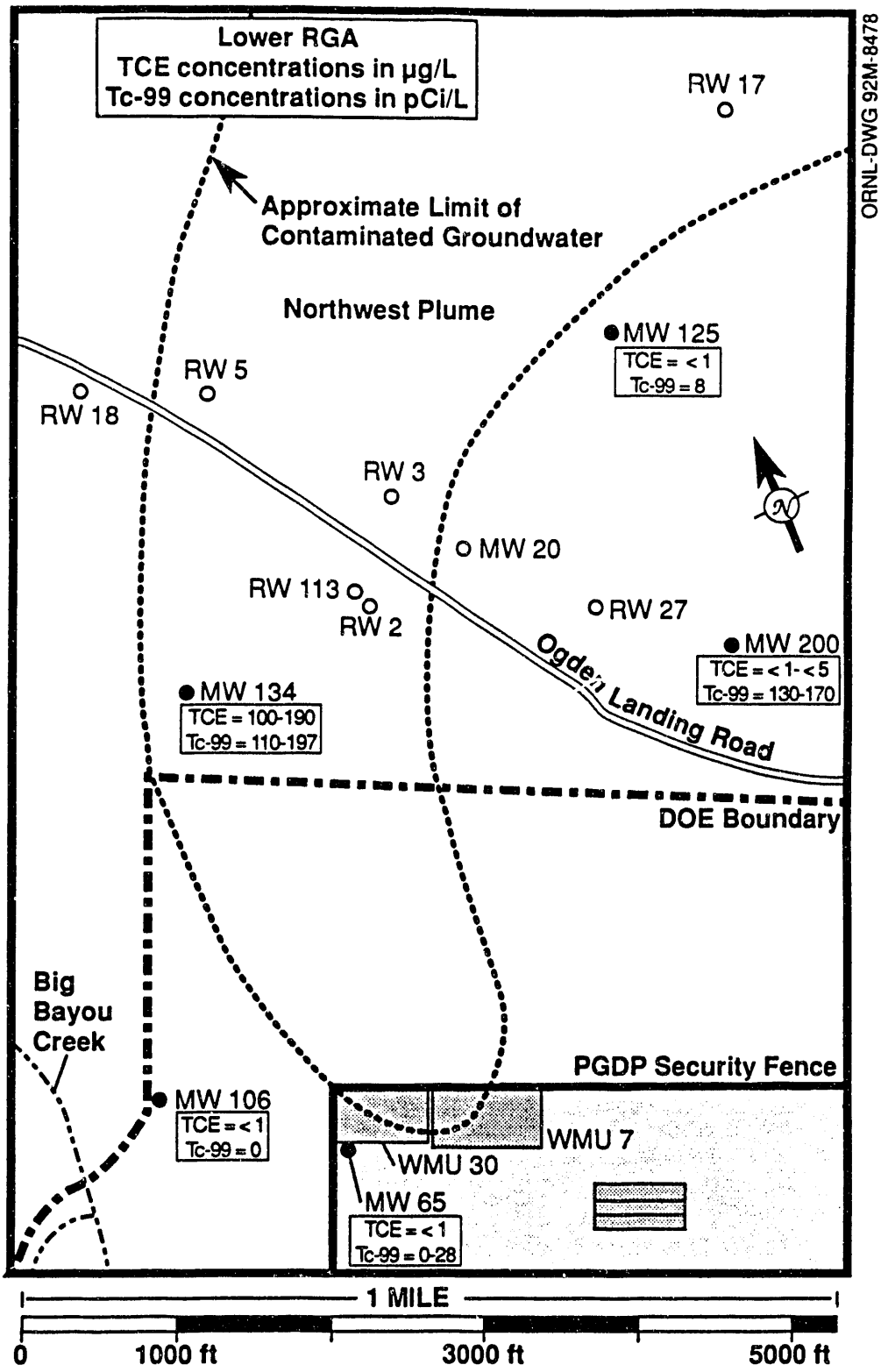

Fig. 4. TCE and ^{99}Tc concentrations in groundwater from the lower RGA in the vicinity of the Northwest plume.

Only limited hydrochemical data currently are available from the lower RGA with which to test this possibility (Fig. 4). Of the four wells screened at this stratigraphic level, only one (MW-134) shows any contamination, and it is located ~0.6 miles from the presumed source. It is essential that additional sampling stations are installed to the north (i.e., downgradient) of MW-66 to look for evidence of DNAPLs at the base of the RGA. Approximately three sampling stations located in a transect across the plume and several hundred feet north of the security fence should provide sufficient information. These stations should be installed by a modified hydropunch technology to permit collection of groundwater samples at multiple depths and to avoid the possibility of DNAPL migration if pure-phase material is encountered.

The SGS should be the shallowest zone sampled in these wells. Although there are questions about the continuity of the sand intervals that comprise this unit, it is desirable to better define the northward extent of contamination in it (especially if pure-phase DNAPLs are involved) before designing a source-containment system.

The association of ^{99}Tc with TCE in the Northwest plume is noteworthy. Figure 5 is a log-linear graph of TCE vs ^{99}Tc for wells completed in the RGA in the vicinity of PGDP that show TCE and ^{99}Tc contamination. Data points for samples from wells within the Northwest plume are emphasized for reference. Several observations are possible. First, there is a striking correlation between the relative concentrations of these two contaminants. The correlation between these parameters can be shown to be linear with a correlation coefficient (r) in excess of 0.95. Second, this geochemical signature is unique for the Northwest plume. Other wells in this area show contamination, but their signature is not consistent with that for the Northwest plume, and they probably monitor contamination from different sources.

One possible explanation for the observed geochemical correlation is the existence of a ^{99}Tc–TCE organo-metallic complex in which these two constituents are associated in a constant ratio permitting them to migrate together, either in the pure phase or dissolved form. We have been unsuccessful in finding evidence for such a complex in the literature but readily acknowledge the possibility. Alternatively, both ^{99}Tc and TCE could be mobilized by dissolution in infiltrating meteoric water: ^{99}Tc in the form of the highly mobile pertechnetate ion (TcO^-_4) and TCE in the dissolved molecular form. If this alternative is correct, it would tend to suggest that the sources of TCE and ^{99}Tc remain in the original, near-surface, waste disposal trench and migrate to the RGA only as dissolved species; migration of pure-phase DNAPLs into the RGA would not be required. Furthermore, near the source, dissolved contaminant migration would be restricted to the upper part of the RGA rather than being distributed throughout this unit.

3.3.2 Recommendations

Currently we are unable to evaluate the existence of DNAPLs in the source area of the Northwest plume. Several credible alternatives are possible and should be addressed as part of the process of determining the most appropriate form of source control for the plume. Several specific steps, as discussed above, are required to provide the necessary information to resolve these uncertainties.

First, given the distribution of monitoring wells associated with the presumed source, there remains some uncertainty as to whether other sources might contribute to the plume. Specifically, additional sampling stations are needed upgradient of WMUs 7 and 30 to confirm

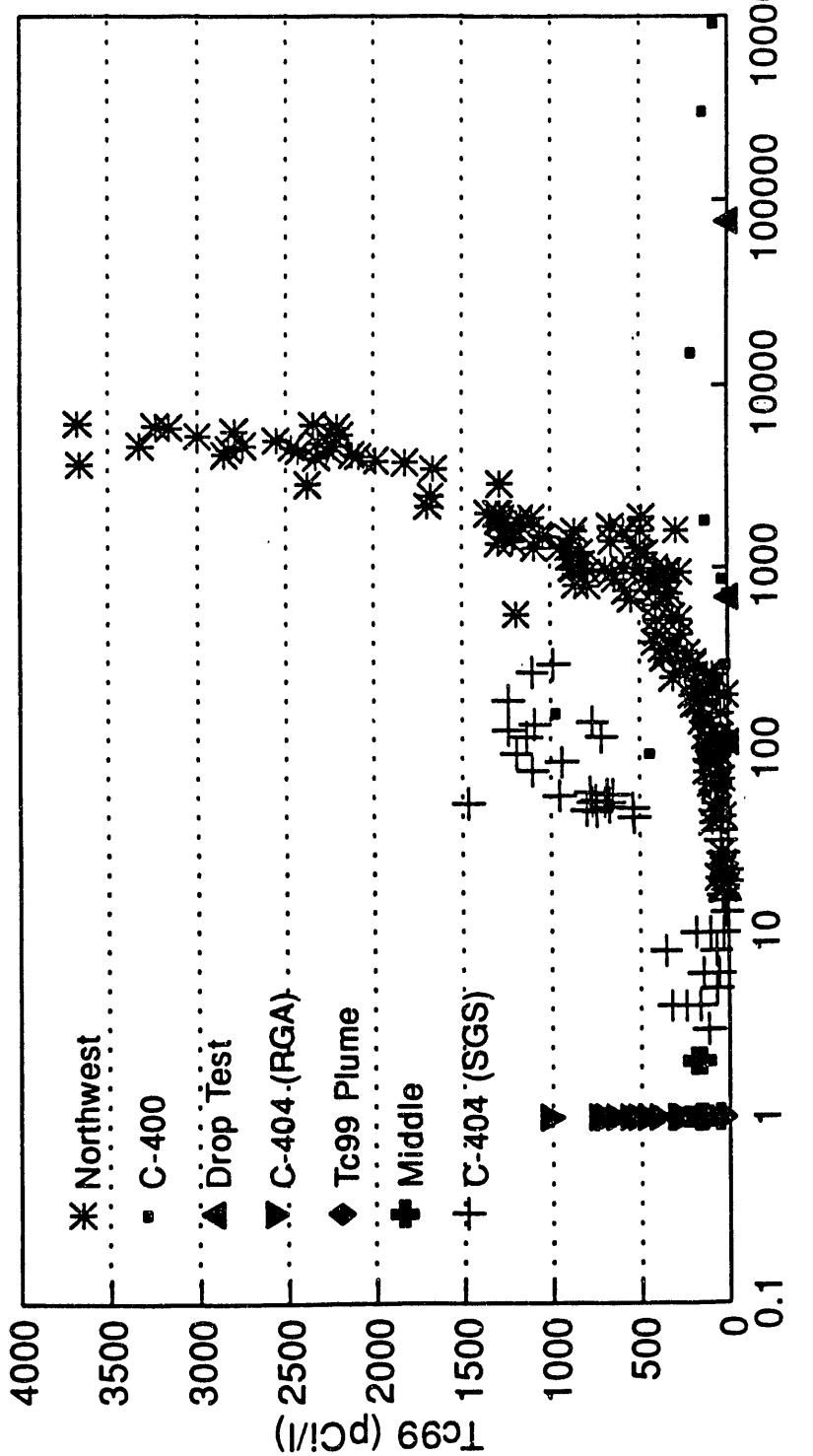

Fig. 5. Graph illustrating the relationship between TCE and ^{99}Tc concentrations in groundwater for the Northwest plume in comparison to other contaminant plumes at PGDP.

that another upgradient source is not a significant contributor to the Northwest plume. Figure 6 illustrates suggested locations for these sampling locations (sites A and B).

Second, as part of this investigation, the vertical distribution of TCE and ^{99}Tc in groundwater must be determined from a transect of sampling stations located downgradient from MW-66. These new stations should be positioned sufficiently distant from the source to avoid intercepting any pure-phase DNAPL, if it exists. If DNAPLs exist as a pure phase in the SGS and/or the RGA, then a decoupling of TCE and ^{99}Tc may have occurred, and heterogeneities in the distribution of these contaminants in the dissolved plume will develop at a scale that should be observable. Sites C-E (Fig. 6) are recommended locations for these new stations.

A necessary final step is the installation of additional sampling stations in those areas of the plume where uncertainties in its lateral extent persist. Examples of such areas of uncertainty are both the western and eastern margins of the plume from the northwest corner of the plant to a point north of Ogden Landing Road where the pumping wells for the pilot study are planned to be (Fig. 6). This information eventually will be needed to support future restoration decisions and activities.

The additional data outlined above can be incorporated into a hydropunch work plan currently in preparation by PGDP personnel. It may be necessary to modify the number, location, and completion depth for some of the sampling stations planned for this project to accommodate the recommendations in this evaluation report. For example, the five stations proposed in Fig. 6 are not included in the hydropunch work plan and are new installations. Furthermore, slight modification of the three transects proposed in the work plan will permit better definition of the lateral boundaries of the plume.

Further National Environmental Policy Act (NEPA) approval might be required to implement a revised hydropunch work plan. Furthermore, some accommodations should be made to deal with the possibility that the hydropunch technology may not work adequately for sampling station installation requiring more conventional installation techniques (e.g., hollow-stem auger). If required, this contingency may necessitate procurement of a drilling subcontractor and relocation of some stations further from the presumed source to minimize the possibility of encountering and mobilizing pure-phase DNAPLs should they exist.

