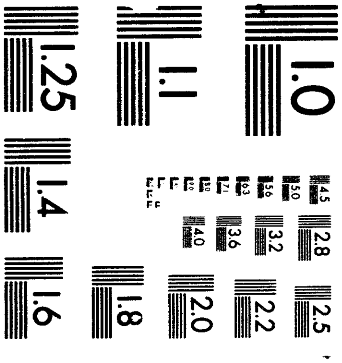
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

1 of 4

DOE/MC/29467-3559

Decontamination Systems Information and Research Program

Quarterly Technical Progress Report for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880, Collins Ferry Road
Morgantown, West Virginia

By

National Research Center for Coal and Energy
West Virginia University
Morgantown, West Virginia 26506

July 1993

ADMINISTRATIVE SUMMARY

West Virginia University (WVU) and the U. S. DOE Morgantown Energy Technology Center (METC) entered into a Cooperative Agreement on August 29, 1992 entitled "Decontamination Systems Information and Research Programs" (DOE Instrument No. : DE-FC21-92MC29467). Stipulated within the Agreement is the requirement that WVU submit to METC a series of Technical Progress Reports on a quarterly basis. This report comprises the third Quarterly Technical Progress Report for Year 1 of the Agreement. This report reflects the progress and/or efforts performed on the nine (9) technical projects encompassed by the Year 1 Agreement for the period of April 1 through June 30, 1993.

A. Administrative Action

A Cooperative Agreement was established between WVU and METC in the Fall of 1992. The original Annual Research Plan consisted of six (6) WVU Research projects. NEPA approval for these projects were received by WVU in Mid-March 1993. At the request of METC a presentation, of these six projects, was scheduled for late May 1993, at which time comments and criticisms on these projects were noted.

A project dealing with the remediation of soil at the Winfield (WV) Lock and Dam was formally approved, for 5 years, in April 1993. This project was also presented at the May 1993 review. A report on its progress is included in this Quarterly report.

The project, which involves technology evaluations by BDM Federal, Inc.,was approved June 11, 1993. Additionally this project will provide a safety analysis of building B-17 at METC, which WVU has access to through a DOE CRADA. Due to the late start on this project, few details are contained in this Quarterly report.

Another project, concerning soil remediation by steam reforming was approved in June 22, 1993. This work will be conducted by Manufacturing Technology Conversion, Inc. (MTCI) as a subcontractor. Some preliminary expenses have been allowed, but due to its late establishment, the report contained in this Quarterly is a general outlook of the project.

On June 29, 1993, proposed Annual Projects for next year were submitted to METC. These will be evaluated for suitability and developed into our 1994 Annual Plan to be submitted next quarter.

Permission was requested to replace Dr. Frank Saus as Principal Investigator with Dr. Raymond Lovett.

B. PROJECT VARIANCES, ACCOMPLISHMENTS AND PROBLEMS

Experimental work is progressing on the six (6) WVU projects. There are currently no problems, but the projects are in the early stages due to the arrival of NEPA approval in March.

A SYSTEMATIC ASSESSMENT OF THE STATE OF HAZARDOUS WASTE CLEAN-UP TECHNOLOGIES

Quarterly Technical Progress Report
for Period April 1 through June 30,1993

Work Performed Under Contract
No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By

Mitchell T. Berg, Department of Industrial Engineering
Brian E. Reed, Department of Civil Engineering
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West Virginia University
Morgantown, West Virginia

MASTER

July 1993

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1.0 EXECUTIVE SUMMARY

It is estimated that over 3700 hazardous waste sites are under the jurisdiction of the Department of Energy (DOE). Over the next 30 years, the Department of Energy (DOE) is committed to bringing all its facilities into compliance with applicable Federal, State, and local environmental laws and regulations. To perform this clean-up effort in the most efficient manner at each site will require that DOE managers have access to all available information on pertinent technologies; i.e., to aid in maximum technology transfer. The purpose of this effort is to systematically develop a database of those currently available and emerging clean-up technologies.

The development of a database of those currently available and emerging clean-up technologies is to be done in several phases: 1) A systems approach, 2) data collection, and 3) software development. Although the project officially started October 1, 1992, our award did not arrive until December, 1992. Thus, our main effort in the first quarter was 1) the recruitment of graduate research assistants, 2) the organization of project responsibilities, and 3) the procurement of software. In the second quarter we have 1) began an initial screening of DOE hazardous waste sites, 2) developed a conceptual model to classify DOE hazardous waste problems, and 3) developed an initial formulation of the structure (or fields) of the database. In the third quarter a user interface was developed to input and retrieve data from the database. This user interface was coded in FOXPRO 2.5 for DOS. Using the conceptual model and the structure of the database developed in quarter II, the user interface allows a user to input, search, retrieve and print records from the database via a menu driven system.

2.0 BACKGROUND

It is estimated that over 3700 hazardous waste sites are under the jurisdiction of the Department of Energy (DOE). These sites were primarily generated from 45 years worth of environmental pollution from the design and manufacture of nuclear materials and weapons, and contain numerous types of wastes including: 1) volatile, low-volatile and nonvolatile organics, 2) radionuclides (e.g., uranium, plutonium and cesium), 3) nonradioactive heavy metals (e.g., chromium, nickel, and lead), and 4) toxic chemicals. These contaminants affect several media including soils (saturated and unsaturated), groundwater, vegetation, and air. Numerous and diverse DOE hazardous waste sites can be enumerated from soils contaminated by organics such as trichloroethylene (TCE) and perchloroethylene (PCE) at the Savannah River site to biota and vegetation contaminated by radionuclides such as radiocesium and radiostrontium at the Oak Ridge site.

Over the next 30 years, the Department of Energy (DOE) is committed to bringing all its facilities into compliance with applicable Federal, State, and local environmental laws and regulations. This clean-up task is quite complex involving numerous sites containing various radioactive, organic and inorganic contaminants. To perform this clean-up effort in the most efficient manner at each site will require that DOE managers have access to all available information on pertinent technologies; i.e., to aid in maximum technology transfer. The purpose of this effort is to systematically develop a database of those currently available and emerging clean-up technologies.

The construction of a database of clean-up technologies requires a systematic development of those steps necessary to achieve clean-up objectives. These steps and associated technology groupings are given in Figure 1.

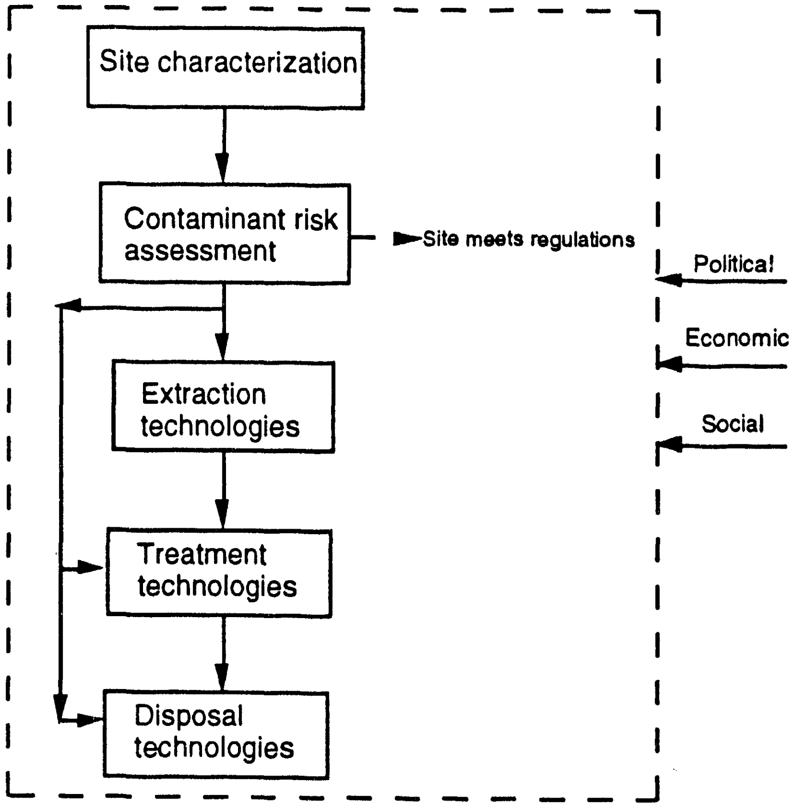

Figure 1: Division of technologies based on primary steps necessary for clean-up

The initial step in assessing a potential hazardous waste site is the characterization and identification of the type and extent of the contamination. In this characterization step technologies are required both for in-situ and ex-situ assessment of contamination levels. Once site characterization is performed, the risks posed by the contamination must be assessed. This step necessitates the use of mathematical models to predict contaminant fate and subsequent impact on local populations. Assuming that a risk exists, technologies must then be examined (or developed) to either extract the contaminant from the fostering media for treatment and/or disposal, treat the contaminant in-situ, or directly dispose of the contaminant. Furthermore, at each step in the clean-up process decisions regarding technology choices must be made within the existing political, economic, and social climate.

Using the conceptual approach given in Figure 1, a systematic assessment of available and emerging technologies in each area will be developed. This will be accomplished for each area by the development of a database of both current and emerging technologies. An example to illustrate the concept of such a database is given in Figure 2. In this simple example, the user of the database may be interested in investigating the available technologies for cleaning up a soil contaminated by dioxin (TCDD). In this case, information regarding soil extraction and treatment procedures is organized such that the user can extract pertinent clean-up information.

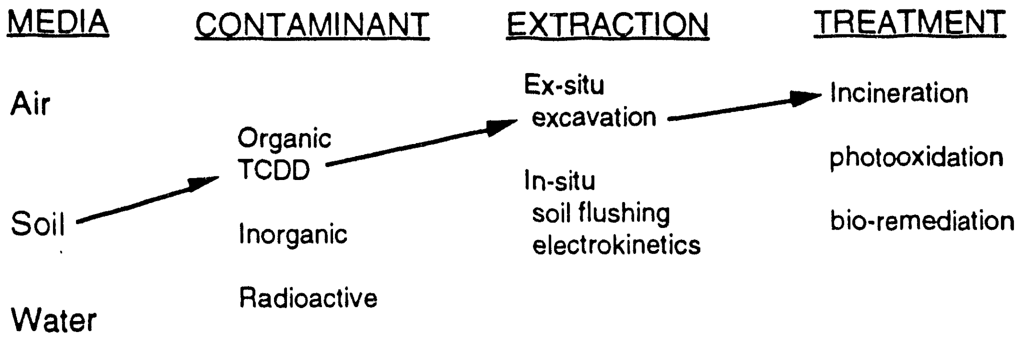

Figure 2: Conceptual view of database construction in which the arrows indicate one path explored for the clean-up of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

It is envisioned in the initial phase of development that a DOE manager via a computer terminal will have access to information in the database via a query system. This system will allow the user to access the different available technologies for each step in the clean-up process, and extract pertinent information on how to proceed and obtain more detailed information. A natural result of such a systematic assessment is the discovery of where clean-up capabilities are lacking. Thus, as the process proceeds, a database will be compiled of those clean-up processes that are in need of further research.

3.0 METHODOLOGY

The development of a database of hazardous waste technologies will be carried out in several phases:

Phase I: A systems approach. This phase involves a systematic development of the components to be included in the database. The approach will drive the development of the computer database. The following sub-tasks are to be performed:

1. An initial screening of DOE hazardous waste sites;
2. The development of a conceptual model to classify DOE hazardous waste problems;
3. An initial formulation of the structure (or fields) of the database.

Phase II: Data collection. In this phase a complete review of the current clean-up technologies will be done. This review will be driven by the database structure developed in phase I (sub-task 3), and will be accomplished through a comprehensive literature review, discussions with clean-up experts, and possible hazardous waste site visitations.

Phase III: Software development. In parallel with the data collection phase of this work, a computer based database is to be developed. This includes a data storage/retrieval system along with user friendly access software. Several main sub-tasks are to be performed including:

1. Development of a user friendly front end (i.e., user interface);
2. Development of the structure of the database;
3. Input of the technologies collected in the data collection phase;
4. Software verification and testing.

4.0 RESULTS AND DISCUSSION

Although the project officially started October 1, 1992, our award did not arrive until December, 1992. Thus, our main effort in the first quarter was 1) the recruitment of graduate research assistants, 2) the organization of project responsibilities, and 3) the procurement of software. As of January, 1992 we have recruited several graduate students who will function both to aid in the collection of data (phase II) and to work on software development. We have also organized project responsibilities toward the collection of data. All faculty will be responsible for the collection of data on characterization, extraction, treatment and disposal technologies in their field of expertise. Such data will be reported to the P.I. for integration into the database. We have also selected and ordered database software for the project. We have selected the relational database software FOX PRO 2.5 as our development package. This software will be run on an Intel 486 based computer.