If the additional characterization investigations outlined above confirm the likely presence of pure-phase DNAPLs in the RGA and it is determined that ^{99}Tc removal from contaminated groundwater is required, then hydraulic containment is the only method currently available for source control. Under these conditions, the proposed pilot pump-and-treat demonstration is appropriate. It is possible to evaluate the general effectiveness of the pumping scheme presented in the work plan by making use of existing estimates of hydraulic data for the RGA and a numerical capture model.

In view of the current understanding of hydrogeologic conditions known to exist in the vicinity of the Northwest plume, the proposed pump-and-treat activity should be more than adequate to provide hydraulic control of the plume in the RGA emanating from the presumed source area in the northwest corner of the plant. Rudimentary capture modeling, using a Capture Zone Velocity Distribution Program adapted from J. F. Keely (1988), has been performed using the following input parameters.

- Regional groundwater velocity: 0.99 ft/d
- Effective saturated thickness: 30 ft
- Effective porosity: 0.20
- Flow (pumping) rate: 250 gpm

This model calculates the position of a stagnation point ~1300 ft downgradient of the pumping wells and a maximum upgradient capture zone width of ~8100 ft. This is considerably wider than what is needed to hydraulically control the Northwest plume in the vicinity of Ogden Landing Road and much larger than what is needed to control it closer to the presumed source. Therefore, a scaled-down version of the work plan may actually be possible if hydraulic containment is refined. It must be noted that minor changes in these individual input parameters can lead to significant differences in calculated results.

In his report (see Appendix C), Dr. S. N. Davis suggested that if a hydraulic containment option is selected for PGDP, consideration should be given to a combination of aquifer pumping and reinjection. This process could facilitate focusing of contamination into a narrow zone to make containment more efficient.

Several activities are either in progress or proposed that should affect the timing and scope of the proposed pump-and-treat test. In particular, they include the groundwater modeling that is being conducted by GeoTrans under contract to PGDP which will update the previous modeling done in 1990 on the basis of a revised conceptual model and recently acquired data. The model will be constructed to evaluate the feasibility and optimum design of an off-site pump-and-treat system and will facilitate the prediction of plume capture by the proposed line of wells. The other activity is the previously mentioned hydropunch sampling program.

3.4 RISK EVALUATION

This section evaluates the groundwater pump-and-treat alternative relative to its potential to effect a reduction of risk. Preferably, the risk evaluation of an alternative should quantify the risk reduction relative to the baseline risk. However, the information is not sufficient to quantify the reduction in risk resulting from the implementation of the pump-and-treat alternative. Therefore, a qualitative risk evaluation of the alternative is used to identify data gaps in this evaluation.

3.4.1 Residential Baseline Risk

The risk characterization included in the Phase I report identified an excess cancer risk of 6×10^{-4} for the residential wells under the reasonable maximum exposure scenario. The Phase II investigation calculated a cancer risk of 7×10^{-4} for the residential wells. The exposure routes driving the risk to residents from the groundwater pathway are ingestion and inhalation of TCE, arsenic, and beryllium.

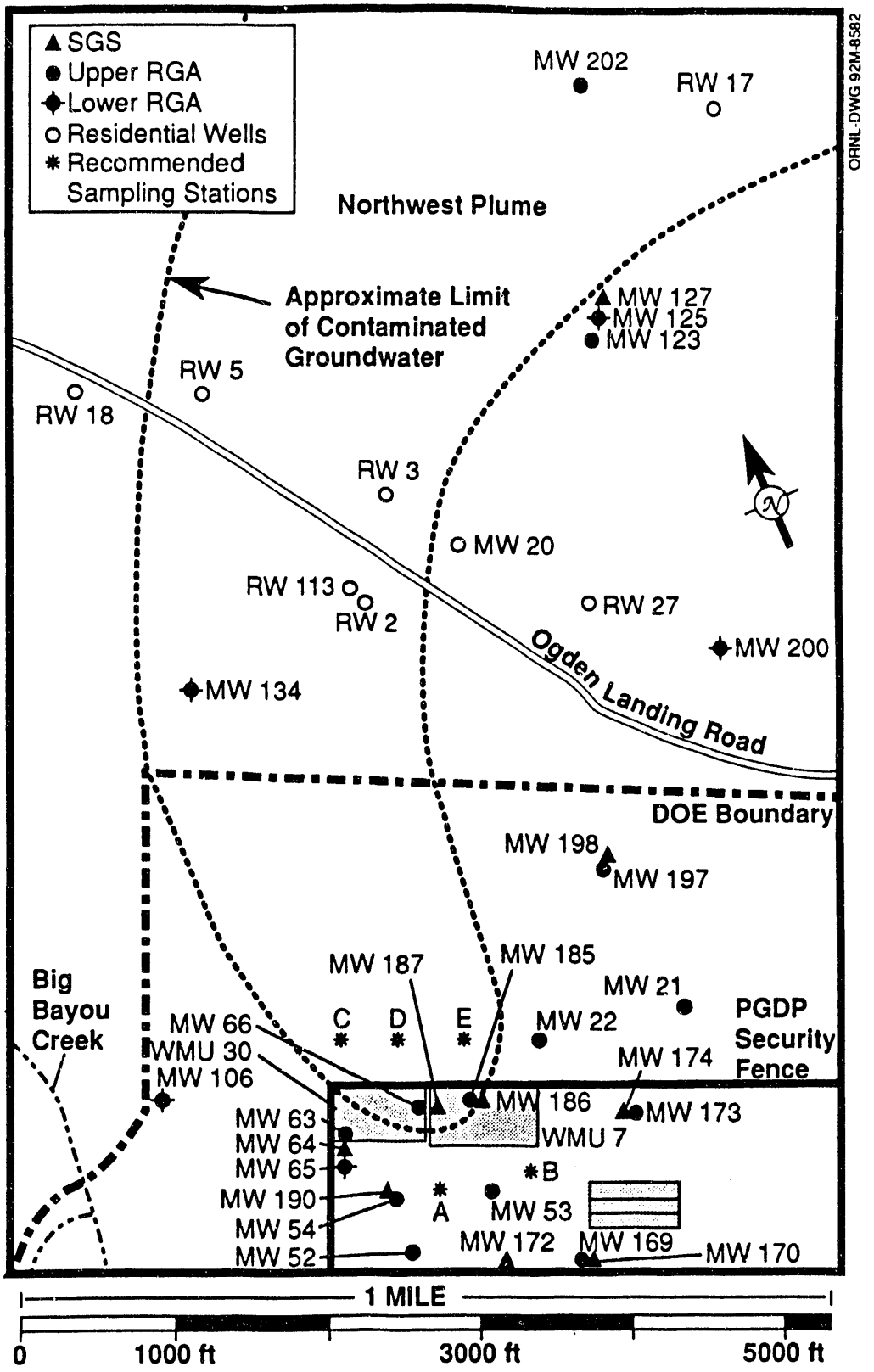

Fig. 6. Location of recommended sampling stations to characterize the contaminant source region for the Northwest plume.

3.4.2 Present Conditions

The risk to residents from exposure to groundwater contaminants under present conditions has not been evaluated. Because residents in the area of the plume have been supplied with an alternate water supply, both major groundwater exposure routes (ingestion and inhalation) assessed in the Phase I and Phase II reports have been eliminated. Because these routes of exposure do not exist at this time, the current risk to residents from domestic exposure to groundwater may be less than the 10^{-4} level.

3.4.3 Risk Reduction

There has been no quantitative assessment of the reduction of the baseline risk as a result of the selected alternative. Additionally, a quantitative evaluation of the effect of the alternative on present risk levels is not possible, because risk under current conditions has not been determined.

There has been no groundwater modeling to determine the rate at which contaminant concentrations will change as a result of plume containment by the pump-and-treat alternative. If the system is effective in containing the plume, concentrations will decrease at some time in the future, as will the baseline risk associated with domestic groundwater use. However, the period of operation necessary to reduce groundwater baseline risk to an acceptable level for area residents has not been determined.

3.5 SOURCE-CONTROL ALTERNATIVES

3.5.1 Viable Alternatives for Source Control

In Sect. 3.1 we introduced a decision tree (Fig. 2) to assist in evaluating the key questions that must be addressed in choosing a defensible approach to source control for the Northwest plume. In fact, this decision process is generally applicable to groundwater at PGDP, and its use need not be restricted to this one area of contamination.

The principal forms of containment that evolve from the decision tree include:

- full-scale pump-and-treat (with or without ^{99}Tc removal);
- in situ air sparging;
- source removal by excavation;
- source removal by in situ bioremediation;
- physical containment of source (e.g., slurry wall, sheet piling, etc.); and
- source fixation (e.g., grout injection).

Additional options exist within these broad categories, so the actual number of source control technologies represented is much larger. The choice to be applied to the Northwest plume at PGDP from among the source-control options listed above depends on the presence or absence of pure-phase DNAPLs in the RGA and the need to treat groundwater for ^{99}Tc removal. Once these questions are resolved, the final option chosen will depend on such factors as cost and site-specific hydrogeologic conditions.

The review team recognizes that the standard approach to remediation of groundwater contamination generally is accepted to be a pump-and-treat system. However, this type of system has definite drawbacks with regard to its overall effectiveness as a treatment technology or a technology that will clean up a contaminated aquifer. Its overall effectiveness in cleaning up aquifers contaminated with pure-phase DNAPLs is less than for aquifers where contamination is dissolved in groundwater. However, pump-and-treat systems have been demonstrated to be effective in creating barriers to contaminant migration, and it is within this context that it is included in the decision tree (Fig. 2).

The alternatives assessment document (SAIC 1991) evaluated a broad range of technologies that are potentially applicable to source control at PGDP. Within the past several years, some improvement has been achieved in defining viable options regarding groundwater treatment for contaminants. The review team found that there are only a few new, alternative, or innovative technologies that were not considered that address groundwater contamination. The following sections will address some of these new technologies.

3.5.1.1 Pump-and-treat with surfactant injection

This technology is a variation of the standard pump-and-treat system that typically is used to treat contaminated groundwater. The concept of this alternative to a traditional pump-and-treat system (and one that was specifically developed to address aquifers contaminated with pure-phase DNAPLs such as TCE) is to inject surfactants upgradient of the area of contamination and at the same time extract mobilized contaminants from a pump-and-treat system at some point downgradient of the location where the DNAPLs exist. After the surfactants have been injected, they reduce the interfacial tension of the DNAPL droplets trapped in pores within the aquifer, causing them to become mobile. The pump-and-treat system is designed to handle removal of both the surfactant and chlorinated solvent. In addition, the extracted water is then routed upgradient, where it is injected with the surfactant, creating a closed-loop system with no need for groundwater discharge to surface water.

Surfactant injection was specifically developed to improve the capability of removing chlorinated solvents from aquifers. One significant drawback of a system of this nature is that by mobilizing the DNAPL droplets there is an increased danger in them migrating under the influence of gravity and escaping the capture zone of the pumping well. Another potential problem is that surfactants remain in the aquifer after treatment. However, the surfactants are biodegradable over time. In addition, the surfactants will tend to immobilize any metal contamination present within the aquifer.

3.5.1.2 Iron filing fence

In terms of construction, this technology is similar to that of installing a grout curtain or slurry wall. A trench is dug to the base of the contaminated aquifer. It is then filled to the top of the aquifer with iron filings. This technology differs, however, from the curtain or slurry wall in that the iron filing wall would be porous, allowing water to pass through it. In addition, it would need to be designed to be at least as permeable or more permeable than the aquifer material. This technology was first developed by the University of Waterloo, Canada, which has conducted bench-scale tests and is currently developing pilot-scale tests to determine the overall effectiveness of this type of treatment. Currently, bench-scale tests

show that chlorinated hydrocarbon in water passing through an iron filing wall is consumed by reaction with the iron and, if the wall is thick enough, will disappear on the downgradient side of the wall. The actual physical chemistry of what happens to the contaminant has not yet been determined. However, the University of Waterloo is actively pursuing this information. Because this technology is relatively new, the type of degradation that would occur downgradient of the wall (i.e., increased iron concentration in groundwater) is not known; the effect the iron filings would have on the ^{99}Tc present in groundwater also is not known. Innovative procedures for the emplacement of the fence that may allow for replacement of depleted iron filings are currently in a concept development stage. As with slurry walls and grout curtains, current technology does not support use of an iron filing fence at PGDP in the RGA because of the depth of this aquifer.