In quarter II we have 1) began an initial screening of DOE hazardous waste sites, 2) developed a conceptual model to classify DOE hazardous waste problems, and 3) developed an initial formulation of the structure (or fields) of the database. An initial screening of DOE hazardous waste sites was initiated using the DOE Environmental

Restoration and Waste Management Five Year Plan[1]. This report, however, gives only very general information on contaminated DOE sites. For example, information is given on the clean-up of volatile organics in saturated soils at the DOE's Savannah River site. The levels and extent of contamination are not given. We are in the process of searching for site specific data on the extent and level of contamination at specific sites.

In order to identify remediation technologies applicable to specific DOE sites, we have developed a conceptual model to classify DOE hazardous waste problems. This entails first the development of a general classification of hazardous waste problems. This general classification is simply a division of contamination problems based on 1) the media in which the pollutant resides, and 2) the chemical characteristics of the pollutants. This division is illustrated by the matrix given in Figure 3 in which the bold boxes indicate a class of technologies used to remediate sites with the given pollutant/media characteristics. Thus, for each step in the remediation process (i.e., characterization, extraction, and treatment) there exists sets of potential technologies that can address the specific problems. The choice of this division was based on the behavior of pollutants in the environment. Pollutant behavior is driven by both its physical/chemical characteristics and the media in which it resides (i.e., pollutant fate and transport are driven by media pollutant interactions along with pollutant characteristics). These fate and transport characteristics will drive the potential technologies that will be applicable for remediation. For example, pollutants which reside in soils and are tightly bound, hydrophobic, and not susceptible to bioremediation (e.g., dioxins) can be remediated using similar approaches. In this case, this class of pollutants is typically excavated and treated ex-situ via thermal or chemical technologies for organics or possible immobilization for inorganics.

	POLLUTANT CLASS		
MEDIA	ORGANICS	INORGANICS	RADIONUCLIDES
SOIL			
GROUND WATER			
AIR			

Figure 3: Classification of technologies into groups used to address combinations of different pollutants with different media.

---

[1] USDOE, 1991. Environmental Restoration and Waste Management Five Year Plan. DOE/S-0090P.

Within each pollutant class we have further grouped chemicals with similar physical and/or chemical characteristics; i.e., groups of chemicals which tend to have similar behavior in the environment. These groups are given in Table 1[2]. In a similar fashion the media in which the pollutant resides canbe subdivided based on its affect on pollutant behavior. In Table 2 we list several factors affecting pollutant behavior in soil, groundwater, and air (Note: this is not intented to be a complete list of factors). Thus, by developing classifications for both the pollutant and the respective media it resides in, we are reducing the subset of remediation technologies that need be explored for a particular circumstance.

For specific hazardous waste problems (i.e., pollutants in specific media) we envision candidate alternative remediation strategies. These alternative remediation technologies themselves can be categorized based on the processes used in remediation. We have categorized remediation technologies into four general classes[1]: 1) physical/chemical, 2) thermal, 3) biological, and 4) immobilization. Within each technology class there exists several specific remediation technologies which can be applied at each stage of the remediation process (i.e., characterization, extraction, treatment and disposal). Physical/chemical technologies include such processes as dehalogenation, air stripping, and chemical sorption; thermal technologies include such processes as vitrification, incineration and fluidized bed combustion; biological technologies include aerobic and anaerobic decomposition; immobilization includes such processes as cement solidification and carbonate immobilization.

---

[2] EPA, 1989. Superfund Treatability Clearinghouse Abstracts. EPA/540/2-89/001.

Table 1
Grouping of Pollutants based on behavior in the environment.

Pollutant Class	Example
Halogenated non-polar aromatics	Chlorobenzene
PCB's, halogenated dioxins and furans	Tetrachlorodibenzo-p-dioxin
Halogenated phenols, cresols, amines, and other polar aromatics	Tetrachlorophenol
Halogenated aliphatic compounds	Vinyl chloride
Halogenated cyclic aliphatics, ethers, esters, and keytones	Toxaphene
Nitrated aromatic and aliphatic compounds	Trinitrotoluene
Heterocyclics and simple non-halogenated aromatics	Benzene
Polynuclear aromatics	Naphthalene
Other polar non-halogenated organic compounds	Methanol
Non-volatile metals	Iron
Volatile metals	Mercury
Other inorganics	Sulfate
Other organics	Methyl Propane
Radionuclides	Cs-137

Table 2

Division of media with several factors affecting pollutant behavior in the environment.

Media	Factor Affecting Transport
SOIL	Texture (%sand,%silt,%clay)
	Grain size distribution
	pH
	Hydraulic conductivity
	Organic content
	Moisture content
	Temperature
	Biota
	Bulk density
	Cation exchange capacity
GROUND WATER	Dissolved organic content
	Colloidal particals
	Dissolved oxygen content
	Temperature
	Biota
	pH
AIR	Pressure
	Temperature
	Humidity

Based on the classification schemes for pollutants, media, and remediation technologies described above, we have developed an initial structure for the database. This structure is illustrated in Figure 4. To date we have created the structure for five relational databases. These databases will contain specific information regarding pollutants and the alternative technologies available for remediation. In conjunction to these databases, a User interface, search routines and a report generator will be developed. The User interface will be used both in the data gathering phase in which the data is input in each database (i.e., the development of input screens) along with User interface during execution of search routines. The search routines will entail programs that generate a "best" match of site specific data on the pollutant and the media it resides in to potential remediation technologies. Finally, report generation routines will be developed to extract information from the database. We are currently in the data gathering phase of the project with only minimal development of screens for User input of information.

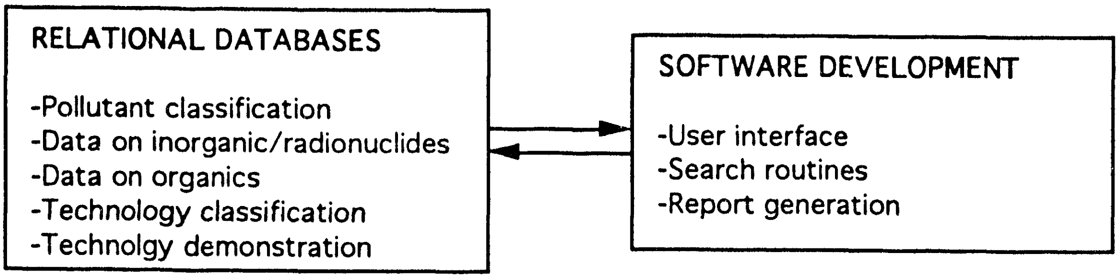

Figure 4: Components of database

Tables 3-7 show the initial structure (or fields) of the relational databases given in Figure 4. Tables 3-5 represent the structure used to collect data on specific inorganic, organic and radioactive pollutants. First, a classification of all pollutants is accomplished by the database represented by Table 3. The groups (i.e., field 2) are assigned based on the classification scheme developed previous (see Table 1). Tables 4-5 then tabulate specific data regarding each pollutant. This data gives information regarding the physical and chemical characteristics of each pollutant that are important for assessing pollutant behavior in different media. Such data includes a pollutants volatility, solubility, molecular weight, etc. Tables 6-7 give the organization for database construction of remediation technologies. Two databases of remediation technologies are to be constructed: 1) a general classification of technologies used to address contaminated sies (Table 6), and 2) a database of technologies already demonstrated at the laboratory, bench or field scale.

Table 3
Division of Pollutants into Classes

Field	Field Name	Description
1	NUM	Pollutant class number (e.g., P01,P02, etc.)
2	GROUP	Name of Pollutant Class identified by NUM
3	CLASS	General class: organic/inorganic/radionuclide
4	POLLUTANT	Specific pollutant

Table 4
Physical and chemical data for specific inorganic and radioactive pollutants

Field	Field Name	Description
1	POLLUTANT	Specific pollutant
2	NUM	Pollutant class number (e.g., P01,P02, etc.)
3	REDOX_NUM	Oxidation number
4	B OIL_PT	Boiling point (C^0)
5	MELT_PT	Melting point (C^0)
6	DENSITY	Density of pollutant (g/ml)
7	SOLUBILITY	Solubility of pollutant (g/100 ml)
8	DIFFUSION	Diffusion coefficient (Cm^2/sec)
9	GIBBS	Standard state free energy (kcal/g-mole)
10	VAPOR_PRESS	Vapor pressure (atm)
11	HENRY_CON	Henry's law constant (atm-m^3/mole)
12	H ALF_LIFE	Half life for radionuclide (year)
13	DAUGHTER	Daughter produced by decay of radionuclide
14	BIO_EFFECT	Description of biological effect of pollutant

Table 5

Physical and chemical data for specific organic pollutants

Field	Field Name	Description
1	POLLUTANT	Specific pollutant
2	NUM	Pollutant class number (e.g., P01,P02, etc.)
3	MOL_WT	Molecular weight (g/mole)
4	BOIL_PT	Boiling point (C^0)
5	MELT_PT	Melting point (C^0)
6	DENSITY	Density of pollutant (g/ml)
7	SOLUBILITY	Solubility of pollutant (g/100 ml)
8	DIFFUSION	Diffusion coefficient (Cm^2/sec)
9	GIBBS	Standard state free energy (kcal/g-mole)
10	VAPOR_PRESS	Vapor pressure (atm)
11	HENRY_CON	Henry's law constant (atm-m^3/mole)
12	LOG_OCT_H2	Log of octanol to water partition coefficient
13	PHOTODEG	Ability of organic to photo degrade (Yes/No)
14	BIODEGRAD	Ability of organic to biodegrade (Yes/No)
15	BIO_AGENTS	Specific biological agents found to degrade
16	POLAR	Is organic polar (Yes/No)
17	BIO_EFFECT	Description of biological effect of pollutant

Table 6
Classification of Technologies used to remediate contaminated sites

Field	Field Name	Description
1	REMED_PHAS	Phase of remediation: Characterization/Extraction/Treatment/Disposal
2	TECH_GROUP	Technology group: Physical-Chemical/Biological/Thermal/Immobilization
3	P ROCESS	Specific process used under TECH_GROUP
4	MEDIA	Process Media: Soil/Ground water/ Air
5	CONTAM_GRP	Pollutant class number (e.g., P01,P02, etc.)
6	REF	References in which technology is described

Table 7
Compilation of technologies that have been demonstarted at laboratory, bench or field scale

Field	Field Name	Description
1	TECHNOLOGY	Title of technology
2	DEVELOPE R	Developer of technology
3	MEDIA	Process Media: Soil/Ground water/ Air
4	DOMAIN	Remediation domain: In-situ/Ex-situ
5	SCALE	Scale of application: Lab/Bench/Field
6	DESCRIPTION	Description of technology
7	APP_WASTE	General class of applicable waste
8	SPEC_W ASTE	Specific waste in which technology is applied
9	WAST_CLASS	Pollutant class number (e.g., P01,P02, etc.)
10	TECH_GROUP	Technology group: Physical-Chemical/Biological/Thermal/Immobilization
11	P ROCESS	Specific process used under TECH_GROUP
12	SITE	Site description (if any)
13	STATUS	Status of work
14	CONTACTS	Specific persons to contact
15	DOCUMENTS	Publications of work
16	COST	Cost data
17	REF	Reference in which information was obtained

In the third quarter, we have used the conceptual model and database structure to develop a user interface. The user interface is a set of routines coded in FOXPRO 2.5 that allows a user to input, retrieve, search and print any record in the database via a menu driven system. The development of a user interface is essential for efficient use of the database along with the protection of data. The code developed to interface between the user and the database is given in the attached Appendix. In conjunction with software development, we have continued gathering data to input into the database. We are currently gathering and inputing data on general descriptions of each technology (as given in Table 6). Furthermore, we are in the process of assessing the available information via external databases (e.g., ATTIC, PROTEC, etc.). We hope to reduce data collection tasks by downloading available information from existing databases.

5.0 CONCLUSION

The resources necessary for the development of a computer database of hazardous waste technologies have been assembled. In the second quarter, we have systematically developed the structure of the database. This structure was driven by the necessity to relate the physical and chemical data of specific hazardous waste sites to specific remediation technologies. We have created the databases (i.e., developed the fields) using Microsoft FOXPRO. We are in the data collection phase of the project. To date, we have entered into the database 296 specific pollutants, and 58 classes of technologies. At this time we are in the process of obtaining specific data on the pollutants entered (i.e., filling out Tables 5 and 6), and obtaining more information regarding specific technology classes (i.e., filling out Table 7). We have also begun entering data on technology demonstrations on the laboratory, bench and field scale. In the third quarter, we have expended a great deal of effort on the development of a user interface. The user interface will allow the access and storage of information via a menu driven system. Once tested this system shall allow any user (not necessarily familiar with FOXPRO) to interface withthe database including inputing, searching and printing database records.