3.5.1.3 In situ sparging through horizontal wells

A new technology that has been demonstrated to be effective for removal of volatile organics at the Savannah River Site is in situ sparging through horizontal wells. The concept is to introduce two horizontal wells to the subsurface. In the case of the Northwest plume at PGDP, the first horizontal well would be installed at the bottom of the RGA and a second horizontal well in the same vertical plane as the first, but above it and in the vadose zone. Air, heated air, or steam would be injected into the lower well. The air passes vertically upward through the aquifer, stripping (volatilizing) volatile constituents. The upper horizontal well is developed to pump air (soil gas) out of the vadose zone and into a collection system where TCE is condensed or into a catalytic converter, which burns off the recovered TCE. This type of system creates a permeable barrier (permeable to groundwater flow but not TCE migration) and has been demonstrated successfully on a relatively small scale. Those sites where it has been applied with some success tend to have relatively permeable strata, which facilitates circulation of the air or steam. At PGDP the fine silt and clay lithologies of the Upper Continental Deposits may be too impermeable to permit adequate air circulation to occur without disruption by soil mixing techniques. This technology would not address the ^{99}Tc present in the groundwater at PGDP, but it could be combined with other technologies for removal of ^{99}Tc contamination.

An added option for the sparging technology is to use methane gas instead of air or steam. Methane has the benefit of inducing methanotropic activity, which is a form of bioremediation for TCE. The concept has not been demonstrated, but tests are planned at the Savannah River Site.

3.5.1.4 Pump-and-treat through horizontal wells

Another technology associated with the pump-and-treat option is to use horizontal wells instead of the traditional series of vertical wells to extract groundwater from the aquifer. In this particular technology, instead of placing a series of vertical wells (five in the case of the proposed pump-and-treat pilot system at PGDP), the concept is to place one or two horizontal wells in a linear alignment perpendicular to groundwater flow. From this alignment, the wells are pumped to retrieve groundwater, and the system would be defined as a containment system. Both TCE and ^{99}Tc could be recovered and treated on the surface.

3.5.1.5 Pulsed ultraviolet radiation treatment of groundwater

A treatment technology that has shown some promise within the past year in association with a pump-and-treat option is pulsed ultraviolet (UV) radiation of groundwater for the treatment of chlorinated solvents. This technology is a variation of a process that has long been used in the waste treatment arena, where contaminated water is passed over UV light, which causes chemical degradation of the chlorinated hydrocarbon molecule into its component parts. Pulsed UV radiation for the treatment of groundwater has recently been used in bench- and pilot-scale tests, and the results have been encouraging. The pulsed UV approach has an advantage over the standard UV approach, because preliminary results indicate that greater degradation and energy consumption efficiencies can be obtained through the use of pulsed UV radiation. Standard UV radiation techniques use lamps that require 500 to 750 watts of power. The pulsed UV lamps that have been pilot tested were ~350 to 400 watts. Pulsed UV radiation does not appear to require the addition of an oxidizing agent (peroxide or ozone) to enhance chemical breakdown of the organic compounds. Of course, the most advantageous use of pulsed UV treatment technology is that there are no off-gases to condense or burn, because the process is a true treatment technology and not a technology that transfers the problem from one state to another. This treatment method should be evaluated as an alternative to reverse osmosis and ion exchange, which were discussed earlier.

3.6 PUBLIC INVOLVEMENT

The HSWA Permit incorporates the ACO under Sects. 104 and 106 of CERCLA by reference; thus, PGDP must comply with the terms found in this ACO. Section XVII states that DOE shall make draft work plans available to the public for review and comment for, at a minimum, a 21-d period. Following the public review, DOE is to notify EPA of any proposed changes to the work plan requested during the comment period and prepare a response to those changes that were not considered.

The HSWA Permit also includes 40 CFR Part 124 by reference. However, Part 124 applies to issuing, modifying, revoking, and reissuing or terminating RCRA permits. Section IV.c. of Appendix C of the HSWA Permit states that upon receipt of the final Corrective Measure Study Report, EPA shall announce its availability to the public for review and comment. Therefore, the real driver for public review of documents generated during the restoration activities at PGDP is found in the CERCLA ACO, which is enforceable by reference in the HSWA Permit.

During the investigative phase, PGDP has always maintained a proactive stance in public participation. One outcome of this program is that the public appears to be concerned over spending large sums of money to remediate the groundwater. They believe that providing clean water to those residences affected by the plant is sufficient corrective action. This stance has been noted by PGDP during public hearings.

4. CONCLUSIONS AND RECOMMENDATIONS

In the evaluation of this proposed pilot study, it is essential to clearly define the objective and in so doing distinguish between source control and remediation. It is obvious that source control must precede or accompany remediation for any cost-effective or lasting cleanup. The most desirable form of source control is removal or isolation of the source to eliminate further releases. If this is not possible, such as in the case of a pure-phase DNAPL that is too deep or widely distributed to contain otherwise, the only currently viable alternative may be hydraulic containment of contaminated groundwater moving away from the source.

In the case of the Northwest plume at PGDP, it is possible that the sources of both the TCE and ^{99}Tc are near-surface and could be amenable to removal or isolation. Evidence includes a very strong correlation between TCE and ^{99}Tc concentration, which suggests close physical association of these chemically dissimilar constituents. Because ^{99}Tc is believed to be in near-surface materials, the same may be true of TCE sources. The relatively low concentrations of TCE associated with the Northwest plume also argue for a relatively diffuse near-surface zone of contamination.

Therefore, for the Northwest plume, technical considerations suggest that the best course of action would be to modify the proposed work plan to include actions to accurately identify the sources of contaminants before a decision is made on the final course of action. If pure-phase DNAPL is not present in the RGA, the choice would be to use removal or primary containment of sources if at all possible. If source characterization reveals that pure-phase DNAPL is present where it cannot be removed or isolated, then control of organic contaminants migrating from the source will be required. The proven technology for such control is hydraulic containment using pumping. However, it is worth at least considering the establishment of a permeable barrier that would allow water to pass but strip organic contaminants of concern. Such an approach would in principle greatly minimize generation of secondary wastes. An air-sparging zone with vapor collection would be one example of a permeable barrier for source control of organic contaminants. This could be done in conjunction with a ^{99}Tc source removal action, because the ^{99}Tc sources are believed to be near-surface.

The risk to residents in the path of the Northwest contaminant plume under present conditions has not been evaluated nor have the changes in risk that would be associated with the interim corrective measure (pump-and-treat) that has been proposed. It is essential to determine the likely duration of the pump-and-treat option to model the effect of the option on changes in contaminant concentrations and associated risks. Further, it seems important to carry simulations over a long enough time period to estimate the ultimate baseline risks for the situation where the sources have been removed and contaminants have either been removed or advection has carried them to the Ohio River. Although all indications are that the Ohio River is the ultimate discharge point for the RGA, it has been suggested that groundwater in the Mississippian limestone might underflow the Ohio River. If contamination associated with PGDP has migrated to this limestone, there is a possiblity of transport into heavily used aquifers on the Illinois side of the river. It seems clear that further analysis is warranted to reach a final conclusion on whether this is a realistic scenario. This clearly will be an essential factor in long-term risk assessment. Finally, regardless of any near-term decision on whether to proceed with the pump-and-treat demonstration, these risk analyses

are needed. In particular, the question of whether ^{99}Tc requires treatment and, if so, to what levels, should be addressed from a risk-based perspective.

As noted in Sect. 3.2.1, it is appropriate to perform a true pilot-scale study of treatment technologies for ^{99}Tc in which the total extraction rate does not exceed ~10 gpm. This test would allow important parameters for ^{99}Tc treatment to be determined and also could provide an opportunity to examine pulsed UV treatment for TCE. Even if the ultimate decision for the Northwest plume does not involve pump-and-treat methods, there is a good chance that the same technology will be required elsewhere at PGDP.

Initial evaluation of the cost estimates indicates they are about a factor of 2 below expected costs. Such a large impact relative to the total site budget should not be ignored. Thus, a more refined and complete cost estimate should be prepared for this project. It should address the factors outlined in Sect. 3.2.2.

The EPA administrator has determined that the HSWA Permit gives the regional EPA office final authority to make various interim decisions during the corrective action process. Further, DOE at this point has only judicial review as an option for appeal of decisions made.

It is also apparent that more planning is needed to deal with plume remediation. Even if the proposed full-scale pump-and-treat facility were implemented today, a significant portion of the downgradient plume would be beyond the capture zone. If it were possible to remove or isolate the primary sources by other means, then the full plume would remain. In either case, use of pump-and-treat methods for plume remediation has been shown to be an ineffective approach. Particularly in cases in which TCE is the contaminant of concern, recent work at the Savannah River Site suggests that some form of a sparging and vapor collection system, employing horizontal wells, represents a very promising alternative. As in the case where sparging is used to create a permeable barrier, if some variation of this option were applied to plume remediation, waste generation would be greatly reduced and treatment could be focused where it is needed, possibly using horizontal injection and extraction wells.

The mandate from EPA and the Commonwealth of Kentucky to produce a work plan for a groundwater pump-and-treat system at PGDP cannot be ignored. From a sitewide perspective, there are probably locations where direct source-control measures for pure-phase DNAPL contamination will not be possible and some form of control for continuing releases will be required. The need for hydraulic containment cannot be ruled out; thus, it is desirable to develop the information needed for full-scale implementation. However, as summarized in Sect. 3.2.1, if ^{99}Tc removal is required, then there is a compelling need to conduct a limited pilot-scale demonstration to support cost-effective design of the full-scale treatment facility.

Prior to submission of the work plan, it is important to incorporate existing plans for source determination for the Northwest plume. It is essential to provide a realistic schedule that identifies the time needed to reach a final decision on whether to pump and treat or to pursue a different course of action for control of the Northwest plume sources. It would also seem essential to evaluate the concentration level at which ^{99}Tc removal becomes a requirement. The outcome of the decision on ^{99}Tc concentrations requiring treatment will drive the technology requirements for control and remediation of the plume.

Given these realities, the recommendations of the team are as follows:

- Place a high priority on an immediate activity to accurately characterize the vertical distribution of the source and contaminants contributing to the Northwest plume (details of requirements are given in Sect. 3.3). Include this activity in the work plan to be submitted.
- Modify the proposed work plan for the pump-and-treat demonstration to include a small (single well at 10 gpm) pilot-scale treatment study as a needed precursor to the full-scale implementation of hydraulic containment if ^{99}Tc removal is required.
- Introduce a decision point into the proposed work plan that would follow the source characterization and small pilot-scale treatability demonstration. The decision would be whether to use removal or isolation for source control (if feasible) or to proceed with a hydraulic containment option.
- Determine through options risk assessments the risk posed to residents under current conditions (with municipal water supplied for household use as an interim corrective measure) and the necessity for ^{99}Tc removal from groundwater as part of the aquifer-restoration activities.
- Continue with a more comprehensive analysis of sitewide remediation needs to create linkages between actions for the Northwest plume and other contamination sites at PGPD as outlined in a summary of alternatives for off-site rememdial actions prepared for PGDP (SAIC 1991).

The review team recognizes that *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1991) will be used to guide the required integrated approach.

During the course of the evaluation, it became apparent to the review team that PGDP staff involved in developing the pump-and-treat work plan assumed the presence of DNAPLs in the source area of the Northwest plume and further assumed that they extended to the base of the RGA. These opinions evolved from the presentation and final report submitted (Kueper 1991). The review team was concerned that Dr. Kueper's interpretations and recommendations, as they pertain to the Northwest plume, may have been misunderstood. Consequently, the review team contacted Dr. Kueper and discussed his findings and recommendations. A summary of the telephone conversation is documented in Appendix F. It is important to recognize that the recommendations of Dr. Kueper and the review team are in complete agreement.

REFERENCES

CH2M Hill. 1991. *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/ER-4, prepared for Martin Marietta Energy Systems, Inc.

CH2M Hill. 1992. *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Draft, KY/SUB/1313-97777C P-03/1991/1, prepared for Martin Marietta Energy Systems, Inc.

EPA (U.S. Environmental Protection Agency). 1986a. "Guidelines for the Health Risk Assessment of Chemical Mixtures," *Federal Register* 51:34014-41.

EPA (U.S. Environmental Protection Agency). 1986b. "Guidelines for Carcinogen Risk Assessments," *Federal Register* 51:33993-34013.

EPA (U.S. Environmental Protection Agency). 1989. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, DC, December 1989.

Keely, J. F. 1988. *The Use of Capture Zone Estimates and Velocity Plots in Solving Ground-Water Contamination Problems*, prepared for the U.S. Environmental Protection Agency by Ground-Water Quality Consultants, 2700 NW 185th Avenue, Portland, Oregon 97229. April 28.

Kueper, Dr. B. H. 1991. *The Occurrence of Dense, Non-Aqueous Phase Liquids in the Subsurface at the Paducah Gaseous Diffusion Plant, Final Report*, KY/ER/Sub/0815-1015/91/2, Queens University, Kingston, Canada, prepared for Martin Marietta Energy Systems, Inc., November 25.

SAIC (Science Applications International Corporation). 1991. *Summary of Alternatives for Remediation of Off-site Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Draft, DOE/OR-1013, prepared for the U.S. Department of Energy.

SAIC (Science Applications International Corporation). 1992. *Treatability Test Work plan for Groundwater Remediation at the Paducah Gaseous Diffusion Plant*, Draft, prepared for Martin Marietta Energy Systems, Inc.

APPENDIX A

Charter: Groundwater Corrective Actions Review Team

Charter: Groundwater Corrective Actions Review Team
April 1992

Goal

The goal of the Groundwater Corrective Actions Review Team is to evaluate the technical merit of and need to implement the proposed pilot groundwater collection and treatability test associated with off-site migration of TCE and ^{99}Tc in the Northwest contaminant plume in the Regional Gravel Aquifer at the Paducah Gaseous Diffusion Plant (PGDP). This review will consider the technical adequacy of the proposal, regulatory requirements, risk to human health and the environment, community relations, and actions already taken in association with the project. The review team will review applicable technologies and alternatives and the rationale leading to the proposed test. Findings of the review team shall be presented in a written report that addresses technical validity and schedule drivers. If appropriate, suggestions may be included for additional actions or modifications to the approach or schedule.

Resources

The resources to carry out this charter include time, expertise, and funding support. The time is constrained by a commitment to have a final action plan to the U.S. Environmental Protection Agency (EPA) by May 22, 1992. This translates to a target date of May 11, 1992, for development of a draft report. There is an added requirement that the review team be organized and working actively by April 1, 1992, when the task will be reviewed by DOE Headquarters (DOE-HQ). At that time, all members should be identified and needed subcontract arrangements for external experts initiated. Expertise to be included on the review team includes hydrogeology, geochemistry, environmental and process engineering, legal/regulatory, risk assessment, and community relations. Funding for the activity will be constrained largely by the time available, but must provide for travel to the site (and to Washington D.C. if DOE-HQ review is needed), short-term consulting by needed outside experts, staff time for review activities, and support services. Environmental Restoration (Technical Integration) will be responsible for administering funds provided through Clayton Gist of the DOE Oak Ridge Field Office (DOE-OR).

Organization

The review team will be chaired by G. W. Bodenstein of DOE-OR. Hydrogeologic and geochemical expertise will come from the Martin Marietta Energy Systems, Inc., Groundwater Program and Hazardous Waste Remedial Actions Program; risk assessment expertise will come from the Office of Risk Assessment at Oak Ridge National Laboratory; engineering expertise involving treatability will come from Energy Systems engineering; and regulatory expertise will come from DOE. Added consultants will provide external balance to the review. If deemed appropriate by DOE, EPA, and the commonwealth of Kentucky, regulators may be briefed at some point prior to final issue of the report. Review team members are: T.O. Early, T.B. Hale, R.R. Bonczek, D.D. Huff, C.T. Rightmire, and M.D. Nickelson. Consultants are S.N. Davis of the University of Arizona and an engineer to be named.

Product

The product developed by this review activity will be a written report that will include a summary of key issues, an evaluation of technical merit of the proposed test plan, an analysis of regulatory and public relations drivers, and, if appropriate, recommendations for added actions or modifications to the plan or the schedule.

APPENDIX B

Correspondence: D. D. Huff to D. G. Cope; D. G. Cope to D. D. Huff

OAK RIDGE NATIONAL LABORATORY
MANAGED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

Geosciences Section
Environmental Sciences Division

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831-6317

Mail Stop 6317
Phone: 615/574-7726
Fax: 615/574-7420

ENVIRONMENTAL SCIENCES DIVISION

DATE: 5/31/93

TO: Name Office # FAX #

Dennis Cope 305-6077

NUMBER OF PAGES: 2
(excluding cover page)

FROM: DD Huff

FAX: FTS 624-7420
615/574-7420

VERIFY #: FTS 624-7726
615/574-7726

OFFICE: 4-7726

COMMENTS: ___

3/31/92

Dennis:

We have been looking ahead to our charge of evaluating the proposed pump and treat test, and we very much want to be sure we understand all the objectives that are intended to be considered as goals for doing the work. I have attached a list of the objectives we identified from our discussions and the materials we were given. I doubt that it is inclusive, and at this point it is not in any order of importance or preference. What I would like to request is that you coordinate a response among the team members to do two things: First, make any appropriate additions or deletions, or other modifications to accurately represent the consensus; and second, please give some indication of the overall importance of each objective. This could be a numerical rank, or simply a H,M, or L for high, medium or low importance.

I apologize for having to impose, but we feel it is important to start from the same base as the project team in evaluating the task. We want to give you the opportunity to feed back to us whether we have understood correctly. I know time is precious, and you are busy. I wonder if we could have a response no later than April 8? That would be of tremedous help in our planning and structuring our report. Thanks. If you have comments or questions, please call me or Tom.

Dale D. Huff

Dale D. Huff, FTS-624-7859

March 31, 1992

OBJECTIVES

Listing of objectives noted for the Pilot Groundwater Collection and Treatability Test for contaminants of the Northwest contaminant plume at the Paducah Gaseous Diffusion Plant (PGDP). This listing is not in any particular order, but is a necessary component of understanding what is to be accomplished and why:

1. Demonstrate and evaluate the effectiveness of a pump and treat system to capture and remediate groundwater contamination. (This is taken from the Systems Requirements Document)

2. Prevent further migration of contaminated groundwater. (Taken from the Sleeman (DOE) to Kutzman (EPA) letter committing to produce a test plan by 5/22/92)

3. Establish an interim corrective measure to address groundwater contamination under the RCRA permit. (Taken from the Scarborough (EPA) to Sleeman (DOE) letter of 8/29/91.)

4. Lay the foundation for site-wide remediation.

5. Protect human health and the environment (Administrative Consent Order). This includes risk management and controlling further spread of contamination.

6. Be proactive. There is a desire to maintain an action bias to avoid being directed by others (Don Wilkes, 3/25/92)

7. Keep commitments already made: "Groundwater will be cleaned up."

8. Maintain favorable public (and regulatory) perception of the plant program. (Statement by Dennis Cope, ER site program manager)

MARTIN MARIETTA

LTR.KY/ER92-006

Internal Correspondence

MARTIN MARIETTA ENERGY SYSTEMS, INC.

April 8, 1992

D. D. Huff

Pilot Groundwater Collection and Treatability Test

In response to your March 31, 1992, letter on Pilot Groundwater Collection and Treatability Test objectives, attached are PGDP comments and rankings of these objectives in addition to some other objectives.

If you have any questions, please contact S. M. Leone of my staff at FTS 355-6050.

S. M. Leone for D. G. Cope

D. G. Cope, C-743-T-01, PGDP (6126)

DGC:SML:sgh

Attachment

cc/att: J. W. Douthitt
R. C. Edwards - DOE/PGDP
S. M. Leone
B. J. Montgomery
W. L. Richards
D. J. Wilkes
ER Document Management Center - NoRC

OBJECTIVES

1. Demonstrate and evaluate the effectiveness and gather real cost data of a pump and treat system to capture and remediate groundwater contamination, and to compare technologies for Tc-99 removal by treatment.
   RANKING: M-H

2. Prevent further migration of contaminated groundwater from one lobe of the off-site plume.
   RANKING: H

3. Establish an interim corrective measures to address groundwater contamination under the RCRA permit, ACO, and the EPA, March 31, 1992, letter.
   RANKING: M-H

4. Lay foundation for site-wide remediation.
   RANKING: M

5. Protect human health and the environment (Administrative Consent Order). This includes risk management and controlling further spread of contamination.
   RANKING: M

6. Be proactive. There is a desire to maintain an action bias to avoid being directed by others.
   RANKING: M

7. Keep commitments already made by plant management: "Groundwater will be cleaned up."
   RANKING: M-L

8. Maintain favorable public (and regulatory) perception of the plant program.
   RANKING: H

9. Pump and treat pilot demonstration is a positive step toward achieving a better understanding of site-wide hydrology and DNAPL problems, and gathering necessary data to support a final decision for groundwater remediation.
   RANKING: H

10. Act as containment for subsequent source removal of DNAPL.
    RANKING: M-H

11. RCRA/CERCLA Corrective Action consistent with latest regulatory guidance.
    RANKING: H

12. Compliance with NCP for future risk to human health and the environment by reducing exposure from "off-site" groundwater pathway.
    RANKING: H

APPENDIX C

Consultant report: Dr. S. N. Davis

SOME POSSIBLE PROBLEMS ASSOCIATED WITH GROUND-WATER REMEDIATION AT THE PADUCAH GASEOUS DIFFUSION PLANT

by

Stanley N. Davis

Hydrogeologist

May 14, 1992

INTRODUCTION

This report is a brief evaluation of possible plans for a pilot remediation project for ground water in the vicinity of the Paducah Gaseous Diffusion Plant which is about 10 miles west of Paducah, Kentucky. The evaluation is based primarily on Volumes 1 and 2 of the October, 1991, draft copy of the report "Results of the Site Investigation, Phase II" (Document No. KY/SUB/13B-97777C P-03/1991/1). A draft copy of a March, 1992, report by Science Applications International Corporation with the title "Treatability Test Workplan for Groundwater Remediation at the Paducah Gaseous Diffusion Plant" and a May 11, 1992, copy of a report by the Groundwater Corrective Action Review Team with the title of "Evaluation of the Proposed Pilot Groundwater Pump and Treat Demonstration for the Paducah Gaseous Diffusion Plant" were also read. In addition, a site visit was made to the Paducah plant on April 20-21, 1992, and conversations were held with Thomas Early, Jay Clausen, Bruce Phillips, Jeff Douthitt, and Walter Richards, all of whom are scientists or engineers employed by Martin Marietta Energy Systems, Inc. During the site visit, a brief reconnaissance was made by car of the northwestern part of the area of concern.

PHYSICAL SETTING

The Paducah Gaseous Diffusion Plant is on the northern tip of the Mississippi Embayment in an area of gently undulating

topography about 2-1/2 miles south of the Ohio River. The plant and surrounding features are shown on the United States Geological Survey 7-1/2-minute Quadrangles, Heath (Kentucky,1978) and Joppa (Illinois and Kentucky, 1982). Surface drainage is generally northward via small streams to the Ohio River. The land elevation at the plant is roughly between 370 and 390 feet above sea level. Water surface elevations of the Ohio River vary widely between about 290 and 340 feet above sea level, with elevations most often about 305 feet.

Water-bearing materials of greatest interest are Cenozoic sediments which vary in age from Eocene to Pleistocene. These sediments overlie Cretaceous clays and fine sands which in turn rest unconformably on Mississippi limestone at a depth of 300 to 400 feet. Although their hydrogeologic characteristics are not described in reports which were reviewed, the Mississippian carbonates yield potable water to wells in the region. The aquifer which is described as having the largest transmissivity is a continental chert gravel (informally called the "regional gravel aquifer") which underlies all except the southernmost part of the area. Secondary aquifers are found in overlying continental deposits (informally called the "shallow ground-water system") and underlying Tertiary sediments (informally called the "deep ground-water system").

Maximum hydraulic gradients of ground water in the three systems all slope northward to the riparian area along the Ohio River which is assumed to be the major discharge area for all the

ground water. Within the plant area, heads are generally highest in the shallow system and lowest in the deep system. Head differences of more than 30 feet exist in the northwest part of the plant. Head differences tend to disappear northward near the Ohio River.

CONTAMINANTS IN GROUND WATER

Contaminants found in ground water which probably originate from operations of the plant are trichloroethylene (TCE), a degreasing agent used in past years, and technetium-99 (Tc-99) which is a radioactive fission product present as the anion TcO_4^- in the water. TCE degrades slowly to other chemicals, but it is still the dominant organic contaminant even in the distal portions of the ground-water system.

Total beta activity of the water is generally slightly larger than the activity of Tc-99 as might be expected when Tc-99 is the dominant radionuclide present. A few samples, however, indicated a much higher total beta activity than the Tc-99 activity. This difference appeared to be significant for 25 of the unfiltered samples and 5 of the filtered samples. If analyses are correct, other sources of beta radiation are probable. Contributions from K-40 are unlikely to account for more than about 20 pCi/L unless a brine rich in potassium is present. The U-238, U-235, and Th-232 decay chains will produce beta decay in the daughter nuclides with short half-lives. Natural Th-232 should be in concentrations somewhat greater than

natural U-238 background, but because of the longer half-life of Th-232 their activities in uncontaminated water should be similar. Natural radionuclides are probably not responsible (in total) for more than about 40 pCi/L of beta activity. Artificial sources of uranium, however, appear to be a possible explanation for high beta counts in samples from MW-58. In contrast, samples from MW-49 have very high beta counts but very low amounts of uranium. Some anomalous beta activities are in the northwest plume, particularly in the TVA wells. If mobile species of radionuclides in addition to Tc-99 are indeed present, this fact needs to be known in order to design a properly functioning pilot plant.