APPENDIX

User Interface Code in FOXPRO 2.5

```
        @ 15,14 SAY "ENVIRONMENTAL REMEDIATION AND RESTORATION DATABASE";
          STYLE 'BI'
        @ 20,16 SAY "Please use the above menu to make a selection"
  CASE choice = 'search'
        DEACTIVATE WINDOW name
        DO disable
  CASE choice = 'help'
        DEACTIVATE WINDOW name
        DO disable
ENDCASE
RETURN
*
*  Procedure to temperarily disable menu choice
PROCEDURE disable
ACTIVATE WINDOW name
WAIT WINDOW 'MENU CHOICE CURRENTLY DISABLED'
RETURN
```

```
        @ 15,14 SAY "ENVIRONMENTAL REMEDIATION AND RESTORATION DATABASE
          STYLE 'BI'
        @ 20,16 SAY "Please use the above menu to make a selection"
  CASE choice = 'search'
        DEACTIVATE WINDOW name
        DO disable
  CASE choice = 'help'
        DEACTIVATE WINDOW name
        DO disable
ENDCASE
RETURN
*
*  Procedure to temperarily disable menu choice
PROCEDURE disable
ACTIVATE WINDOW name
WAIT WINDOW 'MENU CHOICE CURRENTLY DISABLED'
RETURN
```

```
*************************************************************************
*PROGRAM TO EDIT/DELETE A RECORD
PROCEDURE editmenu
PARAMETERS mchoice,srchstring
***********************************************************************
* stopit = true stops editmenu
  stopit = .F.
* hold = true means searchstring has been chosen
hold = .F.
* Mem var for search/mainmenu
runchoice = 1
* Test_in is a boolean variable that determines if user
*   has indexed on a field
test_in = .F.
* Fchoice is the field that the user chooses
fchoice=space(15)
DEFINE WINDOW editsearch FROM 0,0 TO 24,79 COLOR SCHEME 1
* Define POPUP for field choices for organic/inorganic database
DEFINE POPUP efield1 COLOR SCHEME 3
DEFINE BAR 1 OF efield1 PROMPT 'Pollutant'
DEFINE BAR 2 OF efield1 PROMPT 'Chem. Abstract #'
*
* Define POPUP for field choices Technology database
DEFINE POPUP efield2 COLOR SCHEME 3
DEFINE BAR 1 OF efield2 PROMPT 'Technology'
* Define POPUP for field choices for develop database
DEFINE POPUP efield3 COLOR SCHEME 3
DEFINE BAR 1 OF efield3 PROMPT 'Tech. Name'
DEFINE BAR 2 OF efield3 PROMPT 'Technology'
DEFINE BAR 3 OF efield3 PROMPT 'Developer'
DEFINE BAR 4 OF efield3 PROMPT 'Site'
*
*  Execute edit menu until user chooses to go back to main menu.
*
DO WHILE (.NOT. stopit)
  * Set up a screen to get info from user
  ACTIVATE WINDOW editsearch
  @ 3,22 SAY "Input search character string:"
  @ 7,18 SAY "Choose selection criteria and hit ENTER:"
  @ 16,29 SAY "Selections made:"
  DO CASE
    * Set up search screen for organic database.
    CASE mchoice=1
          @ 1,13 SAY "SEARCH FOR RECORD IN ORGANIC POLLUTANT DATABASE"
      @ 17,10 TO 20,65
      @ 18,11 SAY "SEARCH STRING:"
      @ 19,11 SAY "SEARCH CRITERION:"
      * If value is to be held, reprint value in box.
      IF hold = .T.
        @ 4,22 SAY srchstring
        @ 18,30 SAY srchstring
      * Otherwise, get the new value and print in box.
      ELSE
        @ 4,22 GET srchstring VALID dispitem(18,30,srchstring)
      ENDIF
          @ 8,25 GET fchoice PICTURE "@&N" POPUP efield1;
            SIZE 6,25 VALID tindex(@test_in)
      @ 22,28 GET runchoice FUNCTION '*H SEARCH;MAINMENU'
      READ CYCLE
```

```
 * Set up search screen for inorganic/radionuclide database.
 CASE (mchoice=2.or.mchoice=3)
       @ 1,13 SAY "SEARCH FOR RECORD IN INORGANIC/RADIONUCLIDE DATABASE"
   @ 17,10 TO 20,65
   @ 18,11 SAY "SEARCH STRING:"
   @ 19,11 SAY "SEARCH CRITERION:"
   * If value is to be held, reprint value in box.
   IF hold = .T.
     @ 4,22 SAY srchstring
     @ 18,30 SAY srchstring
   * Otherwise, get the new value and print in box.
   ELSE
     @ 4,22 GET srchstring VALID dispitem(18,30,srchstring)
   ENDIF
       @ 8,25 GET fchoice PICTURE "@&N" POPUP efield1;
         SIZE 6,25 VALID tindex(@test_in)
       @ 22,28 GET runchoice FUNCTION '*H SEARCH;MAINMENU'
       READ CYCLE

 * Set up search screen for technology database.
 CASE mchoice=4
       @ 1,17 SAY "SEARCH FOR RECORD IN TECHNOLOGY DATABASE"
   * Define POPUP for field choices
   @ 17,10 TO 20,65
   @ 18,11 SAY "SEARCH STRING:"
   @ 19,11 SAY "SEARCH CRITERION:"
   * If value is to be held, reprint value in box.
   IF hold = .T.
     @ 4,22 SAY srchstring
     @ 18,30 SAY srchstring
   * Otherwise, get the new value and print in box.
   ELSE
     @ 4,22 GET srchstring VALID dispitem(18,30,srchstring)
   ENDIF
       @ 8,25 GET fchoice PICTURE "@&N" POPUP efield2;
     SIZE 6,25 VALID tindex(@test_in)
       @ 22,28 GET runchoice FUNCTION '*H SEARCH;MAINMENU'
   READ CYCLE

 * Set up search screen for develop database.
 CASE mchoice=5
       @ 1,19 SAY "SEARCH FOR RECORD IN DEVELOP DATABASE"
   * Read runchoice=goto mainmenu or run search
   @ 17,10 TO 20,65
   @ 18,11 SAY "SEARCH STRING:"
   @ 19,11 SAY "SEARCH CRITERION:"
   * If value is to be held, reprint value in box.
   IF hold = .T.
     @ 4,22 SAY srchstring
     @ 18,30 SAY srchstring
   * Otherwise, get the new value and print in box.
   ELSE
     @ 4,22 GET srchstring VALID dispitem(18,30,srchstring)
   ENDIF
       @ 8,25 GET fchoice PICTURE "@&N" POPUP efield3;
         SIZE 6,25 VALID tindex(@test_in)
   @ 22,28 GET runchoice FUNCTION '*H SEARCH;MAINMENU'
       READ CYCLE
ENDCASE
```

```
* Convert field choices in POPUP to match field choices in database files.
IF fchoice='Chem. Abstract #'
  fchoice='CAS_NUM'
ENDIF
IF fchoice='Tech. Name'
  fchoice='TECH_NAME'
ENDIF
  * If the user chooses the search button, control is passed
  * to the search routine.
  IF (runchoice = 1)
    * If there is a search criterion selected do the search
    IF (test_in = .T.)
      DEACTIVATE WINDOW editsearch
      DO search WITH mchoice,fchoice,srchstring
    * Otherwise display a message and go back to editmenu.
    ELSE
      * If the user forgets to enter a field to search on, a screen
      *   appears to instruct the user to do so.
      WAIT WINDOW 'YOU MUST CHOOSE A SEARCH CRITERION.  Press ENTER to continue.
      * Hold is first initialized as .F.
      * However, if the user does not enter a field on the first screen in
      *  editmenu, hold becomes .T. so that the value of the searchstring
      *  is not lost.
      hold = .T.
    ENDIF
* Otherwise, return to the mainmenu
  ELSE
    DEACTIVATE WINDOW editsearch
    *stopit= .T.
    EXIT
  ENDIF
ENDDO
RETURN
*------------------------------------------------------------------*
* Function testindex determines if a user has indexed on a field
* Prints fchoice in the "Selections Made" box and returns true
*   if a user has indexed on a field
FUNCTION tindex
PARAMETER test_in
test_in = .T.
@ 19,30 SAY fchoice
RETURN test_in
*------------------------------------------------------------------*
* Function dispitem prints the value of the srchstring in the
*  "Selections Made" box
FUNCTION dispitem
PARAMETER x,y,item
@ x,y SAY item
RETURN
*
*
*********************************************************************
* ROUTINE TO SEARCH
PROCEDURE search
PARAMETERS mchoice,fchoice,srchstring
*********************************************************************
* Make search string lower case
srchstring = ALLTRIM(LOWER(srchstring))
DEFINE WINDOW dispsrch FROM 0,0 TO 24,79 COLOR SCHEME 5
CLEAR
```

```
ACTIVATE WINDOW dispsrch
* Find nearest record
SET NEAR ON
* Open the specified database
DO CASE
  CASE mchoice=1
        USE C:\METC\DATABASE\DATA\ORGAN_CH.DBF
  CASE (mchoice=2 .OR. mchoice=3)
        USE C:\METC\DATABASE\DATA\INOR_RAD.DBF
  CASE mchoice=4
        USE C:\METC\DATABASE\DATA\TECHNOLO.DBF
  CASE mchoice=5
        USE C:\METC\DATABASE\DATA\DEVELOP.DBF
ENDCASE
* Choice index to order database
SET ORDER TO TAG &fchoice
SEEK srchstring
* If the string is found, then display the record
IF (FOUND() .OR. (.NOT. EOF()))
  DEACTIVATE WINDOW dispsrch
  DO disprec WITH mchoice
* If the string is not found, message will appear, and control
*   is passed to editmenu
ELSE
        * If the search string is not found a screen appears and informs
        *   the user.
        WAIT WINDOW 'Search string not found!  Press ENTER to continue.'
        DEACTIVATE WINDOW dispsrch
        * Reassign search string as a character value before passing
        *  control back to editmenu.
        srchstring = SPACE(30)
    RETURN
ENDIF
SET EXACT ON
```

```
*******************************************************************
* PROCEDURE TO DISPLAY RECORDS
PROCEDURE disprec
PARAMETERS mchoice,recnum
*******************************************************************
contin = .T.
* Mem var for edit/delete/previous menu
editdel = 0
printit = 0
DEFINE WINDOW display FROM 0,0 TO 24,79 COLOR SCHEME 1
* This do while loop allows the user to go back and forth between
*   the displayed record and either the first screen in editrec or
*   the first screen in printrpt.
DO WHILE contin
ACTIVATE WINDOW display
DO CASE
  * Display organic pollutant record
  CASE mchoice = 1
    @ 0,23 SAY "RECORD FROM ORGANIC DATABASE"
    @ 3,4 SAY "POLLUTANT:" GET pollutant DISABLE
        @ 4,4 SAY "CAS #:" GET cas_num DISABLE
    @ 5,4 SAY "CLASS #:" GET poll_num DISABLE
    @ 6,4 SAY "MOLECULAR WEIGHT (amu):" GET mol_wt DISABLE
    @ 7,4 SAY "BOILING POINT (C):" GET boil_pt DISABLE
        @ 8,4 SAY "MELTING POINT (C):" GET melt_pt DISABLE
        @ 9,4 SAY "VAPOR PRESSURE (Pa):" GET vapor_pres DISABLE
        @ 10,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET henry_con DISABLE
    @ 11,4 SAY "SOLUBILITY (mg/L):" GET solubility DISABLE
        @ 12,4 SAY "SOLUBILITY PH:" GET sol_ph DISABLE
    @ 13,4 SAY "LOG OCTONOL TO WATER PARTITION COEFF:" GET log_oct_h2 DISABLE
    @ 14,4 SAY "IT CAN PHOTODEGRADE (T/F):" GET photodeg DISABLE
    @ 15,4 SAY "IT CAN BIODEGRADE (T/F):" GET biodegrad DISABLE
    @ 16,4 SAY "IT IS POLAR (T/F):" GET polar DISABLE
    * Define set of push buttons to edit/delete/previous menu
    @ 20,22 GET editdel FUNCTION '*H EDIT;DELETE;PREVIOUS MENU'
    @ 22,30 GET printit FUNCTION '*H PRINT RECORD' COLOR SCHEME 7
    READ CYCLE
 * Display inorganic pollutant record
 CASE mchoice = 2
   @ 0,22 SAY "RECORD FROM INORGANIC DATABASE"
   @ 3,4 SAY "POLLUTANT:" GET pollutant DISABLE
   @ 4,4 SAY "CAS #:" GET cas_num DISABLE
   @ 5,4 SAY "CLASS #:" GET poll_num DISABLE
   @ 6,4 SAY "VALENCE OF POLLUTANT:" GET redox_num DISABLE
   @ 7,4 SAY "MOLECULAR WEIGHT (amu):" GET mol_wt DISABLE
   @ 8,4 SAY "BOILING POINT (C):" GET boil_pt DISABLE
   @ 9,4 SAY "MELTING POINT (C):" GET melt_pt DISABLE
   @ 10,4 SAY "DENSITY (g/L):" GET density DISABLE
   @ 11,4 SAY "SOLUBILITY (mg/L):" GET solubility DISABLE
   @ 12,4 SAY "SOLUBILITY PH:" GET sol_ph DISABLE
   @ 13,4 SAY "DIFFUSION (cm^2/sec):" GET diffusion DISABLE
   @ 14,4 SAY "VAPOR PRESSURE (Pa):" GET vapor_pres DISABLE
   @ 15,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET henry_con DISABLE
   * Define set of push buttons to edit/delete/previous menu
   @ 20,22 GET editdel FUNCTION '*H EDIT;DELETE;PREVIOUS MENU'
   @ 22,30 GET printit FUNCTION '*H PRINT RECORD' COLOR SCHEME 7
   READ CYCLE
 * Display radionuclide record
 CASE mchoice = 3
   @ 0,21 SAY "RECORD FROM RADIONUCLIDE DATABASE"
```

```
  @ 2,4 SAY "POLLUTANT:" GET pollutant DISABLE
  @ 3,4 SAY "CAS #:" GET cas_num DISABLE
  @ 4,4 SAY "CLASS #:" GET poll_num DISABLE
  @ 5,4 SAY "VALENCE OF POLLUTANT:" GET redox_num DISABLE
  @ 6,4 SAY "MOLECULAR WEIGHT (amu):" GET mol_wt DISABLE
  @ 7,4 SAY "BOILING POINT (C):" GET boil_pt DISABLE
  @ 8,4 SAY "MELTING POINT (C):" GET melt_pt DISABLE
  @ 9,4 SAY "DENSITY (g/L):" GET density DISABLE
  @ 10,4 SAY "SOLUBILITY (mg/L):" GET solubility DISABLE