REMEDIATION OPTIONS

According to verbal accounts, the pilot remediation project will probably be a pump and treat operation utilizing several wells. The Science Applications report mentions treating 360,000 gallons of pumped water per day which, presumably, would require somewhere between 5 and 15 producing wells arranged in a pattern yet to be determined. A number of observation wells will also be drilled.

The purpose of this section of my evaluation is to simply list a small number of other options and suggest that some combination of these options might be feasible. Inasmuch as planning is well underway, only minor modifications of the basic pump and treat plans may actually be possible. Also, many of the

options may have already been considered and rejected for various political or economic reasons. Nevertheless, from a purely hydrogeologic perspective, all options should be kept open as long as possible in order to take advantage of new hydrogeologic data as it becomes available.

A. Passive, low-cost options.

1. No action. Some natural bioremediation may take place.
2. Use a system of deep drainage ditches and diversions of surface water in order to "focus" flow of contaminated water into a narrow band which then would discharge into the river. This would control and reverse spread of contaminants and would have minimal requirements for maintenance. Much of the TCE could be partitioned to the atmosphere by producing small cascades of water over weirs. Unfortunately, political and regulatory problems would be difficult.
3. Improve nonpermeable caps over areas which are being leached by infiltrating surface precipitation. Much of this work has probably been completed.

B. Early intensive work followed by passive period.

1. Rapid removal and treatment of contaminants by selectively pumping from "hot spots" and use of vapor extraction for shallow "hot spots" having excessive amounts of TCE. Install drainage ditches for long-term discharge of very low levels of contaminants to the river. This option does not solve the problem of the probable occurrence of

a separate liquid TCE phase. Also, any planned discharge of contaminants to the river would be politically difficult.

2. Inject clay or cement slurry walls around and over local "hot spots" to partly confine contamination which would come from these major sources. Although very expensive at the onset and of unknown effectiveness, a carefully designed system might be less expensive in the long run than a project involving a well field which might be operated for many decades. Even though complete containment would be unlikely, slowly leaking contaminants would be diluted by normal ground-water flow and would eventually be at concentrations lower than any health concerns.

C. Expensive, long-term projects.

1. Use a picket line of extraction wells across major contaminant plumes to intercept contaminants. Well water would then be collected for treatment in surface facilities. I assume that this will be the general idea of the pump and treat pilot plant which is presently being considered. This option will be discussed in greater detail in the next section of this evaluation.

2. Circle the entire plant with an injected cutoff curtain of clay. This might have popular appeal but would be very expensive and probably not feasible technically. In

addition, an effective cutoff curtain, even if it could be constructed, might not be stable over long periods.

PUMP AND TREAT OPTION

Potential problems. Although details of the proposed pilot operation are not known at this time, several possible problems should be noted.

A. Owing to the large investment of time and money into the pilot plant, the tendency will be to retain the pilot plant with associated wells as the initial component of the final remediation effort even though other options may ultimately prove to be better choices. Stated in another way, once the commitment is made for a pump and treat plan, it will be difficult to reverse this decision.

B. A cutoff time for the pump and treat operation will be difficult to set. When will the pumping stop? Will regulators force continued operation beyond reasonable limits? The operating cost of this option is large, and the possibility of pumping and treating water for a number of decades is not attractive.

C. Pumping may actually make contamination worse, at least from the short-term viewpoint. Presumably the gravel aquifer will be pumped. This will lower heads in the gravel and induce ground water from above and below to enter the gravel. Inasmuch as contaminants are seeping downward through the shallow ground water system, and any separate phase of TCE

could be at the bottom of, or below, the gravel, pumping could easily start a large slug of contaminants moving through the gravel aquifer.

D. If the presumed excess beta activity in contaminated water is real and related to some human origin, pumping could accelerate migration of radionuclides which are far more hazardous than Tc-99. If subsequent remedial action is needed to remove these hypothetical radionuclides, then the operation of the pump and treat pilot plant will have made remediation more difficult.

E. Storage and ultimate disposal of concentrated contaminants is not a trivial task. Regulations may change so that the problem of disposal may be ultimately almost impossible, particularly for the Tc-99.

Information needed. The gathering of information required for the provisional design of the pilot plant is still underway. The following check-list, therefore, cannot reflect adequately the present status of the project. For example, detailed stratigraphy of the subsurface is being compiled and may be sufficiently accurate for the design, but I have listed this item because I have not seen the final report containing this information.

A. The exact nature of all of the ground-water contaminants should be reviewed critically by some individual who has access to plant records. Although I do not expect any surprises, this item is so very important that it cannot be

reviewed too often. Information on organic constituents appears possibly complete, but the radiochemistry may possibly be incomplete. For example, if Sr-90 were present, only 10 pCi/L would be of public health interest. This would be beta activity wnich would be overwhelmed in some of the samples with other sources of beta activity. It would simply go undetected unless it is searched for specifically.

B. Minute details of subsurface stratigraphy are important and should be available when designing the pilot pump and treat operation. Many of tne logs given in the massive CH2M Hill reports appear to be too generalized. They should be checked against field notes. New drill holes may be required.

C. The distribution and original sources of contaminants in the subsurface need to be known better. What and where are the sources? Are they still feeding contaminants into the subsurface? If so, how long will the sources last? Are dense, separate phases present deep in the ground-water system? Will these serve as secondary sources for decades into the future? Specifically, TCE concentrations near the head of the northwestern contaminant plume are far below saturation, but further work is needed to eliminate the possibility of having some dense, separate phase present at depth. Intelligent placement of recovery wells and long-term projections of recovery operations will be impossible without a good knowledge of sources of contamination. Proposed hydropunch work may prove useful in this regard.

D. Although very difficult to achieve, a better picture of the hydrogeologic characteristics of the ground-water system would be useful. Effects of boundary conditions, seasonal recharge, fluctuations of river elevations, and other factors may be important in the overall system. Because long-term pumping during aquifer tests could result in the discharge of contaminants of unacceptable concentrations, such tests, although essential, need very careful planning. Information gained is required for hydrogeologic models. The models in turn can test various assumptions concerning the hydrogeologic system, but an initial input of basic data concerning aquifer and aquitard properties is needed.

E. Although not strictly part of the pilot project, an item of possible widespread public interest should be addressed very briefly in connection with contamination at the plant. This is the question of possible contamination of the Mississippian aquifer. Some evidence should be presented that the Cenozoic and Cretaceous clays are continuous and lack permeability to transmit contaminants into the Mississippian carbonate rocks. Also, if vertical gradients are upward, this should be stated. The probability that the carbonate rocks will be contaminated seems to be very small, but the use of this aquifer in the region and the very rapid movement of contaminants in carbonate rocks make the question important. Travel of contaminants to heavily pumped wells in carbonate rock north of the Ohio River is entirely possible.

11

In addition, if gradients are downward into the carbonate rocks, past drilling records should be consulted to make sure that unplugged abandoned wells are not present.

The question of travel of contaminants through post-Mississippian sediments to points north of the Ohio River should be addressed briefly. Inasmuch as the river and permeable sediments deposited recently by the river cut into the regional gravel aquifer, the river would most likely serve as a line sink for the flow field. "Pumping" of contaminants northward during flood stage, although theoretically possible, appears to be unlikely because the entire thickness of the gravel aquifer is probably either directly or indirectly in hydraulic contact with the river.

APPENDIX D

Regulatory Framework

Regulatory Framework

On July 16, 1991, a Hazardous and Solid Waste Amendments (HSWA) Permit was issued to the Paducah Gaseous Diffusion Plant (PGDP), with the U.S. Department of Energy (DOE) as the owner/operator and Martin Marietta Energy Systems, Inc., as the co-operator. The effective date of this Permit is August 19, 1991. This Permit in conjunction with the Hazardous Waste Management Permit issued by the Commonwealth of Kentucky, constitutes the Resource Conservation and Recovery Act (RCRA) Permit for PGDP. The HSWA Permit requires PGDP to investigate any releases of hazardous waste or hazardous constituents pursuant to this Permit at PGDP regardless of the time at which the waste was placed in such unit and to take appropriate corrective action for any releases [Sect. 3004(u) of RCRA], including corrective actions beyond the facility boundary [Sect. 3004(v) of RCRA]. This Permit also stipulates that PGDP must comply with all terms and conditions of the Administrative Consent Order (ACO) under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Sects. 104 and 106.

Section 3004(u) of RCRA provides that any permit issued after November 1984, must require corrective action for all releases of hazardous waste or constituents from any solid waste management unit (SWMU) regardless of when the waste was placed at such unit. The provision applies to any SWMU, including inactive units, at any treatment, storage, or disposal facility seeking a permit under Sect. 3005(c) of RCRA (130 Cong. Rec. H11129, daily ed., October 3, 1984).

Section 3004(u) contemplates that EPA will issue standards addressing corrective action for such releases. However, until EPA establishes and codifies such standards it will be up to EPA on a case by case basis as to what the appropriate corrective action will be, with guidance from the general regulation 40 CFR 264.101, which was codified on July 15, 1985. The Subpart S Regulations have been proposed for corrective action for SWMUs; however, these regulations have not been codified nor does it appear that they will be in the near future.

On March 28, 1986, EPA proposed to codify Sect. 3004(v) by adding 40 CFR 264.100(e) and 264.101(c) to the current regulations. This proposal required owner/operators of hazardous waste treatment, storage, and disposal facilities to institute corrective action beyond the facility boundary where necessary to protect human health and the environment unless the owner/operator is denied access to adjacent lands despite the owner/operator best efforts. However, these regulations were codified on December 1, 1987, to clarify that the owner/operators are not relieved of responsibilities to perform on-site corrective action if off-site access is denied.

Under Sect. 104 of CERCLA, which the facility is subject to by reference in the HSWA Permit, any officer, employee, or representative of the President would be authorized to access information, inspect and sample, or even issue compliance orders if there is reasonable basis to believe that there may be a release or threat of a release of hazardous substances, pollutants, or contaminants. Thus, PGDP has no relief from performing off-site corrective action unless it can be demonstrated that it is technically impractical. However, if it is determined that attainment of a remedy requirement is not technically practical and no practical alternative technologies are available, it will be necessary to determine what

alternatives or additional requirements, if any, will be needed to ensure that the remedy adequately protects human health and the environment.

It is clear that Congress intended the term "release" under 40 CFR 264.101 to encompass at least releases to groundwater and to be at least as inclusive as the definition of release in Sect. 101 of CERCLA. The Senate legislative history notes that to ensure corrective action is taken in response to releases, the administrator will need to revise the groundwater monitoring requirements of 40 CFR Part 264 Subpart F. [S. Rep. No. 284. 98th Cong., 1st Sess. 32 (1983)].

Similarly, the house legislative history notes that the corrective action required for a release must be accomplished in a manner currently prescribed in 40 CFR 264.100 [H.R. Rep. No. 98th Cong., 1st Sess. Part 1, 60 (1983)]. The requirements of 40 CFR 264.100 pertain only to the cleanup of groundwater. Under this interpretation, EPA would only apply corrective action to those releases to the uppermost aquifer (40 CFR 260.10) and only those which exceed the 40 CFR Part 264 Subpart F Groundwater Protection Standards. This standard is defined as either the background concentration of the constituent or the maximum contaminant level for the constituent by the National Interim Primary Drinking Water Regulation (40 CFR Part 264 Table 1), unless the owner or operator demonstrates that an alternate concentration limit is warranted.

This cleanup issue is one of the most controversial issues relating to groundwater corrective action, or "how clean is clean." EPA believes that different cleanup levels will be appropriate in different situations and that levels are best established as part of the remedy selection process. For example, as indicated earlier, potentially drinkable groundwater would be cleaned up to levels safe for drinking throughout the contaminated plume regardless of whether the water was in fact being consumed. If groundwater were not a potential source of drinking water because of high levels of natural contamination, the owner/operator might successfully argue that cleanup was unnecessary.

Final remediation goals under HSWA and CERCLA, however, are established on acceptable exposure levels that are protective of human health and the environment. For example, for systemic toxicants, acceptable exposure levels are to be concentration levels to which human populations, including sensitive groups, may be exposed during a lifetime without adverse effect during a lifetime, incorporating an adequate margin of safety. For known or suspected carcinogens, acceptable exposure levels are concentration levels that represent an excess upper bound lifetime cancer risk to an individual between 10^{-4} and 10^{-6} using information between dose and response.