  @ 11,4 SAY "SOLUBILITY PH:" GET sol_ph DISABLE
  @ 12,4 SAY "DIFFUSION (cm^2/sec):" GET diffusion DISABLE
  @ 13,4 SAY "VAPOR PRESSURE (Pa):" GET vapor_pres DISABLE
  @ 14,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET henry_con DISABLE
  @ 15,4 SAY "HALF LIFE (yrs):" GET half_life DISABLE
  @ 16,4 SAY "DAUGHTER:" GET daughter DISABLE
  @ 17,4 SAY "EMISSION 1:" GET emission_1 DISABLE
  @ 18,4 SAY "EMISSION 2:" GET emission_2 DISABLE
  @ 19,4 SAY "EMISSION 3:" GET emission_3 DISABLE
  @ 17,30 SAY "ENERGY 1 (mev):" GET energy_1 DISABLE
  @ 18,30 SAY "ENERGY 2 (mev):" GET energy_2 DISABLE
  @ 19,30 SAY "ENERGY 3 (mev):" GET energy_3 DISABLE
  * Define set of push buttons to edit/delete/previous menu
  @ 22,22 GET editdel FUNCTION '*H EDIT;DELETE;PREVIOUS MENU'
  @ 22,62 GET printit FUNCTION '*H PRINT RECORD' COLOR SCHEME 7
  READ CYCLE
* Display technology record
CASE mchoice = 4
  @ 0,21 SAY "RECORD FROM TECHNOLOGY DATABASE"
  @ 3,4 SAY "TECHNOLOGY:" GET technology DISABLE
  @ 4,4 SAY "SUB-CLASS:" GET sub_class DISABLE
  @ 5,4 SAY "TECHNOLOGY GROUP:" GET tech_group DISABLE
  @ 6,4 SAY "DOMAIN:" GET domain DISABLE
  @ 7,4 SAY "MEDIA 1:" GET media1 DISABLE
  @ 8,4 SAY "MEDIA 2:" GET media2 DISABLE
  @ 9,4 SAY "MEDIA 3:" GET media3 DISABLE
  @ 10,4 SAY "REMEDIATION PHASE 1:" GET rem_phase1 DISABLE
  @ 11,4 SAY "REMEDIATION PHASE 2:" GET rem_phase2 DISABLE
  @ 12,4 SAY "REMEDIATION PHASE 3:" GET rem_phase3 DISABLE
  @ 13,4 SAY "REMEDIATION PHASE 4:" GET rem_phase4 DISABLE
  * Define set of push buttons to edit/delete/previous menu
  @ 20,22 GET editdel FUNCTION '*H EDIT;DELETE;PREVIOUS MENU'
  @ 22,30 GET printit FUNCTION '*H PRINT RECORD' COLOR SCHEME 7
  READ CYCLE
* Display develop record
CASE mchoice = 5
  @ 0,22 SAY "RECORD FROM DEVELOP DATABASE"
  @ 3,4 SAY "COMPANY'S NAME FOR TECHNOLOGY:" GET tech_name DISABLE
  @ 4,4 SAY "TECHNOLOGY:" GET technology DISABLE
  @ 5,4 SAY "DEVELOPER:" GET developer DISABLE
  @ 6,4 SAY "GENERAL TECHNOLOGY GROUP:" GET tech_group DISABLE
  @ 7,4 SAY "SITE:" GET site DISABLE
  @ 8,4 SAY "DOMAIN:" GET domain DISABLE
  @ 9,4 SAY "SCALE:" GET scale DISABLE
  @ 10,4 SAY "MEDIA 1:" GET media1 DISABLE
  @ 11,4 SAY "MEDIA 2:" GET media2 DISABLE
  @ 12,4 SAY "MEDIA 3:" GET media3 DISABLE
  @ 13,4 SAY "REMEDIATION PHASE 1:" GET rem_phase1 DISABLE
  @ 14,4 SAY "REMEDIATION PHASE 2:" GET rem_phase2 DISABLE
  @ 15,4 SAY "REMEDIATION PHASE 3:" GET rem_phase3 DISABLE
  @ 16,4 SAY "REMEDIATION PHASE 4:" GET rem_phase4 DISABLE
```

```
   * Define set of push buttons to edit/delete/previous menu
   @ 20,22 GET editdel FUNCTION '*H EDIT;DELETE;PREVIOUS MENU'
   @ 22,30 GET printit FUNCTION '*H PRINT RECORD' COLOR SCHEME 7
   READ CYCLE
 NDCASE
* Control passes depending on which push button is chosen
 O CASE
  * If edit is chosen, control is passed to editrec.
  CASE editdel = 1
    DEACTIVATE WINDOW display
    DO editrec WITH mchoice,.F.,recnum IN C:\METC\DATABASE\PROG\EDITREC.PRG
  * If delete is chosen, control is passed to delrec
  CASE editdel = 2
    DEACTIVATE WINDOW display
    DO delrec WITH mchoice IN C:\METC\DATABASE\PROG\DELREC.PRG
  * If previous menu is chosen, control is passed to edit2
  CASE editdel = 3
    DEACTIVATE WINDOW display
    CLOSE DATABASES
    * When returning control to edit2 clear the searchstring.
    srchstring = SPACE(30)
 NDCASE
* If the PRINT RECORD button is chosen, pass control to the
*   printrpt program.
 F printit = 1
 O C:\METC\DATABASE\PROG\PRINTRPT.PRG WITH mchoice,recnum
 rintit = 0
 NDIF
* If the DELETE or PREVIOUS MENU buttons are chosen, exit the
*   do while loop and return to edit2.
 F (editdel = 2).OR.(editdel = 3)
  EXIT
 NDIF
 NDDO
 ETURN
```

```
'****************************************************************
PROCEDURE addmedia
PARAMETER key,sacancel,addopt
****************************************************************
* Program to add/edit a record to MEDIA.DBF
* This program is called by editrec.prg when the user pushes
*   the Media Info checkbox
medloop = .T.
first = .F.
* Mem var for continue/previous record and media selection buttons
contpr=0
mediabut=1
* Specify the media selection window
DEFINE WINDOW mediasel FROM 0,0 TO 24,79 PANEL SHADOW COLOR SCHEME 5
* Open the media database.
SELECT 4
  USE C:\METC\DATABASE\DATA\MEDIA.DBF ALIAS media
* If the value of key, which is passed from editrec, is 0 find the
*   largest value of media_key and add 1 to create a new media_key.
IF key = 0
   first = .T.
   SET ORDER TO TAG media_key ASCENDING
   GOTO BOTTOM
   key=media_key+1
   SCATTER MEMVAR BLANK
   m.media_key=key
* Otherwise, find the value of media_key that matches the value of
*   key, which is passed from editrec.
ELSE
   SET ORDER TO TAG media_key
   SEEK key
   SCATTER MEMVAR
ENDIF
* This do while loop allows the user to move back and forth between
*   the two screens in addmedia.
DO WHILE medloop
ACTIVATE WINDOW mediasel
@ 5,5 SAY "SELECT A MEDIA TYPE IN ORDER TO SUPPLY DETAILED MEDIA INFORMATION"
@ 8,29 GET mediabut FUNCTION '*R SOIL MEDIA;WATER MEDIA;AIR MEDIA'
* Define set of pushbuttons to save/cancel
*@ 14,15 SAY "Push CONTINUE to add media data; push PREVIOUS RECORD to exit"
@ 15,23 GET contpr FUNCTION '*H CONTINUE;PREVIOUS RECORD';
  VALID edmedia(contpr,mediabut)
READ CYCLE
* If the PREVIOUS RECORD button is chosen, exit the do while loop
*   and return to the last screen displayed in editrec.
IF contpr = 2
  EXIT
ENDIF
ENDDO
RETURN
*--------------------------------------------------------------------*
* This function is the second screen in addmedia.
FUNCTION edmedia
PARAMETERS contpr,mediabut
DEFINE WINDOW addsoil FROM 0,0 TO 24,79 PANEL SHADOW COLOR SCHEME 5
* If the CONTINUE button is chosen, display the second screen
*   in addmedia.
IF contpr=1
  SELECT 4
```

```
 DO CASE
  * If media=soil is selected
   CASE mediabut=1
     DEACTIVATE WINDOW mediasel
     * Specify the soil window
     ACTIVATE WINDOW addsoil
     * Mem var for save/cancel
     sacancel=0
     * Put "soil" into media1.
     m.media1="soil"
     * Initialize POPUP variable
     soiltext=SPACE(15)
     * If the value of s_texture is blank, have UNKNOWN appear in
     *   th popup.
     IF m.s_texture = '               '
       STORE "UNKNOWN        " TO soiltext
     * Otherwise, have the value it has been given appear in the popup.
     ELSE
       STORE m.s_texture TO soiltext
     ENDIF
     IF addopt = .T.
       @ 1,24 SAY "ADD SOIL MEDIA INFORMATION"
     ELSE
       @ 1,24 SAY "EDIT SOIL MEDIA INFORMATION"
     ENDIF
     @ 3,4 SAY "MEDIA#1:" GET m.media1
     * Caption over POPUP box
     @ 4,55 SAY "CHOOSE SOIL TEXTURE:"
     * Selection from POPUP is placed next to "SOIL TEXTURE:"
     @ 4,4 SAY "SOIL TEXTURE:" GET soiltext
     @ 5,4 SAY "PERCENT SAND(%):" GET m.s_sand_per
     @ 6,4 SAY "PERCENT SILT(%):" GET m.s_silt_per
     @ 7,4 SAY "PERCENT CLAY(%):" GET m.s_clay_per
     @ 8,4 SAY "SOIL pH:" GET m.s_ph
     @ 9,4 SAY "HYDRAULIC CONDUCTIVITY(cm/s):" GET m.s_hydr_con
     @ 10,4 SAY "ORGANIC CONTENT(%):" GET m.s_org_cont
     @ 11,4 SAY "MOISTURE CONTENT(%):" GET m.s_h2o_cont
     @ 12,4 SAY "SOIL VOLUME TREATED(m^3):" GET m.s_volume
     @ 13,4 SAY "SOIL TEMPERATURE(m^3):" GET m.s_temp
     @ 14,4 SAY "BULK DENSITY(kg/m^3):" GET m.s_bulk_den
     @ 15,4 SAY "CATION EXCHANGE CAPACITY(meq/g):" GET m.s_cat_exch
     @ 16,4 SAY "SOIL BIOTA DESCRIPTION:" GET s_biota
     @ 17,4 SAY "SOIL ADDITIONAL INFORMATION:" GET s_comment
     @ 19,15 SAY "Push SAVE to add media data; push CANCEL to exit"
     @ 5,55 GET soiltext PICTURE "@^ UNKNOWN        ;CLAY;SILTY CLAY;SANDY CLAY
LAY LOAM;SILTY CLAY LOAM;SANDY CLAY LOAM;SANDY LOAM;SILT LOAM;LOAM;;
OAMY SAND;SAND;SILT" WHEN schoice()
     * Create push buttons to save or exit the screen.
     @ 20,29 GET sacancel FUNCTION '*H SAVE;CANCEL'
     READ CYCLE
     * Selection from POPUP is copied into s_texture
     m.s_texture=soiltext
     * If save is chosen, save the record and return to the first
     *   screen in addmedia.
     IF sacancel=1
       IF (addopt=.T.).OR.(first=.T.)
         APPEND BLANK
       ENDIF
       GATHER MEMVAR
       DEACTIVATE WINDOW addsoil
```

```
      SELECT 4
      USE
      SELECT 1
      RETURN
    * Otherwise, return to the first screen in addmedia.
    ELSE
     m.media1 = "     "
     DEACTIVATE WINDOW addsoil
     SELECT 4
     USE
     SELECT 1
     RETURN
    ENDIF
* If media=water is selected
CASE mediabut=2
  DEACTIVATE WINDOW mediasel
  * Specify the water window
  DEFINE WINDOW addwater FROM 0,0 TO 24,79 PANEL SHADOW COLOR SCHEME 5
  ACTIVATE WINDOW addwater
  * Mem var for save/cancel
  sacancel=0
  * Put "water" into media2.
  m.media2="water"
  IF addopt = .T.
    @ 1,23 SAY "ADD WATER MEDIA INFORMATION"
  ELSE
    @ 1,23 SAY "EDIT WATER MEDIA INFORMATION"
  ENDIF
  @ 3,4 SAY "MEDIA#2:" GET m.media2
  @ 4,4 SAY "WATER ORGANIC CONTENT(mg/L):" GET m.w_org_cont
  @ 5,4 SAY "WATER COLLOIDAL CONTENT(mg/L):" GET m.w_colloid
  @ 6,4 SAY "DISSOLVED OXYGEN CONTENT(mg/L):" GET m.w_oxy_cont
  @ 7,4 SAY "DEPTH TO WATER TABLE(m):" GET m.w_depth
  @ 8,4 SAY "VOLUMETRIC FLOW RATE(m^3/hr):" GET m.w_flow
  @ 9,4 SAY "WATER TEMPERATURE(deg C):" GET m.w_temp
  @ 10,4 SAY "WATER pH:" GET m.w_ph
  @ 11,4 SAY "WATER BIOTA DESCRIPTION:" GET w_biota
  @ 12,4 SAY "WATER ADDITIONAL INFORMATION:" GET w_comment
  @ 16,15 SAY "Push SAVE to add media data; push CANCEL to exit"
  @ 17,29 GET sacancel FUNCTION '*H SAVE;CANCEL'
  READ CYCLE
  * If save is chosen, save the record and return to the first
  *   screen in addmedia.
  IF sacancel=1
    IF (addopt=.T.).OR.(first=.T.)
      APPEND BLANK
    ENDIF
    GATHER MEMVAR
    DEACTIVATE WINDOW addwater
    SELECT 4
    USE
    SELECT 1
    RETURN
  * Otherwise, return to the first screen in addmedia.
  ELSE
    DEACTIVATE WINDOW addwater
    SELECT 4
    USE
    SELECT 1
    RETURN
```

```
   ENDIF
  * If media=air is selected
 CASE mediabut=3
   DEACTIVATE WINDOW mediasel
   * Specify the air window
   DEFINE WINDOW addair FROM 0,0 TO 24,79 PANEL SHADOW COLOR SCHEME 5
   ACTIVATE WINDOW addair
   * Mem var for save/cancel
   sacancel=0
   * Put "air" into media3.
   m.media3="air"
   * Store air data to variables
   IF addopt = .T.
       @ 1,25 SAY "ADD AIR MEDIA INFORMATION"
   ELSE
       @ 1,25 SAY "EDIT AIR MEDIA INFORMATION"
   ENDIF
   @ 3,4 SAY "MEDIA#3:" GET m.media3
   @ 4,4 SAY "AIR ABSOLUTE PRESSURE(Pa):" GET m.a_pressure
   @ 5,4 SAY "AIR VOLUMETRIC FLOW RATE(m^3/hr):" GET m.a_flow
   @ 6,4 SAY "AIR TEMPERATURE(deg C):" GET m.a_temp
   @ 7,4 SAY "AIR HUMIDITY(%):" GET m.a_humidity
   @ 8,4 SAY "AIR ADDITIONAL INFORMATION:" GET a_comment
   @ 16,15 SAY "Push SAVE to add media data; push CANCEL to exit"
   @ 17,29 GET sacancel FUNCTION '*H SAVE;CANCEL'
   READ CYCLE
   * If save is chosen, save the record and return to the first
   *   screen in addmedia.
   IF sacancel=1
     IF (addopt=.T.).OR.(first=.T.)
       APPEND BLANK
     ENDIF
     GATHER MEMVAR
     DEACTIVATE WINDOW addair
     SELECT 4
     USE
     SELECT 1
     RETURN
   * Otherwise, return to the first screen in addmedia.
   ELSE
     DEACTIVATE WINDOW addair
     SELECT 4
     USE
     SELECT 1
     RETURN
   ENDIF
 ENDCASE
 If the PREVIOUS RECORD button has been chosen, return to the calling
   program(addmedia), and then return to the last screen displayed
   in editrec.
LSE
 DEACTIVATE WINDOW mediasel
 SELECT 4
 USE
 SELECT 1
 RETURN
NDIF
-------------------------------------------------------------------*
 Display new choice for popup selection
UNCTION schoice
```

SHOW GETS
RETURN

```
*HELP PROGRAM TO DEFINE FIELDS
*
cancel = 1
*
*Indicate which database to use
SELECT 2
USE C:\METC\DATABASE\DATA\DEFINE.DBF
*
*Define help window
DEFINE WINDOW help FROM 0,0 TO 25,85 PANEL SHADOW COLOR SCHEME 8
ACTIVATE WINDOW help
*
*Create and title definition box
@ 3,5 SAY "DEFINITION:"
@ 4,5 TO 6,76
*
*Explain field abbreviations
@ 8,43 SAY "C - Character Field"
@ 9,43 SAY "N - Numeric Field"
@ 10,43 SAY "M - Memo Field"
@ 11,43 SAY "L - Logical Field"
*Create and title field name list and mainmenu button
@ 10,5 SAY "CHOOSE FIELD NAME:"
*display message at bottom
@ 23,20 SAY "(Double click mouse on selected field)"
DEFINE POPUP lfields PROMPT STRUCTURE SCROLL MARGIN;
    MARK ">" COLOR SCHEME 5
@ 17,43 GET cancel FUNCTION '*H PREVIOUS SCREEN'
@ 11,10 GET test PICTURE "@&N" POPUP lfields SIZE 11,14 DEFAULT " ";
VALID dispitem(test)
READ CYCLE
*
*Clear window and exit to previous screen if cancel is pushed
IF cancel = 1
        DEACTIVATE WINDOW help
        DEACTIVATE POPUP help
        SELECT 1
        RETURN
ENDIF
*
*Write definition in box
FUNCTION dispitem
PARAMETER item
@ 5,6 SAY &item
*
*End
```

```
* Define main menu for hazardous waste technology database
*
*  Define a window and display initial greeting
CLEAR
DEFINE WINDOW name FROM 0,0 TO 25,79 PANEL SHADOW;
COLOR SCHEME 1

*  Define the menu used to select action
DEFINE MENU main IN WINDOW name
*
DEFINE PAD addpad OF main PROMPT 'ADD' AT 0,3
DEFINE PAD editpad OF main PROMPT 'EDIT' AT 0,18
DEFINE PAD srchpad OF main PROMPT 'SEARCH' AT 0,33
DEFINE PAD endit OF main PROMPT 'EXIT' AT 0,48
DEFINE PAD helppad OF main PROMPT 'HELP' AT 0,63
*
ON PAD addpad OF main ACTIVATE POPUP add
ON PAD editpad OF main ACTIVATE POPUP edit
ON PAD srchpad OF main ACTIVATE POPUP search
ON PAD endit OF main ACTIVATE POPUP exit
ON PAD helppad OF main ACTIVATE POPUP help
*
* Define ADD popup/menu
*
DEFINE POPUP add FROM 1,3 IN WINDOW name COLOR SCHEME 4
DEFINE BAR 1 OF add PROMPT 'ORGANIC';
MESSAGE 'Add an organic pollutant to database'
DEFINE BAR 2 OF add PROMPT 'INORGANIC';
MESSAGE 'Add an inorganic pollutant to database'
DEFINE BAR 3 OF add PROMPT 'RADIONUCLIDE';
MESSAGE 'Add a radionuclide pollutant to database'
DEFINE BAR 4 OF add PROMPT 'TECHNOLOGY';
MESSAGE 'Add a general technology to database'
DEFINE BAR 5 OF add PROMPT 'DEVELOP';
MESSAGE 'Add a developed/demonstrated technology to database'
*
ON SELECTION POPUP add DO control WITH 'add', BAR()
*
* Define EDIT/DELETE popup/menu
*
DEFINE POPUP edit FROM 1,18 IN WINDOW name COLOR SCHEME 4
DEFINE BAR 1 OF edit PROMPT 'ORGANIC';
MESSAGE 'Delete/edit organic pollutant in database'
DEFINE BAR 2 OF edit PROMPT 'INORGANIC';
MESSAGE 'Delete/edit an inorganic pollutant to database'
DEFINE BAR 3 OF edit PROMPT 'RADIONUCLIDE';
MESSAGE 'Delete/edit a radionuclide pollutant to database'
DEFINE BAR 4 OF edit PROMPT 'TECHNOLOGY';
MESSAGE 'Delete/edit a general technology in database'
DEFINE BAR 5 OF edit PROMPT 'DEVELOP';
MESSAGE 'Delete/edit a developed/demonstrated technology in database'
*
ON SELECTION POPUP edit DO control WITH 'edit', BAR()
*
*
* Define SEARCH popup/menu
*
DEFINE POPUP search FROM 1,33 IN WINDOW name
DEFINE BAR 1 OF search PROMPT 'SEARCH';
```

```
MESSAGE 'Search routines to be developed....'
*
ON SELECTION POPUP search DO control WITH 'search', BAR()
*
*
* Define EXIT selection
*
DEFINE POPUP exit FROM 1,48 IN WINDOW name COLOR SCHEME 4
DEFINE BAR 1 OF exit PROMPT 'EXIT';
MESSAGE 'End database session'
*
ON SELECTION POPUP exit DO control WITH 'quit',0
*
* Define HELP popup/menu
*
DEFINE POPUP help FROM 1,63 IN WINDOW name COLOR SCHEME 4
DEFINE BAR 1 OF help PROMPT 'HELP';
MESSAGE 'HELP routines to be developed....'
*
ON SELECTION POPUP help DO control WITH 'help', BAR()
*
RETURN
```

```
•    'PROCEDURE printrpt
PARAMETERS mchoice,recnum
DEFINE WINDOW choices FROM 0,0 TO 24,79 PANEL SHADOW COLOR SCHEME 1
ACTIVATE WINDOW choices
SET TALK OFF
prnchoice=1
@ 5,13 SAY"This option allows you to print the record as a report!"
@ 10,20 SAY"Please select a printing option."
@ 12,32 GET prnchoice FUNCTION '*V PRINTER;SCREEN;CANCEL'
READ CYCLE
DO CASE
        CASE prnchoice=1
          DO printer WITH mchoice,recnum
        CASE prnchoice=2
          DO screen WITH mchoice,recnum
        CASE prnchoice=3
          DEACTIVATE WINDOW choices
          *DO disprec IN C:\METC\DATABASE\PROG\DISPREC.PRG WITH mchoice,recnum
          RETURN
ENDCASE
*
**********************************************************************
*
PROCEDURE printer
PARAMETERS mchoice,recnum
STORE RECNO() TO recnum
DO CASE
        CASE mchoice=1
          REPORT FORM C:\METC\DATABASE\RPT\ORGANIC.FRX TO PRINT RECORD recnum NO
        CASE mchoice=2
          REPORT FORM C:\METC\DATABASE\RPT\INORGAN.FRX TO PRINT RECORD recnum NO
        CASE mchoice=3
          REPORT FORM C:\METC\DATABASE\RPT\RADIONUC.FRX TO PRINT RECORD recnum N
        CASE mchoice=4
          REPORT FORM C:\METC\DATABASE\RPT\TECHRPT.FRX TO PRINT RECORD recnum NO
        CASE mchoice=5
          REPORT FORM C:\METC\DATABASE\RPT\DEVLOPER.FRX TO PRINT RECORD recnum N
ENDCASE
DEACTIVATE WINDOW choices
DO disprec IN C:\METC\DATABASE\PROG\DISPREC.PRG WITH mchoice,recnum
*
*****************************************************************************
*
PROCEDURE screen
PARAMETERS mchoice,recnum
STORE RECNO() TO recnum
SET TALK OFF
DO CASE
        CASE mchoice=1
          REPORT FORM C:\METC\DATABASE\RPT\ORGANIC.FRX RECORD recnum PREVIEW
        CASE mchoice=2
          REPORT FORM C:\METC\DATABASE\RPT\INORGAN.FRX RECORD recnum PREVIEW
        CASE mchoice=3
          REPORT FORM C:\METC\DATABASE\RPT\RADIONUC.FRX RECORD recnum PREVIEW
        CASE mchoice=4
          REPORT FORM C:\METC\DATABASE\RPT\TECHRPT.FRX RECORD recnum PREVIEW
        CASE mchoice=5
          REPORT FORM C:\METC\DATABASE\RPT\DEVLOPER.FRX RECORD recnum PREVIEW
ENDCASE
DEACTIVATE WINDOW choices
```

```
DO disprec IN C:\METC\DATABASE\PROG\DISPREC.PRG WITH mchoice,recnum
```

```
                                                                  **************
* PROCEDURE  TO DELETE A RECORD
PROCEDURE delrec
PARAMETERS mchoice
******************************************************************
* Mem var for yes/no if you want to delete record
yesno = 1
DEFINE WINDOW delete FROM 7,31 TO 14,49 PANEL SHADOW;
COLOR SCHEME 8
DEFINE WINDOW really FROM 7,28 TO 14,53 PANEL SHADOW;
COLOR SCHEME 1
ACTIVATE WINDOW delete
* Get user input yes/no
@ 1,2 SAY "ARE YOU SURE?"
@ 3,3 GET yesno FUNCTION '*H YES;NO'
READ CYCLE
* If the YES button is chosen ...
IF yesno = 1
  * Check again to make sure user wants to delete record
  DEACTIVATE WINDOW delete
  ACTIVATE WINDOW really
  * Get user confirmation
  @ 1,2 SAY "ARE YOU REALLY SURE?"
  @ 3,7 GET yesno FUNCTION '*H YES;NO'
  READ CYCLE
  * If user chooses yes delete record; otherwise return
  *   to edit menu
  * If the YES button is chosen again, delete the record.
  IF yesno = 1
    DELETE
    PACK
  ENDIF
  * Close the window and the databases and return to edit2.
  DEACTIVATE WINDOW really
  CLOSE DATABASES
  * When returning control to editmenu, clear the searchstring
  *  and reassign hold as .F.
  srchstring = SPACE(30)
  RETURN
* If the NO button is chosen, close the window and the databases
*   and return to edit2.
ELSE
  DEACTIVATE WINDOW delete
  CLOSE DATABASES
  * When returning control to edit2, clear the searchstring
  *  and reassign hold as .F.
  srchstring = SPACE(30)
  RETURN
ENDIF
```

```
*********************************************************************
* PROCEDURE TO EDIT RECORD
PROCEDURE editrec
PARAMETERS mchoice,addopt,recnum
*********************************************************************
continue = .T.
okcancel = 0
sacancel = 0
screen = 1
change1 = 0
change2 = 0
pushd = 0
pushtg = 0
pushsc = 0
check = 0
picks = 0
pickw = 0
picka = 0
pickc = 0
picke = 0
pickt = 0
pickd = 0
picalph = 0
picbeta = 0
picgamm = 0
ymedia = SPACE(6)
ypollut = SPACE(7)

DEFINE WINDOW record FROM 0,0 TO 24,79 COLOR SCHEME 5
ACTIVATE WINDOW record

* Define help popup
DEFINE MENU fhelp IN WINDOW record
DEFINE PAD helppad OF fhelp PROMPT 'HELP' AT 0,70
ON PAD helppad OF fhelp ACTIVATE POPUP help
DEFINE POPUP help FROM 1,70 IN WINDOW record COLOR SCHEME 1
DEFINE BAR 1 OF help PROMPT 'Fields';
MESSAGE 'Definitions of database fields'
ON SELECTION POPUP help DO helpit WITH BAR()

* Open database which user wants if add was chosen in mainmenu
*    and scatter the data to empty memory variables.
IF addopt = .T.
  DO CASE
    CASE mchoice = 1
      USE C:\METC\DATABASE\DATA\ORGAN_CH.DBF
    CASE (mchoice = 2 .OR. mchoice = 3)
      USE C:\METC\DATABASE\DATA\INOR_RAD.DBF
    CASE mchoice = 4
      USE C:\METC\DATABASE\DATA\TECHNOLO.DBF
    CASE mchoice = 5
      USE C:\METC\DATABASE\DATA\DEVELOP.DBF
  ENDCASE
  GOTO BOTTOM
  SCATTER MEMVAR BLANK
* Otherwise, scatter the data to the existing memory variables
ELSE
  SCATTER MEMVAR
ENDIF
```

```
* This segment will print the current contents of the field
*  on the designated screen.
DO CASE
  * What to do with checkboxes in radionuclide database.
  CASE mchoice = 3
    * Write the current contents of the specified field on the
    *   screen beside the checkboxes.
    IF m.emission_1 = 'alpha'
      m.picalph = 1
      @ 18,32 SAY m.emission_1
    ENDIF
    IF m.emission_2 = 'beta'
      m.picbeta = 1
      @ 19,32 SAY m.emission_2
    ENDIF
    IF m.emission_3 = 'gamma'
      m.picgamm = 1
      @ 20,32 SAY m.emission_3
    ENDIF

  * What to do with push buttons and checkboxes in
  *   technology database.
  CASE mchoice = 4
    * Write the current contents of the specified field on the
    *   screen above the push buttons.
    @ 7,12 SAY m.domain
    @ 5,30 SAY m.tech_group
    * Write the current contents of the specified field on the
    *   screen beside the checkboxes.
    IF m.media1 = 'soil'
      m.picks = 1
      @ 10,34 SAY m.media1
    ENDIF
    IF m.media2 = 'water'
      m.pickw = 1
      @ 11,34 SAY m.media2
    ENDIF
    IF m.media3 = 'air'
      m.picka = 1
      @ 12,34 SAY m.media3
    ENDIF
    IF m.rem_phase1 = 'characterization'
      m.pickc = 1
      @ 14,50 SAY m.rem_phase1
    ENDIF
    IF m.rem_phase2 = 'extraction'
      m.picke = 1
      @ 15,50 SAY m.rem_phase2
    ENDIF
    IF m.rem_phase3 = 'treatment'
      m.pickt = 1
      @ 16,50 SAY m.rem_phase3
    ENDIF
    IF m.rem_phase4 = 'disposal'
      m.pickd = 1
      @ 17,50 SAY m.rem_phase4
    ENDIF
NDCASE

CTIVATE MENU fhelp NOWAIT
```

```
* Display record to edit or add
DO CASE
  * Setup screen to edit/add a record in the organic database.
  CASE mchoice = 1
    * Display appropriate heading to add/edit organic database
    IF addopt = .T.
       @ 1,24 SAY "ADD A RECORD TO ORGANIC DATABASE"
    ELSE
       @ 1,24 SAY "EDIT A RECORD IN ORGANIC DATABASE"
    ENDIF
    @ 3,4 SAY "POLLUTANT:" GET m.pollutant VALID lcase(@m.pollutant)