The term "hazardous constituent" as used in the SWMU definition is intended to mean those constituents listed in Appendix VIII of 40 CFR Part 261 [H.R. Rep. No.198, 98th Cong., 1st Sess., Part 1, 60-61 (1983)] and includes hazardous constituents released from solid waste and those that are reaction byproducts from hazardous constituents. The RCRA Facility Investigation Guidance (OSWER Directive 9502.00-6C) states that the selection and use of monitoring constituents and indicator parameters is a site-specific process, and the selection of specific monitoring constituents starts with the universe found in Appendix VIII. Based on site-specific considerations (contaminated media, sampling and analysis of waste from the unit, or industry-specific information) this list can be shortened to an appropriate set of monitoring constituents.

One of EPA's primary objectives in development of the RCRA corrective action regulations is to achieve substantive consistency with the policies and procedures of the remedial action program under CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986. Sections 104 and 106 of CERCLA authorized EPA to take response actions, including removal or remedial measures, when a release or threat of a release of a hazardous substance which may threaten human health or the environment is discovered. Generally, these authorities are used in situations where contamination has occurred at sites that are not under the control of a RCRA owner or operator. Where contamination is related to activities at hazardous waste management facilities that are currently operating or have conducted treatment, storage, or disposal of hazardous waste at any time since November 19, 1980, both RCRA and CERCLA potentially apply.

The ACO, under Sects. 104 and 106 of CERCLA, was signed by DOE and EPA and approved by the Department of Justice. The effective date was November 23, 1988. Section II of this ACO, "Statement of Purpose," stipulates these items:

"In entering this Consent Order, the mutual objectives of EPA and DOE include:

- to determine fully the nature and extent of the threat to human health or welfare and the environment caused by the off-site contamination of the groundwater from the PGDP;
- to ensure that the environmental effects associated with the releases described herein are thoroughly investigated and appropriate action taken as necessary to protect the public health, welfare and the environment;
- to establish a work plan and schedule(s) for developing, implementing and monitoring any necessary response actions at the site in accordance with CERCLA; and,
- to facilitate the cooperation, exchange of information and participation of the Parties in such action."

Two phases of site investigation resulted from the ACO. The Phase I report (CH2M Hill 1991) was to investigate the contamination of groundwater and surface waters from PGDP both on site and off site. This report was finalized and approved by EPA in July of 1992. The Phase II report (CH2M Hill 1992), which was to fill in data gaps from Phase I and identify contaminant sources, was finalized and forwarded to EPA in April of 1992. It has not been approved as of April 16, 1992. The summary of remedial alternatives for PGDP (SAIC 1991) was prepared and forward in draft to EPA in December 1991. Comments were due from EPA in May of 1992.

On March 31, 1992, EPA and the Kentucky Department for Environmental Protection (KYDEP) jointly issued a letter directing DOE: "pursuant to Condition II.E.1.a. of the EPA RCRA Permit and Condition IV.E.1.a. of the state RCRA Permit, to carry out interim corrective measures for the off-site releases associated with sources contributing to these offsite releases." This March 31, 1992, letter references DOE's two corrective measures activities that were in the DOE letter of February 27, 1992, to EPA. The two identified measures were:

"First, we plan to pursue a groundwater Pump-and-treat Pilot System. The goal of this is to prevent further migration of contaminated groundwater."

"Additionally, we will be pursuing Institutional Controls as an Interim Measure for Outfalls, Creeks, and Lagoons....signs warning against consumption of fish from the creeks and outfalls, and against recreational use would be posted to minimize the risks from direct contact with contaminated sediments and ingestion of contaminated fish. Fences would be installed along outfall 011 and little Bayou Creek to McCaw Road and along the North-South Diversion Ditch (outfall 003) to Ogden Landing Road. Fences would be extended around waste management unit (WMU) 18 to limit access to humans and some migratory wildlife (deer)."

This February 27, 1992, letter also stated that "all interim measures will be conducted in a manner consistent with the Interim Measures provisions of the Resources Conservation and Recovery Act (RCRA)." The regional administrator will consider the immediacy and magnitude of the threat to human health or the environment as primary factors in determining whether an interim measure(s) is required. Factors that could be considered in determining whether an interim measure is required are:

- Actual or potential exposure of nearby populations or animals to hazardous constituents;
- The time required to develop and implement a final remedy;
- Actual or potential contamination of drinking water supplies or sensitive ecosystems;
- Further degradation of the medium which may occur if remedial action is not carried out expeditiously;
- Presence of hazardous waste or hazardous constituents in drums, barrels, or other bulk storage containers that may pose a threat of release;
- Presence of high levels of hazardous constituents in soils at or near the surface which may migrate; or
- Weather conditions which may cause releases of hazardous constituents or the migration of existing contamination.

Interim measures may encompass a broad range of possible actions. For example, a facility that has contaminated a public drinking water supply may be required to make available alternate drinking water or initiate a groundwater pump-and-treat system to control further migration of the plume. Section II.E.1.b. of the HSWA Permit states that interim measures are designed to mitigate any current or potential threat(s) to human health or the environment and are consistent with and integrated into any long-range solution at the facility.

The March 31, 1992, letter from EPA and KYDEP stipulates that a work plan to carry out interim corrective measures for the off-site releases associated with sources contributing to these off-site releases should be forwarded to EPA by May 22, 1992, per DOE's letter of February 27, 1992. However Condition II.E.1.a. of the HSWA Permit states that the work plan shall be submitted within 90 days of notification by the regional administrator. This notification was the March 31, 1992, letter from EPA and KYDEP. Thus, the latest due date for submission of this work plan should be June 29, 1992, according to the requirements of the HSWA Permit.

The evaluation of alternatives for remediation of groundwater at PGDP included consideration of pump-and-treat technology to intercept and remove TCE and ^{99}Tc from the

groundwater and prevent the continued spread of contamination downgradient of PGDP. The pilot demonstration work plan describes a treatment facility to remove contaminants from groundwater and provides data needed to select among treatment options for scaling up. The work plan is consistent with the intent of Sect. II.E.1.a. of the HSWA Permit for an Interim Measures Work Plan.

On September 1, 1991, DOE and Energy Systems forwarded comments during the public comment period on the draft RCRA Permits from EPA and KYDEP. Comment 17 requested to expand the dispute resolution clause to include all sections under Part II (corrective action) of the RCRA HSWA Permits. DOE and Energy Systems were concerned about the impact of revisions of RFI work plans and other plans by the regional administrator and the impacts that these changes may have upon the schedules and available resources for implementation of the plan or on other work under the HSWA Permit.

EPA responded that it, too, was concerned about the impact to schedules and resources resulting from revisions of RFI work plans and other plans. Such concerns have previously been expressed in the Administrative Order Denying Review of a HSWA Permit issued to United Technology Corporation/Pratt & Whitney Group (RCRA Appeal No. 88-34, dated February 12, 1990). Under that appeal, the petitioner argued that the permit improperly made no provisions for an administrative appeal (or dispute resolution) of certain interim decision and approvals by the regional EPA office during the corrective action process. These interim decisions and approvals generally involve reviews of various work plans, schedules, and even interim measures.

The administrator decided that allowing an administrative appeal from such interim decisions and approvals would lead to unnecessary and undesirable delays in the corrective action process. Should the petitioner be dissatisfied with an interim decision by the regional EPA office, the petitioner is free to pursue and available opportunities for judicial review. The administrator also declared that the permit properly gives to the regional EPA office final authority to make various interim decisions during the corrective action process; the ultimate corrective measures are to be added to the permit through a major modification.

DOE and Energy Systems did not choose to appeal this permit on the basis of the conditions of a no-dispute-resolution clause in Sect. II.

APPENDIX E

Risk Assessment Tables

Table 6-2
GROUNDWATER DATA SUMMARY FOR
ANALYSIS OF OFFSITE RECEPTORS: CHEMICALS DETECTED[a]

(page 1 of 2)

Contaminant	Residential Wells			Monitoring Wells			TVA Wells		
	Detection Frequency[c]	Concentration µg/l[b]		Detection Frequency	Concentration µg/l[b]		Detection Frequency	Concentration µg/l[a]	
		Range	Average[d]		Range	Average		Range	Average
ORGANIC:									
Aroclor-1260	ND[e]	--	--	ND[e]	--	--	ND[e]	--	--
4-Nitrophenol				2/17	15.0-15.0	15.0			
Bis(2-ethylhexyl)phthalate	6/44	2.0-69.0	27.8	8/17	5.0-320.0	105.9			
Di-n-butyl phthalate	2/44	2.0-3.0	2.5	1/17	2.0	2.0			
Di-n-octyl phthalate	1/44	27.0	27.0	1/17	5.0	5.0			
Diethyl phthalate				1/17	2.0	2.0	1/4	11.0	11.0
1,2-Dichloroethane	4/61	1.0-2.0	1.3						
1,2-Dichloroethene (total)	2/61	5.0-18.0	11.5	4/41	2.0-12.0	7.3			
2-Butanone				1/27	7.0	7.0			
Benzene				1/42	3.0	3.0			
Carbon disulfide	NA[f]			1/42	2.0-2.0	2.0	NA[f]		
Carbon tetrachloride	3/61	1.0-8.0	5.3						
Chloroform	6/61	1.0-34.0	13.3	3/42	2.0	2.0			
Tetrachloroethene	3/61	1.0-2.0	1.3						
Toluene	2/61	1.0-2.0	1.5	5/42	1.0-23.0	7.6			
Trichloroethene	15/61	1.0-1,600.0	380.0	18/42	1.4-340.0	106.3	5/28	1.0-74.0	16.0
Xylene				2/42	3.0-4.0	3.5			

Table 6-2
GROUNDWATER DATA SUMMARY FOR
ANALYSIS OF OFFSITE RECEPTORS: CHEMICALS DETECTED[a]

(page 2 of 2)

Contaminant	Residential Wells			Monitoring Wells			TVA Wells		
	Detection Frequency[c]	Concentration µg/l[b]		Detection Frequency	Concentration µg/l[b]		Detection Frequency	Concentration µg/l[a]	
		Range	Average[d]		Range	Average		Range	Average
INORGANIC									
Aluminum	30/44	24.1-3,400	384.1	19/19	31.4-66,300	11,170.4	5/6	1,270-58,600	14,528
Arsenic	6/44	1.3-2.5	1.9	4/18	0.6-1.9	1.0	3/6	1.8-38.2	14
Barium	44/44	19.4-464	121.2	19/19	42.8-1,030	325.8	6/6	71.2-536	189.3
Beryllium	12/44	0.05-2.5	0.6	9/19	0.2-9.3	3.3	3/6	2.4-4.2	3
Cadmium	2/44	1.8-1.9	1.9	4/18	3.0-4.1	3.6			
Chromium	8/44	4.4-107	19.5	16/19	7.0-224	76.3	4/6	7.4-94.6	33.8
Copper	33/44	5.4-1,120	59.3	19/19	3.6-1,280	126.5	4/6	16.9-76	36.5
Iron	31/44	23.1-166,000	7,422.5	19/19	51.3-288,000	38,278.2	6/6	491-121,000	32,383.5
Lead	37/44	1.0-287	15.6	19/19	0.6-82.6	13.6	5/6	2.0-21.3	8.7
Magnesium	44/44	1,810-24,300	7,908	19/19	5,950-20,500	11,149.5	6/6	3,570-15,900	8,075
Manganese	34/44	1.2-423	63.2	19/19	128.0-2,880	993.8	5/6	116-2,530	933.6
Mercury	3/44	0.2-0.2	0.2						
Nickel	8/44	5.7-58.6	17.9	16/19	6.1-159	61.5	4/6	21.4-73.8	47.4
Selenium	16/43	1.1-13.8	4.7	13/19	0.4-7.2	3.5	3/4	1.6-10.3	5.1
Silver	3/44	2.1-10.3	6.1	3/16	12.4-27.5	19.9	1/6	4.9-4.9	4.9
Zinc	39/44	3.4-5,090	291.7	19/19	41.7-990	218.6	6/6	48.1-371	178.9

[a]Source: EDMS-009, October 24, 1990; EDMS-009, November 28, 1990.
[b]Total metals (unfiltered samples).
[c]Number detected/number analyzed, including duplicates.
[d]Average of only detected values, including duplicates.
[e]Not detected; number of samples not specified.
[f]not analyzed

Table 6-10
SUMMARY OF RADIOLOGICAL EXPOSURE CONCENTRATIONS FOR GROUNDWATER

Contaminant	Residential Wells			Monitoring Wells			TVA Wells		
	Detection Frequency[a]	Concentration (pCi/l)		Detection Frequency	Concentration		Detection Frequency	Concentration (pCi/l)	
		Range	Average		Range	Average		Range	Average
Tc-99	19/49	1.82-1,200.0	190.2	18/39	4.0-220.0	91.5	5/28	4.3-110.0	48.7
U-238	2/7	1.5-3.4	2.45	16/31	0.21-8.8	1.7	13/18	0.6-97.0	10.2
U-235	1/2	0.13	0.13	3/16	0.07-0.22	0.13	2/8	0.1-2.6	1.4
U-234	2/6	1.8-3.1	2.45	16/31	0.18-4.9	1.4	15/18	0.3-9.5	3.5
Th-230	2/7	0.21-1.1	0.65	9/31	.08-3.5	1.4	10/18	0-2.0	0.7
Np-237	0/7	NA[b]	NA	0/31	NA	NA	0/17	NA	NA
Pu-239	3/16	0.02-0.07	0.05	1/31	0.6	0.6	1/20	2.0	2.0

[a]Number detected/number analyzed
[b]not applicable

Table 6-36
TOTAL EXCESS LIFETIME CANCER RISK ASSOCIATED WITH INGESTION AND INHALATION EXPOSURES TO CONTAMINANTS DURING RESIDENTIAL USE OF GROUNDWATER: AVERAGE EXPOSURE ASSUMPTIONS[a]

Well Category	Excess Lifetime Cancer Risk			Percent Attributable To Individual Contaminants
	Ingestion[b]	Inhalation[c]	Total[d]	
Residential Wells	2×10^{-5}	2×10^{-5}	4×10^{-5}	Trichloroethene: 50 Arsenic: 34
Monitoring Wells	1×10^{-5}	5×10^{-6}	1.5×10^{-5}	Arsenic: 35 Bis(2-ethylhexyl)phthalate: 35 Trichloroethene: 28
TVA Wells	5×10^{-7}	7×10^{-7}	1.2×10^{-6}	Trichloroethene: 100

[a]Summarized from site risk-characterization tables in Appendix 6C, which list all contributors to risk.
[b]Includes carcinogens or suspected carcinogens.
[c]Inhalation risks calculated only for volatile organic chemicals.
[d]Sum of ingestion and inhalation risks.