    @ 4,4 SAY "CAS #:" GET m.cas_num VALID lcase(@m.cas_num)
        @ 5,4 SAY "CLASS #:" GET m.poll_num VALID lcase(@m.poll_num)
    @ 6,4 SAY "MOLECULAR WEIGHT (amu):" GET m.mol_wt
    @ 7,4 SAY "BOILING POINT (C):" GET m.boil_pt
        @ 8,4 SAY "MELTING POINT (C):" GET m.melt_pt
        @ 9,4 SAY "VAPOR PRESSURE (Pa):" GET m.vapor_pres
        @ 10,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET m.henry_con
    @ 11,4 SAY "SOLUBILITY (mg/L):" GET m.solubility
        @ 12,4 SAY "SOLUBILITY PH:" GET m.sol_ph
    @ 13,4 SAY "LOG OCTONOL TO WATER PARTITION COEFF:" GET m.log_oct_h2
    @ 14,4 SAY "IT CAN PHOTODEGRADE (T/F):" GET m.photodeg
    @ 15,4 SAY "IT CAN BIODEGRADE (T/F):" GET m.biodegrad
    @ 16,4 SAY "IT IS POLAR (T/F):" GET m.polar
    @ 18,17 SAY "(Check desired box for further information.)"
    * Draw a box around check box choices.
    @ 19,4 TO 21,72
    * Create check boxes for memo fields.
    @ 20,6 GET m.check PICTURE '@*C BIOLOGICAL AGENTS';
      VALID dispmemo('bio_agents',addopt)
    @ 20,32 GET m.check PICTURE '@*C BIOLOGICAL EFFECT';
      VALID dispmemo('bio_effect',addopt)
    @ 20,58 GET m.check PICTURE '@*C REFERENCE';
      VALID dispmemo('reference',addopt)
    * Create push buttons to save the record or exit the screen.
    @ 22,31 GET okcancel FUNCTION '*H SAVE;CANCEL'
    READ CYCLE

  * Setup screen to edit/add a record in the inorganic database.
  CASE mchoice = 2
    * Display appropriate heading to add/edit inorganic database
        IF addopt = .T.
       @ 1,21 SAY "ADD A RECORD TO INORGANIC DATABASE"
    ELSE
           @ 1,21 SAY "EDIT A RECORD IN INORGANIC DATABASE"
        ENDIF
        @ 3,4 SAY "POLLUTANT:" GET m.pollutant VALID lcase(@m.pollutant)
        @ 4,4 SAY "CAS #:" GET m.cas_num VALID lcase(@m.cas_num)
        @ 5,4 SAY "CLASS #:" GET m.poll_num VALID lcase(@m.poll_num)
        @ 6,4 SAY "VALENCE OF POLLUTANT:" GET m.redox_num;
          VALID lcase(@m.redox_num)
        @ 7,4 SAY "MOLECULAR WEIGHT (amu):" GET m.mol_wt
        @ 8,4 SAY "BOILING POINT (C):" GET m.boil_pt
        @ 9,4 SAY "MELTING POINT (C):" GET m.melt_pt
        @ 10,4 SAY "DENSITY (g/L):" GET m.density
        @ 11,4 SAY "SOLUBILITY (mg/L):" GET m.solubility
        @ 12,4 SAY "SOLUBILITY PH:" GET m.sol_ph
        @ 13,4 SAY "DIFFUSION (cm^2/sec):" GET m.diffusion
        @ 14,4 SAY "VAPOR PRESSURE (Pa):" GET m.vapor_pres
```

```
      @ 15,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET m.henry_con
  @ 17,16 SAY "(Check desired box for further information.)"
  * Draw a box around check box choices.
  @ 18,16 TO 20,60
  * Create check boxes for memo fields.
  @ 19,18 GET m.check PICTURE '@*C BIOLOGICAL EFFECT';
    VALID dispmemo('bio_effect',addopt)
  @ 19,46 GET m.check PICTURE '@*C REFERENCE';
    VALID dispmemo('reference',addopt)
      * Create push buttons to save the record or exit the screen.
      @ 22,31 GET okcancel FUNCTION '*H SAVE;CANCEL'
      READ CYCLE

* Setup screen to edit/add a record in the inor_rad database.
CASE mchoice = 3
  * Display appropriate heading to add/edit radionuclide database
  IF addopt = .T.
     @ 0,22 SAY "ADD A RECORD TO RADIONUCLIDE DATABASE"
  ELSE
         @ 0,22 SAY "EDIT A RECORD IN RADIONUCLIDE DATABASE"
      ENDIF
      @ 1,4 SAY "POLLUTANT:" GET m.pollutant VALID lcase(@m.pollutant)
      @ 2,4 SAY "CAS #:" GET m.cas_num VALID lcase(@m.cas_num)
      @ 3,4 SAY "CLASS #:" GET m.poll_num VALID lcase(@m.poll_num)
      @ 4,4 SAY "VALENCE OF POLLUTANT:" GET m.redox_num;
        VALID lcase(@m.redox_num)
      @ 5,4 SAY "MOLECULAR WEIGHT (amu):" GET m.mol_wt
  @ 6,4 SAY "BOILING POINT (C):" GET m.boil_pt
      @ 7,4 SAY "MELTING POINT (C):" GET m.melt_pt
      @ 8,4 SAY "DENSITY (g/L):" GET m.density
      @ 9,4 SAY "SOLUBILITY (mg/L):" GET m.solubility
      @ 10,4 SAY "SOLUBILITY PH:" GET m.sol_ph
      @ 11,4 SAY "DIFFUSION (cm^2/sec):" GET m.diffusion
      @ 12,4 SAY "VAPOR PRESSURE (Pa):" GET m.vapor_pres
      @ 13,4 SAY "HENRY'S CONSTANT (Pa-m^3/mol):" GET m.henry_con
      @ 14,4 SAY "HALF LIFE (yrs):" GET m.half_life
      @ 15,4 SAY "DAUGHTER:" GET m.daughter VALID lcase(@m.daughter)
      @ 16,4 SAY "TYPE OF EMISSION: (Check all types of emission.)"
      * Draw a box and create emission checkboxes.
      @ 17,7 TO 21,18
      @ 18,20 SAY "EMISSION 1:"
      @ 18,8 GET m.picalph PICTURE '@*C ALPHA';
        VALID place(18,32,picalph,'emission_1')
      @ 19,20 SAY "EMISSION 2:"
      @ 19,8 GET m.picbeta PICTURE '@*C BETA';
        VALID place(19,32,picbeta,'emission_2')
      @ 20,20 SAY "EMISSION 3:"
      @ 20,8 GET m.picgamm PICTURE '@*C GAMMA';
        VALID place(20,32,picgamm,'emission_3')
      @ 18,42 SAY "ENERGY 1 (mev):" GET m.energy_1
      @ 19,42 SAY "ENERGY 2 (mev):" GET m.energy_2
      @ 20,42 SAY "ENERGY 3 (mev):" GET m.energy_3
      * Draw a box around check box choices.
      @ 5,52 SAY "Check to view memo fields."
  @ 6,52 TO 9,76
  * Create check boxes for memo fields.
      @ 7,54 GET m.check PICTURE '@*C BIOLOGICAL EFFECT';
    VALID dispmemo('bio_effect',addopt)
  @ 8,54 GET m.check PICTURE '@*C REFERENCE';
    VALID dispmemo('reference',addopt)
```

```
      * Create push buttons to save the record or exit the screen.
      @ 22,31 GET okcancel FUNCTION '*H SAVE;CANCEL'
      READ CYCLE

* Setup screen to edit/add a record in the technology database.
CASE mchoice = 4
  * Display appropriate heading to add/edit technology database
  IF addopt = .T.
     @ 0,20 SAY "ADD A RECORD TO TECHNOLOGY DATABASE"
  ELSE
     @ 0,20 SAY "EDIT A RECORD IN TECHNOLOGY DATABASE"
  ENDIF
 @ 2,4 SAY "TECHNOLOGY:" GET m.technology VALID lcase(@m.technology)
      @ 3,4 SAY "SUB-CLASS:" GET m.sub_class VALID lcase(@m.sub_class)
      @ 4,12 SAY "(Choose the correct technology group and domain.)"
      @ 5,4 SAY "GENERAL TECHNOLOGY GROUP:"
      @ 6,12 GET m.pushtg FUNCTION;
        '*HN BIOLOGICAL;THERMAL;IMMOBILIZATION;PHYSICAL/CHEMICAL';
        VALID push (5,30,pushtg,'tech_group')
      @ 7,4 SAY "DOMAIN:"
      @ 8,12 GET m.pushd FUNCTION '*HN IN-SITU;EX-SITU';
        VALID push(7,12,pushd,'domain')
      @ 9,4 SAY "MEDIA: (Check all applicable media.)"
      @ 10,25 SAY 'MEDIA 1:'
      @ 11,25 SAY 'MEDIA 2:'
      @ 12,25 SAY 'MEDIA 3:'
  @ 10,12 GET m.picks PICTURE '@*C SOIL';
    VALID place(10,34,picks,'media1')
      @ 11,12 GET m.pickw PICTURE '@*C WATER';
        VALID place(11,34,pickw,'media2')
      @ 12,12 GET m.picka PICTURE '@*C AIR';
        VALID place(12,34,picka,'media3')
      @ 13,4 SAY;
        "REMEDIATION PHASE: (Check all appropriate remediation phases.)"
  @ 14,36 SAY "REM. PHASE 1:"
  @ 15,36 SAY "REM. PHASE 2:"
  @ 16,36 SAY "REM. PHASE 3:"
  @ 17,36 SAY "REM. PHASE 4:"
  @ 14,12 GET m.pickc PICTURE '@*C CHARACTERIZATION';
    VALID place(14,50,pickc,'rem_phase1')
  @ 15,12 GET m.picke PICTURE '@*C EXTRACTION';
    VALID place(15,50,picke,'rem_phase2')
  @ 16,12 GET m.pickt PICTURE '@*C TREATMENT';
    VALID place(16,50,pickt,'rem_phase3')
  @ 17,12 GET m.pickd PICTURE '@*C DISPOSAL';
    VALID place(17,50,pickd,'rem_phase4')
  * Draw a box around check box choices.
  @ 18,4 SAY "(Check desired box for further information.)"
  @ 19,4 TO 21,74
  * Create check boxes for memo fields.
  @ 20,6 GET m.check PICTURE '@*C DESCRIPTION';
    VALID dispmemo('descript',addopt)
  @ 20,31 GET m.check PICTURE '@*C REFERENCE';
    VALID dispmemo('reference',addopt)
  @ 20,55 GET m.check PICTURE '@*C POLLUTANT INFO';
    VALID addextra('ypollut',m.poll_key)
  * Create push buttons to save the record or exit the screen.
      @ 22,31 GET okcancel FUNCTION '*H SAVE;CANCEL'
      READ CYCLE
```

```
* Setup screen to edit/add a record in the develop database.
CASE mchoice = 5
  * This DO WHILE loop allows the user to go back and forth between
  *  two screens when in the develop database.
  DO WHILE continue

    DO CASE
      CASE screen = 1
        * Define and activate the first screen of the develop record.
        DEFINE WINDOW record FROM 0,0 TO 24,79 COLOR SCHEME 5
        ACTIVATE WINDOW record

        * Write the current contents of the specified field on the
        *   screen above the push buttons.
        @ 18,56 SAY m.tech_group
        @ 16,33 SAY m.domain
        @ 18,15 SAY m.scale

        * Display appropriate heading to add/edit develop database
        IF addopt = .T.
          @ 0,22 SAY "ADD A RECORD TO DEVELOP DATABASE"
        ELSE
          @ 0,22 SAY "EDIT A RECORD IN DEVELOP DATABASE"
        ENDIF
        @ 2,4 SAY "COMPANY'S NAME FOR TECHNOLOGY:"
        @ 3,16 GET m.tech_name VALID lcase(@m.tech_name)
        @ 4,4 SAY "TECHNOLOGY:" GET m.technology;
          VALID lcase(@m.technology)
        @ 5,4 SAY "DEVELOPER:" GET m.developer VALID lcase(@m.developer)
        @ 6,4 SAY "SITE:" GET m.site VALID lcase(@m.site)
            @ 8,10 SAY;
              "(Choose the correct scale, domain, and technology group.)"
        @ 10,12 SAY "SCALE:"
            * Draw a box around scale push buttons and define choices.
        @ 11,10 TO 16,18
            @ 12,11 GET m.pushsc FUNCTION '*VN BENCH;LAB;PILOT;FIELD';
              VALID push(18,15,pushsc,'scale')
        @ 10,29 SAY "DOMAIN:"
            * Draw a box around domain push buttons and define choices.
            @ 11,27 TO 14,37
            @ 12,28 GET m.pushd FUNCTION '*VN IN-SITU;EX-SITU';
              VALID push(16,33,pushd,'domain')
        @ 10,48 SAY "TECHNOLOGY GROUP:"
            * Draw a box around tech group push buttons and define choices.
            @ 11,46 TO 16,66
            @ 12,47 GET m.pushtg FUNCTION;
              '*VN BIOLOGICAL;THERMAL;IMMOBILIZATION;PHYSICAL/CHEMICAL';
              VALID push (18,56,pushtg,'tech_group')
            * Display choices made for the three fields.
        @ 18,8 SAY 'SCALE:'
        @ 16,25 SAY 'DOMAIN:'
        @ 18,44 SAY 'TECH GROUP:'
        * Enable user to continue to the next screen.
        @ 22,56 GET change1 PICTURE '@*CT NEXT SCREEN' COLOR SCHEME 1
        * Create push buttons to save the record or exit the screen.
        @ 22,30 GET okcancel PICTURE '@*H SAVE;CANCEL'
        READ CYCLE
        * If the "NEXT SCREEN" checkbox is chosen, change the
        *  value of the screen to 2(second screen), and
        *  reinitialize the value of the checkbox to 0.
```

```
    IF change1 = 1
      screen = 2
      change1 = 0
    ENDIF

  CASE screen = 2
    check = 0
    * Define and activate the second screen of the develop record.
    DEFINE WINDOW devscreen FROM 0,0 TO 24,79 COLOR SCHEME 5
    ACTIVATE WINDOW devscreen

    * Define help popup for second develop screen
    DEFINE MENU fhelp2 IN WINDOW devscreen
    DEFINE PAD helppad OF fhelp2 PROMPT 'HELP' AT 0,70
    ON PAD helppad OF fhelp2 ACTIVATE POPUP help
    DEFINE POPUP help FROM 1,70 IN WINDOW devscreen COLOR SCHEME 1