Table 6-37
TOTAL EXCESS LIFETIME CANCER RISK ASSOCIATED WITH INGESTION AND INHALATION EXPOSURES TO CONTAMINANTS DURING RESIDENTIAL USE OF GROUNDWATER: MAXIMUM EXPOSURE ASSUMPTIONS[a]

Well Category	Excess Lifetime Cancer Risk			Percent Attributable To Individual Contaminants
	Ingestion[b]	Inhalation[c]	Total[d]	
Residential Wells	3×10^{-4}	3×10^{-4}	6×10^{-4}	Trichloroethene: 74 Arsenic: 16 Bis(2-ethylhexyl)phthalate: 4
Monitoring Wells	1×10^{-4}	8×10^{-5}	1.8×10^{-4}	Bis (2-ethylhexyl) phthalate: 40 Trichloroethene: 34 Arsenic: 26
TVA Wells	5×10^{-5}	7×10^{-4}	7.5×10^{-4}	Arsenic: 99

[a]Summarized from site risk-characterization tables in Appendix 6C, which list all contributors to risk.
[b]Includes carcinogens or suspected carcinogens.
[c]Inhalation risks calculated only for volatile organic chemicals.
[d]Sum of ingestion and inhalation risks.

Table 6-38
SUMMARY OF LIKELIHOOD OF NONCARCINOGENIC EFFECTS ASSOCIATED WITH INGESTION AND INHALATION OF CONTAMINANTS DURING RESIDENTIAL USE OF GROUNDWATER: AVERAGE EXPOSURE ASSUMPTIONS[a]

Well Category	Hazard Index			Percent Attributable To Individual Contaminants
	Ingestion[b]	Inhalation[c]	Total[d]	
Residential Wells	0.6	0.3	0.9	Carbon Tetrachloride: 27 Cadmium: 14 Chromium: 14 Bis (2-ethylhexyl) pthalate: 5
Monitoring Wells	1.1	0.03	1.1	Chromium: 28 Manganese: 18 Cadmium: 13 Silver: 12 Bis (2-ethylhexyl) phthalate: 10
TVA Wells	0.5	0	0.5	Manganese: 38 Chromium: 27 Barium: 11

[a]Summarized from site risk-characterization tables in Appendix 6C, which list all contributors to risk.
[b]Included regardless of toxic effect, mechanism of action, or degree of confidence in the underlying toxicologic database.
[c]Includes only volatile organic compounds.
[d]Sum of inhalation and ingestion hazard indices.

Table 6-39
SUMMARY OF LIKELIHOOD OF NONCARCINOGENIC EFFECTS ASSOCIATED WITH INGESTION AND INHALATION OF CONTAMINANTS DURING RESIDENTIAL USE OF GROUNDWATER: MAXIMUM EXPOSURE ASSUMPTIONS[a]

Well Category	Hazard Index			Percent Attributable To Individual Contaminants
	Ingestion[b]	Inhalation[c]	Total[d]	
Residential Wells	2	0.7	2.7	Chromium: 31 Carbon Tetrachloride: 17 Manganese: 6 Bis(2-ethylhexyl)phthalate: 5
Monitoring Wells	3.8	0.1	3.9	Chromium: 33 Manganese: 21 Bis(2-ethylhexyl)phthalate: 12 Barium: 11
TVA Wells	1.7	0	1.7	Manganese: 42 Chromium: 31 Barium: 13

[a]Summarized from site risk-characterization tables in Appendix 6C, which list all contributors to risk.
[b]Included regardless of toxic effect, mechanism of action, or degree of confidence in the underlying toxicologic database.
[c]Includes only volatile organic compounds.
[d]Sum of inhalation and ingestion hazard indices.

Table 6-53
SUMMARY OF EXCESS TOTAL CANCER INCIDENCE RISK FROM INGESTION OF RADIOLOGICALLY CONTAMINATED GROUNDWATER

Well Category	Assumptions for Average Exposure		Assumptions for Upper-Bound Exposure	
	Excess Cancer Risk*	Major Components of Risk (Percent)	Excess Cancer Risk*	Major Components of Risk (Percent)
Residential Wells	4.34×10^{-6}	U-238 (34) U-234 (36) Tc-99 (26)	5.43×10^{-5}	Tc-99 (63) U-238 (18) U-234 (18)
Monitoring Wells	2.78×10^{-6}	U-238 (37) U-234 (32) Tc-99 (20)	4.92×10^{-5}	U-238 (51) U-234 (30) Tc-99 (13)
TVA Wells	9.84×10^{-6}	U-238 (62) U-234 (23) U-235 (9) Tc-99 (3)	3.18×10^{-4}	U-238 (87) U-234 (9) U-235 (2)

*Summarized from risk-characterization tables in Appendix 6D.

Table 2-1
Summary of Range of Reported Values for Chemicals of Potential Concern at the PGDP
PGDP Phase II Public Health and Ecological Assessment
(Page 1 of 4)

Chemical	Onsite Groundwater	Offsite Groundwater	Surface Water	Onsite Soils	Offsite Soils	Sediment	Biota
	(µg/l)	(µg/l)	(µg/l)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)[a]
VOLATILE ORGANIC COMPOUNDS							
1,1,1-Trichloroethane	2-16	-	-	0.007-0.07	0.008	-	NA
1,1,2-Trichloroethane	1-230	-	-	0.001-0.02	-	-	NA
1,2-Dichloroethene (total)	1-7,900	1-17	-	-	-	-	NA
Benzene	12	-	-	-	-	-	NA
Carbon tetrachloride	4-21	8	-	-	-	-	NA
Chloroform	3-23	1-46	1-6	0.004-0.01	0.023	-	NA
Chloromethane	180	-	-	-	-	-	NA
Dichlorodifluoromethane	2	-	-	-	-	-	NA
Ethyl benzene	3	-	-	-	-	-	NA
Tetrachloroethene	5-240	1	-	0.002-0.01	-	0.001	NA
Toluene	2-59	-	-	0.001-0.03	0.006	0.001-0.21	NA
Trichloroethene	2-890,000	1-1,600	1-12	0-1.1	-	0.009	NA
Vinyl chloride	7,500	-	-	-	-	-	NA
Xylenes	5-13	-	-	0.003-0.01	-	0.001	NA
1,1-Dichloroethane	-	-	-	0.006-0.01	-	-	NA
1,1-Dichloroethene	1-86	-	-	0.004	-	-	NA
1,2-Dichloroethane	6	-	-	-	-	-	NA

Table 2-1
Summary of Range of Reported Values for Chemicals of Potential Concern at the PGDP
PGDP Phase II Public Health and Ecological Assessment
(Page 2 of 4)

Chemical	Onsite Groundwater	Offsite Groundwater	Surface Water	Onsite Soils	Offsite Soils	Sediment	Biota
	(µg/l)	(µg/l)	(µg/l)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)[a]
SEMIVOLATILE ORGANIC COMPOUNDS							
2-Chlorophenol	-	-	-	0.065-0.15	-	-	NA
2-Nitroaniline	65	-	-	-	-	-	NA
4-Bromophenylether	-	-	-	-	0.44	-	NA
Acenaphthene	-	-	-	0.046-0.16	0.23	-	NA
Anthracene	-	-	-	0.047-0.24	0.46	-	NA
Benzo[a]anthracene	-	-	-	0.041-0.52	0.06-1	0.16-0.25	NA
Benzo[a]pyrene	-	-	-	0.052-0.43	0.15-0.95	0.14-0.18	NA
Benzo[b]fluoranthene	-	-	-	0.071-0.55	0.13-1.1	0.15-0.25	NA
Benzo[g,h,i]perlyene	-	-	-	0.054-0.34	0.25-0.49	0.27	NA
Benzoic acid	230	-	-	0.042-0.37	-	-	NA
Benzo[k]fluoranthene	-	-	-	-	0.13-0.78	1.1	NA
Chrysene	-	-	-	0.044-0.55	0.09-1.1	0.14-0.27	NA
Dibenz[a,h]anthracene	-	-	-	0.056-0.07	0.26	-	NA
Fluoranthene	2	-	-	0.044-1.2	0.04-3	0.22-0.61	NA
Fluorene	-	-	-	0.14	0.21	-	NA
Indeno[1,2,3-cd]pyrene	-	-	-	0.051-0.32	0.53	0.27	NA
Isophorone	10	-	-	-	-	-	NA

Table 2-1
Summary of Range of Reported Values for Chemicals of Potential Concern at the PGDP
PGDP Phase II Public Health and Ecological Assessment
(Page 3 of 4)

Chemical	Onsite Groundwater	Offsite Groundwater	Surface Water	Onsite Soils	Offsite Soils	Sediment	Biota
	(µg/l)	(µg/l)	(µg/l)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)[a]
Pentachlorophenol	-	-	-	0.055-0.53	-	0.14	-
Phenanthrene	1	-	-	0.036-1.1	0.04-2.3	0.21-0.5	-
Phenol	27	29-57	-	0.046-0.74	-	-	-
Pyrene	1	3	-	0.048-2.1	0.04-1.7	0.17-0.56	-
PCBs/PESTICIDES							
2,3,7,8-TCDD (Dioxin)	-	-	-	0.003-0.037	-	-	-
Aldrin	-	-	-	0.076-0.19	-	-	-
DDE	-	-	-	-	0.061-0.067	-	-
DDT	-	-	-	0.02-0.022	0.026-0.064	-	-
Dibenzofuran	-	-	-	0.08-0.084	0.12	-	-
Endosulfan II	-	-	0.017	-	-	-	-
Octachlorodibenzo-p-Dioxin (total)	-	-	-	0.002-0.039	-	0.001-0.01	-
PCBs	-	-	-	0.039-475	-	0.07-11	0.108-21.1
INORGANICS							
Aluminum	97.8-270,000	20.5-65,900	102-2,280	174-18,200	364-15,700	687-17,500	4.1-275
Antimony	-	9.3-11.5	-	0.39-20.9	-	0.55-1.4	-
Arsenic	1-289	0.9-9.7	0.8-9.8	0.39-18.7	1.1-11.2	2.2-33.7	0.034-0.96
Barium	50.4-2,870	6.3-1,250	8.5-394	2-289	6.2-151	7.4-922	0.17-35.3
Beryllium	0.25-54.4	0.2-10.3	-	0.052-11.9	0.29-8.5	0.51-29.4	0.012-2.2

Table 2-1
Summary of Range of Reported Values for Chemicals of Potential Concern at the PGDP
PGDP Phase II Public Health and Ecological Assessment
(Page 4 of 4)

Chemical	Onsite Groundwater	Offsite Groundwater	Surface Water	Onsite Soils	Offsite Soils	Sediment	Biota
	(µg/l)	(µg/l)	(µg/l)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)[a]
Cadmium	1.2-70	0.74-4.1	-	0.57-12.8	0.35-2.1	0.65-4.2	0.16-1.9
Chromium	3.2-611	2.2-272	1.6-7	0.78-258	6.6-107	10.8-260	0.55-7.2
Cobalt	3.8-673	2-112	2.7-2.8	0.77-30.2	3.1-13.8	3-50.7	-
Copper	2.5-242	0.9-122	1.5-27.7	0.96-231	2.6-21.4	2.8-17,400	1.1-37.9
Lead	0.9-225	0.7-97	0.6-17.3	0.66-323	1.6-41.2	3.2-36.5	0.1-44.2
Manganese	2.5-23,600	0.37-3,530	31.1-2,750	4.5-2,920	15.9-1,400	5.3-4,150	3.2-93.7
Mercury (total)	0.22-0.26	0-0.1	0.19	0.011-7.7	-	0.2	0.62-9.2
Nickel, soluble salts	7.3-531	1.4-140	4.6-7.4	0.92-85.4	3.7-21.5	2.9-85.7	0.56-44.6
Selenium	0.66-9.5	0.62-12.6	0.4-1.6	0.16-0.98	0.14-0.7	0.15-6.2	0.11-3.3
Thallium	0.7-0.8	0.7-0.8	0.8	0.37	0.28	0.22-1.3	-
Vanadium	1.7-753	1-180	1.2-8.8	1-68.9	6-37.5	9.6-80.7	-
Zinc	3.6-1,960	3.4-545	13.1-78.3	0.83-390	7.3-65.1	9-174	-

[a]Fish and deer only.