    DEFINE BAR 1 OF help PROMPT 'Fields';
    MESSAGE 'Definitions of database fields'
    ON SELECTION POPUP help DO helpit WITH BAR()
    ACTIVATE MENU fhelp2 NOWAIT

    * Write the current contents of the specified field on the
    *   screen beside the checkboxes.
    IF m.media1 = 'soil'
      m.picks = 1
      @ 5,34 SAY m.media1
    ENDIF
    IF m.media2 = 'water'
      m.pickw = 1
      @ 6,34 SAY m.media2
    ENDIF
    IF m.media3 = 'air'
      m.picka = 1
      @ 7,34 SAY m.media3
    ENDIF
    IF m.rem_phase1 = 'characterization'
      m.pickc = 1
      @ 11,50 SAY m.rem_phase1
    ENDIF
    IF m.rem_phase2 = 'extraction'
      m.picke = 1
      @ 12,50 SAY m.rem_phase2
    ENDIF
    IF m.rem_phase3 = 'treatment'
      m.pickt = 1
      @ 13,50 SAY m.rem_phase3
    ENDIF
    IF m.rem_phase4 = 'disposal'
      m.pickd = 1
      @ 14,50 SAY m.rem_phase4
    ENDIF


    * Display appropriate heading to add/edit develop database
    IF addopt = .T.
      @ 1,22 SAY "ADD A RECORD TO DEVELOP DATABASE"
    ELSE
      @ 1,22 SAY "EDIT A RECORD IN DEVELOP DATABASE"
    ENDIF
    @ 3,4 SAY "MEDIA: (Check all applicable media.)"
```

```
    @ 5,25 SAY 'MEDIA 1:'
    @ 6,25 SAY 'MEDIA 2:'
    @ 7,25 SAY 'MEDIA 3:'
    @ 5,12 GET m.picks PICTURE '@*C SOIL';
      VALID place(5,34,picks,'media1')
    @ 6,12 GET m.pickw PICTURE '@*C WATER';
      VALID place(6,34,pickw,'media2')
    @ 7,12 GET m.picka PICTURE '@*C AIR';
      VALID place(7,34,picka,'media3')
    @ 9,4 SAY;
      "REMEDIATION PHASE: (Check all appropriate remediation phases.)"
    @ 11,36 SAY "REM. PHASE 1:"
    @ 12,36 SAY "REM. PHASE 2:"
    @ 13,36 SAY "REM. PHASE 3:"
    @ 14,36 SAY "REM. PHASE 4:"
    @ 11,12 GET m.pickc PICTURE '@*C CHARACTERIZATION';
      VALID place(11,50,pickc,'rem_phase1')
    @ 12,12 GET m.picke PICTURE '@*C EXTRACTION';
      VALID place(12,50,picke,'rem_phase2')
    @ 13,12 GET m.pickt PICTURE '@*C TREATMENT';
      VALID place(13,50,pickt,'rem_phase3')
    @ 14,12 GET m.pickd PICTURE '@*C DISPOSAL';
      VALID place(14,50,pickd,'rem_phase4')
    * Draw a box around check box choices.
    @ 17,17 SAY "(Check desired box for further information.)"
    @ 18,4 TO 21,73
    * Create check boxes for memo fields.
    @ 19,5 GET m.check PICTURE '@*C DESCRIPTION';
      VALID dispmemo('descript',addopt)
    @ 20,5 GET m.check PICTURE '@*C DOCUMENTS';
      VALID dispmemo('documents',addopt)
    @ 19,24 GET m.check PICTURE '@*C STATUS';
      VALID dispmemo('status',addopt)
    @ 20,24 GET m.check PICTURE '@*C COST';
      VALID dispmemo('cost',addopt)
    @ 19,38 GET m.check PICTURE '@*C CONTACTS';
      VALID dispmemo('contacts',addopt)
    @ 20,38 GET m.check PICTURE '@*C REFERENCE';
      VALID dispmemo('reference',addopt)
    @ 19,55 GET m.check PICTURE '@*C MEDIA INFO';
      VALID addextra('ymedia',m.media_key)
    @ 20,55 GET m.check PICTURE '@*C POLLUTANT INFO';
      VALID addextra('ypollut',m.poll_key)
    @ 22,54 GET change2 PICTURE '@*CT PREVIOUS SCREEN' COLOR SCHEME 1
    * Create push buttons to save or exit the screen.
    @ 22,30 GET okcancel FUNCTION '*H SAVE;CANCEL'
    READ CYCLE
    * If the "PREVIOUS SCREEN" checkbox is chosen, change the
    *  value of the screen to 1(first screen), and
    *  reinitialize the value of the checkbox to 0.
    IF change2 = 1
      screen = 1
      change2 = 0
    ENDIF
ENDCASE

* If at any time in either screen SAVE or CANCEL are chosen,
*  exit the DO WHILE loop and continue the program.
IF (okcancel = 1).OR.(okcancel = 2)
  EXIT
```

```
      ENDIF

  ENDDO
ENDCASE

* Pass control depending on which push button is chosen
* If SAVE is chosen, transfer the memory variables to the database
IF okcancel = 1
  IF addopt = .T.
    APPEND BLANK
  ENDIF
  GATHER MEMVAR
ELSE
   * If SAVE is chosen and then CANCEL, only save the values given
   *   to media_key and poll_key.
   IF sacancel = 1
     DO CASE
       CASE mchoice = 4
         GATHER MEMVAR FIELDS poll_key
       CASE mchoice = 5
         GATHER MEMVAR FIELDS media_key,poll_key
     ENDCASE
   ENDIF
ENDIF
* If CANCEL is chosen or after SAVE choice is executed,
*   deactivate window and pass control
DEACTIVATE WINDOW record
DEACTIVATE WINDOW devscreen
  * If in add mode, pass control to mainmenu
      IF addopt = .T.
        CLOSE DATABASES
        RETURN
  * If in edit mode, pass control to editmenu
      ELSE
        * When returning control to edit2 clear the searchstring.
        srchstring = SPACE(30)
        RETURN
      ENDIF

*-------------------------------------------------------------------*
* This function can be used with any of the fields where there are
*   specific choices given in push buttons.
* This function will display the choice made on the screen.

FUNCTION push
PARAMETERS x,y,push,fldname
* x and y are the coordinates where the choice will be written.
* Push determines which button was pushed.
* Fldname is the name of the field which is being edited.

* When a button is pushed, determine which field is being used.
DO CASE
  * Assign a value to the field domain depending on which
  *   button was chosen.
  CASE fldname = 'domain'
    DO CASE
      CASE push = 1
        m.domain = 'in-situ'
      CASE push = 2
        m.domain = 'ex-situ'
```

```
   ENDCASE

 * Assign a value to the field tech_group depending on which
 *   button was chosen.
 CASE fldname = 'tech_group'
   DO CASE
      CASE push = 1
        m.tech_group = 'biological       '
      CASE push = 2
        m.tech_group = 'thermal          '
      CASE push = 3
        m.tech_group = 'immobilization   '
      CASE push = 4
        m.tech_group = 'physical/chemical'
   ENDCASE

   * Assign a value to the field scale depending on which
   *   button was chosen.
   CASE fldname = 'scale'
     DO CASE
       CASE push = 1
         m.scale = 'bench'
       CASE push = 2
         m.scale = 'lab  '
       CASE push = 3
         m.scale = 'pilot'
       CASE push = 4
         m.scale = 'field'
     ENDCASE
ENDCASE

* Display the choice made at the specified coordinates.
@ x,y SAY m.&fldname
* Reassign push to 0.
push = 0
RETURN
*-----------------------------------------------------------------*
* This function can be used with any of the fields where there are
*   specific choices given in check boxes.
* This function will confirm that the user has chosen a check box
*   by placing the contents of the field on the screen.

FUNCTION place
PARAMETER x,y,pick,fieldnm
* x and y are the coordinates where the choice will be written.
* Pick determines whether the checkbox was clicked or unclicked.
* Fieldnm is the name of the field which is being edited.

* If a checkbox is unclicked pick = 0. Assign blanks to the field.
IF pick = 0
  DO CASE
    CASE mchoice = 3
      m.&fieldnm = '     '
    CASE mchoice = 4
      m.&fieldnm = '                '
    CASE mchoice = 5
      m.&fieldnm = '                '
  ENDCASE
* If a checkox is clicked, pick = 1. Assign the choice to the field.
ELSE
```

```
 DO CASE
    CASE fieldnm = 'emission_1'
      m.emission_1 = 'alpha'
    CASE fieldnm = 'emission_2'
      m.emission_2 = 'beta'
    CASE fieldnm = 'emission_3'
      m.emission_3 = 'gamma'
    CASE fieldnm = 'media1'
      m.media1 = 'soil'
    CASE fieldnm = 'media2'
      m.media2 = 'water'
    CASE fieldnm = 'media3'
      m.media3 = 'air'
    CASE fieldnm = 'rem_phase1'
      m.rem_phase1 = 'characterization'
    CASE fieldnm = 'rem_phase2'
      m.rem_phase2 = 'extraction'
    CASE fieldnm = 'rem_phase3'
      m.rem_phase3 = 'treatment'
    CASE fieldnm = 'rem_phase4'
      m.rem_phase4 = 'disposal'
  ENDCASE
NDIF

* Write the new field contents at the designated coordinates.
@ x,y SAY m.&fieldnm
* Reassign pick to 0.
ick = 0
ETURN
*-----------------------------------------------------------------*
* This function converts all data entry to lower case.
UNCTION lcase
ARAMETER string
tring = LOWER(string)
ETURN
*-----------------------------------------------------------------*
* This procedure calls another program which defines fields
*   for the user.
ROCEDURE helpit
ARAMETERS mchoice
O CASE
  CASE mchoice = 1
    DO fieldhel IN c:\metc\database\prog\fieldhel.prg
NDCASE
ETURN
*
*-----------------------------------------------------------------*
 This function creates a region to add/edit memo fields.
UNCTION dispmemo
ARAMETERS check, addopt
avecan = 0
esno = 0

 Determine whether user wants to save changes before displaying
   the memo window.
EFINE WINDOW save FROM 0,0 TO 24,79
CTIVATE WINDOW save
 8,13 TO 14,64 COLOR SCHEME 7
 10,15 SAY "Do you want to save changes made in this record?"
 12,32 GET yesno FUNCTION '*H YES;NO'
```

```
READ CYCLE
DO CASE
  * Gather the changes before continuing to the memo screen
  *   if user chooses yes.
  CASE yesno = 1
    GATHER MEMVAR
    DEACTIVATE WINDOW save
  * Otherwise, continue to the memo screen without saving changes.
  CASE yesno = 2
    DEACTIVATE WINDOW save
ENDCASE

* If in add mode, scatter the data to a blank memory.
IF addopt = .T.
  SCATTER MEMO MEMVAR BLANK
* Otherwise, scatter the data to the requested memo field.
ELSE
  SCATTER MEMO MEMVAR
ENDIF

DEFINE WINDOW dispmemo FROM 0,0 TO 25,79 COLOR SCHEME 7
ACTIVATE WINDOW dispmemo
@ 1,31 SAY 'MEMO REQUESTED'

* Create a text editing region and push buttons.
@ 3,2 EDIT m.&check SIZE 18,75 SCROLL COLOR SCHEME 10
@ 22,32 GET savecan FUNCTION '*H SAVE;CANCEL'
READ CYCLE

* The SAVE/CANCEL buttons give the user the option to save
*   or disregard the changes to the memo.
DO CASE
  * If the user chooses SAVE, the memo data will be gathered.
  CASE savecan = 1
    GATHER MEMVAR MEMO
    DEACTIVATE WINDOW dispmemo
  * Otherwise, the changes to the memo field will be disregarded.
  CASE savecan = 2
    DEACTIVATE WINDOW dispmemo
ENDCASE
RETURN
*-------------------------------------------------------------------*
* This function will allow the user to add/edit pollutant or
*   media information.
FUNCTION addextra
PARAMETER medpoll,key
* Determine whether user wants to save changes before displaying
*   the memo window.
yesno = 0
DEFINE WINDOW save FROM 0,0 TO 24,79
ACTIVATE WINDOW save
@ 8,13 TO 14,64 COLOR SCHEME 7
@ 10,15 SAY "Do you want to save changes made in this record?"
@ 12,32 GET yesno FUNCTION '*H YES;NO'
READ CYCLE
DO CASE
  * Gather the changes before continuing to the memo screen
  *   if user chooses yes.
  CASE yesno = 1
    GATHER MEMVAR
```

```
    DEACTIVATE WINDOW save
  * Otherwise, continue to the memo screen without saving changes.
  CASE yesno = 2
    DEACTIVATE WINDOW save
ENDCASE

DO CASE
  CASE medpoll = 'ymedia'
    DO addmedia IN c:\metc\database\prog\addmedia.prg;
       WITH key,sacancel,addopt
  CASE medpoll = 'ypollut'
    DO addpollu IN c:\metc\database\prog\addpollu.prg;
       WITH key,sacancel,addopt
ENDCASE
RETURN
*------------------------------------------------------------------*
```