NOTES:
PCBs were reported in sediments during the BMP at concentrations between 0.02 and 5.62 mg/kg.
Metals analyses for water were performed on unfiltered samples, which contained the higher concentrations of the parameters of concern.
Soils and sediments reported on dry weight basis.
Biota samples reported on a wet weight (as received) basis.
Complete data summary tables for media (frequency of detection, maximum, minimum, and averages) are presented in Appendix C.
"Onsite areas" include those areas inside the PGDP security fence and those operating WMUs outside the security fence.
- = Not detected.
NA = Not analyzed.

Table 2-2
Summary of Range of Reported Values for Radionuclides of Potential Concern at the PGDP
PGDP Phase II Public Health and Ecological Assessment

Chemical	Onsite Groundwater	Offsite Groundwater	Surface Water	Onsite Soils	Offsite Soils	Sediment	Biota
	(pCi/l)[a]	(pCi/l)[a]	(pCi/l)	(pCi/g)	(pCi/g)	(pCi/g)	(pCi/g)[b]
RADIONUCLIDES							
Np-237	ND-2.9	ND-1.1	ND	0.04-3.03	ND-0.77	0.21-63.0	ND
Pu-239	ND-29[c]	ND-59[c]	0.08-18.3	0.008-21.0	ND-0.14	0.004-85.0	ND
Tc-99	ND-3,500	ND-240	2.3-37	0-640	ND-54.1	0.2-3,500	ND-5.95
Th-230	ND-31	ND-3.4	0.3-8.3	0.047-999	ND-3.09	0.02-1,300	ND
U-234	ND-160	ND-24	0.19-62	0.01-120	ND-1.4	0.029-150	ND
U-235	ND-5.0	ND-0.92	0.09-1.7	0.005-5.1	ND-0.07	0.008-12.0	ND
U-238	ND-260	ND-24	0.85-66	0.014-290	ND-6.2	0.023-720	ND-1.29

[a]For groundwater, dissolved and total samples are included in the range of concentrations.
[b]Fish and deer only.
[c]Maximum Pu-239 values listed are suspect. These results are currently being validated. Table will be updated when validation is complete.

NOTES: Soils and sediments reported on dry weight basis.
Biota samples reported on a wet weight (as received) basis.
Complete data summary tables for media (frequency of detection, maximum, minimum, and averages) are presented in Appendix C.
"Onsite areas" include those areas inside the PGDP security fence and those operating WMUs outside the security fence.

ND = Not detected.

Table 3-13
Summary of Risk Estimates for Current and Potential Future Domestic Use of Groundwater
PGDP Phase II Public Health and Ecological Assessment
(Page 1 of 2)

	Chemical		Radiological
Well Category	**Excess Cancer Risk**	**Hazard Index**	**Excess Cancer Risk**
ONSITE MONITORING WELLS			
Ingestion	2×10^{-2}	22	3×10^{-5}
Inhalation	4×10^{-2}	6.5	
TOTAL	6×10^{-2}	28	3×10^{-5}
Major Contributors	Vinyl Chloride, TCE	Sb, 1-2-DCE	Tc-99, U-238, U-234, Np-237
RESIDENTIAL WELLS			
Ingestion	4×10^{-4}	2.4	2×10^{-5}
Inhalation	3×10^{-4}	0.9	
TOTAL	7×10^{-4}	3.3	2×10^{-5}
Major Contributors	TCE, As, Be	Carbon Tetrachloride, Sb, Tl	Tc-99, U-234, U-238, Np-237
OFFSITE MONITORING WELLS			
Ingestion	4×10^{-4}	2.5	2×10^{-5}
Inhalation	4×10^{-5}	0.08	
TOTAL	5×10^{-4}	2.6	2×10^{-5}
Major Contributors	As, Be, TCE	Ag, Be, Cr	U-234, U-238, Pu-239
TVA WELLS			
Ingestion	3×10^{-3}	8.8	6×10^{-5}
Inhalation	3×10^{-7}	0.04	
TOTAL	3×10^{-3}	8.8	6×10^{-5}
Major Contributors	As, Be, TCE	Sb, As, Mn	U-238, U-234
MW 134			
Ingestion	6×10^{-5}	0.3	7×10^{-6}
Inhalation	1×10^{-6}	0.02	
TOTAL	6×10^{-5}	0.3	7×10^{-6}
Major Contributors	As, Be, TCE	Mn, Ba, As	Tc-99, U-234, U-238

Table 3-13
Summary of Risk Estimates for Current and Potential Future Domestic Use of Groundwater
PGDP Phase II Public Health and Ecological Assessment
(Page 2 of 2)

	Chemical		Radiological
Well Category	**Excess Cancer Risk**	**Hazard Index**	**Excess Cancer Risk**
MW 144			
Ingestion	2×10^{-4}	0.4	3×10^{-7}
Inhalation	5×10^{-5}	0.07	
TOTAL	3×10^{-4}	0.5	3×10^{-7}
Major Contributors	As, TCE, Be	As, Mn, Ba	Tc-99, U-234
MW 179			
Ingestion	7×10^{-5}	0.53	3×10^{-5}
Inhalation	1×10^{-6}	0.02	
TOTAL	7×10^{-5}	0.6	3×10^{-5}
Major Contributors	As, Be, TCE	Mn, Cr, As	Tc-99, U-238
MW 200			
Ingestion	5×10^{-4}	3.1	6×10^{-6}
Inhalation	1×10^{-6}	0.02	
TOTAL	5×10^{-4}	3.2	6×10^{-6}
Major Contributors	Be, As, TCE	Cr, V, Be	Tc-99, U-238

NOTE: Summaries from risk tables are presented in Appendix H.

APPENDIX F

Correspondence: T. O. Early to G. W. Bodenstein

OAK RIDGE NATIONAL LABORATORY
MANAGED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

Earth Sciences Section
Environmental Sciences Division

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831-6317

Mail Stop 6317
Phone: 615/576-2103
Fax: 615/574-7420

May 29, 1992

G. W. Bodenstein
Department of Energy
Information Resource Center MS-EW913
Oak Ridge, Tennessee 37831-8541

Dear Gary,

On May 15, 1992 the Groundwater Corrective Action Review Team (Review Team) that is evaluating the proposed pilot pump-and-treat project for the Paducah Gaseous Diffusion Plant (PGDP) met with Department of Energy, Oak Ridge Field Office (DOE-OR) and Martin Marietta Energy Systems management representatives. At this meeting, it was apparent that there were different perceptions among participants about the conclusions reached by an expert consultant, Dr. Bernard Kueper (Queen's University), regarding the possibility of encountering trichloroethylene (TCE), a dense non-aqueous phase liquid (DNAPL), at PGDP in the source area of the Northwest plume and what approach should be followed in addressing this problem. At the suggestion of Dr. J.R. Merriman, I contacted Dr. Kueper on friday, May 22 and reviewed his original findings to insure that we have a proper understanding of his technical position. Following is a summary of this conversation.

I explained to Dr. Kueper that management at PGDP and the DOE site representative at Paducah who had read his report and were present at his briefing to plant personnel and regulatory staff from the State of Kentucky and the Environmental Protection Agency (September 13, 1991) were of the opinion that PGDP should assume that DNAPLs were present in the source. They also were of the opinion that the DNAPLs had migrated to the base of the Regional Gravel Aquifer (RGA). I told Dr. Kueper that these assumptions plus the concern that any disturbance of pure phase DNAPL pools near the source might result in their remobilization became the primary technical drivers leading to development of the pilot pump-and-treat proposal.

Dr. Kueper was concerned that his report and comments made by him in the public meeting may have been misinterpreted. He noted that the major focus of his assessment at PGDP was DNAPLs associated with TCE leaks at the C-400 Building and that he addressed the source of the Northwest plume only as a peripheral issue. However, he explained that in order to lessen the potential for intrusion into suspected or possible DNAPL sources, he normally cautions clients to adopt a conservative approach. In this specific instance, he suggested that PGDP should assume, until proven otherwise, that DNAPLs are present in the source area of the Northwest plume and may have migrated to the base of the RGA. He emphasized that there are additional characterization activities that can and should be completed for this plume before deciding upon a source containment option. He noted that results of these activities likely will answer the critical questions of DNAPL presence and its distribution at this site. Specifically,

he recommended that some additional, downgradient monitoring wells that are screened in the lower RGA could help determine the presence or absence of a dissolved plume of TCE that might be associated with residual, pure phase DNAPLs at the base of the RGA. These wells should be placed sufficiently far from the source area to avoid intercepting pure phase DNAPL pools, if they exist. If no evidence for DNAPLs is found, the options available for effective source containment expand considerably beyond the proposed pump-and-treat project and could include more conventional technologies of physical containment such as sheet piling and impermeable caps.

You will note that Dr. Kueper's recommendations are essentially identical to those of the Review Team as documented in its evaluation report. We support a flexible approach to source control that will permit PGDP to adopt technologies other than hydraulic containment by pump-and-treat if the additional characterization data obtained suggest that such options are appropriate.

I hope that this information will clarify Dr. Kueper's position and will be useful in determining the approach to follow for addressing groundwater contamination in the Northwest plume. If you should have further questions, please contact me at 576-2103.

Very truly yours,

T.O. Early

TOE:mjj

cc: B. Kueper

DISTRIBUTION

1. F. P. Baxter
2. D. T. Bell
3. R. R. Bonczek
4. D. G. Cope
5. M. F. P. DeLozier
6. J. W. Douthitt
7. T. O. Early
8. C. D. Goins
9. T. B. Hale
10. D. D. Huff
11. K. G. Kahl
12–16. D. M. Matteo
17. L. W. McMahon
18. J. R. Merriman
19. G. R. Miller
20. M. D. Nickelson
21. F. S. Patton, Jr.
22. C. T. Rightmire
23. P. A. Rubin
24. G. E. Rymer
25. L. G. Shipe
26. S. H. Stow
27. J. H. Swanks
28. H. A. Sydnor
29. R. I. Van Hook, Jr.
30. D. R. Watkins
31. R. K. White
32. S. L. Winters
33. T. F. Zondlo
34. Carol Young
35–36. Paducah Plant Library
37–39. ER Document Management Center
40–42. ER Document Management Center at Paducah

43. Office of Assistant Manager for Energy Research and Development, Department of Energy Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, Tennessee 37831-8600
44. G. W. Bodenstein, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, Tennessee 37831-8541
45. C. S. Gist, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, Tennessee 37831-8541
46–47. R. L. Nace, Branch Chief, Nonenrichment Facilities, Oak Ridge Program Division, Office of Eastern Area Programs, Office of Environmental Restoration, EM-423, Trevion 2, U.S. Department of Energy, Washington, DC 20585
48. S. P. Riddle, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
49–68. R. C. Sleeman, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
69. D. W. Swindle, Radian Corporation, 120 South Jefferson Circle, Oak Ridge, TN 37830
70–71. H. M. Thron, Chief, Enrichment Facilities, Oak Ridge Program Division, Office of Eastern Area Programs, Office of Environmental Restoration, EM-423, Trevion 2, U.S. Department of Energy, Washington, DC 20585
72–73. Robert Edwards, DOE Oak Ridge Field Office, Building C-100, Paducah, Kentucky 34220-1410
74. Don Wilkes, Science Applications International Corporation, Paducah Gaseous Diffusion Plant, Paducah, Kentucky 42002-1410
75. Dr. S. N. Davis, 6540 W. Box Canyon Drive, Tucson, Arizona 85745
76. Dr. G. Reed, Department of Civil Engineering, University of Tennessee, Knoxville, Tennessee 37916
77–78. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

DATE
FILMED
7/2/93