SITE REMEDIATION TECHNOLOGIES: DRAIN-ENHANCED SOIL FLUSHING (DESF) FOR ORGANIC CONTAMINANTS REMOVAL

Quarterly Technical ProgressReport
for Period April 1 through June 30, 1993

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Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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ABSTRACT

The effectiveness of the soil flushing process is limited by the extent with which the contaminant is extracted from the soil and solubilized in the flushing solution, and the ease with which the flushing solution moves through the contaminated soil. Generally, for fine grained soils, both the extraction of the contaminant from the soil and movement of flushing solution are less than that observed for large grained soils (i.e., sands). Thus, soil flushing is not always effective for remediating contaminated aquifers and the use of "pump and treat systems" on extremely long term basis is often required.

Prefabricated Vertical Drains (PVD) can be used to shorten the drainage path of the flow and therefore expedite the soil flushing process. Because the installation process is relatively simple and inexpensive, fluid extraction using this process can prove to be practical and cost-effective. Compared to conventional well fields and drains, the use of PV drains would expedite the contaminant recovery and reduce both labor and material costs.

Work conducted in this research investigates major parameters affecting the efficiency of contaminant extraction using PV drains. A single polycyclic aromatic hydrocarbon (PAH), in this case naphthalene ($C_{10}H_8$), is chosen as the study contaminant. Analysis to be conducted include naphthalene (by GC method 8100, USEPA, SW-846), and total organic carbon or chemical oxygen demand. The testing program include column and batch studies to estimate appropriate environmental and engineering parameters for the soils, contaminants, and surfactant under consideration. In addition, several pilot scale systems (Contaminant Recovery Cells, CRC) in which the recovery efficiency of the PV drains will be evaluated.

Literature review was conducted to investigate the existing theories dealing with applications of PVD and their applicability to the soil type to be used in the project. Laboratory work was conducted to evaluate the proper mix of the soil to be used in the testing program. Compaction tests according to ASTM 698D and permeability tests according to ASTM D5084 were conducted using blends of kaolinite and Ottawa sand. The blends consisted of 80/20 percent by dry weight sand to kaolinite. The average coefficient of permeability varied with the moisture content of the samples and was estimated to be on the order of 1×10^{-5} to 1×10^{-4} cm/sec. Based on the results of these experiments the blend to be used in the experiment will be 80/20 sand to kaolinite.

On-going testing program includes performance of batch isotherms and flexible wall soil flushing permeability tests to estimate appropriate environmental and engineering parameters for the soils, contaminants, and surfactants under consideration. In addition, several pilot scale tests using Contaminant Recovery Cells (CRC) are underway. The recovery efficiency of the PVD system will be evaluated from these tests. Analysis to be conducted include naphthalene (by GC method 8100, USEPA, SW-846), and total organic carbon or chemical oxygen demand.

A contact was established with the NILEX corporation, one of the largest installers of the PVD in the U.S. The Nilex Corporation indicated strong interest in the project and discussion is underway regarding their involvement as industrial partners. In addition to contaminant recovery, results from this research program will indicate the feasibility of using PVD system for collection and detection of leachate in cases where waste was placed in unlined areas. Furthermore, the feasibility of using the PVD system to deploy micro-organisms for in situ bioremediation will be postulated from the results of this research.

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1.0 INTRODUCTION

Recently, the United States Environmental Protection Agency (USEPA) evaluated the progress of 112 sites where groundwater extraction was an integral part of containment and/or restoration activities (USEPA 1989a,b,c). The majority of the 112 sites were contaminated with organic compounds. The type and concentration of these organic compounds were found to be extremely diverse. In general, chemicals such as TCE, creosote, and PCBs have been reported as contaminants of concern (USEPA 1989d). In addition to the variety of contaminants and concentrations that prevail at these sites, wide variations in soil type, geological formation, and hydrogeologic conditions exist. A "typical" contaminated soil is difficult to define and remediation measures are usually developed on a site-specific basis.

There are a number of approaches to remediation that are used at contaminated sites. Examples are in-situ bioremediation, vacuum or air stripping, immobilization, and soil washing/flushing. In the case of in-situ bioremediation, organic compound(s) are biochemically degraded within the contaminated subsurface. Air or steam stripping are feasible if the Henry's Law constant of the organic compound(s) is greater than 3×10^{-3} atm/m^3 mol. In the case of immobilization techniques, contaminants are tightly bounded within a solid matrix that minimizes their migration. Solidification, stabilization, and vitrification are the principal immobilization techniques. Contrary to immobilization, the soil washing/flushing approach promotes contaminant solubilization and migration in the liquid phase so that the contaminants can be easily flushed from the soil matrix. Soil washing refers to ex-situ remediation of soils whereas soil flushing refers to in-situ extraction of contaminants (i.e., pump and treat technology). Considering all remediation approaches, only soil flushing and stripping remove contaminant(s) from the contaminated zone without excavating the soil. Of these two, soil flushing is the process of investigation in this research proposal.

The effectiveness of the soil flushing process is limited by the extent that the contaminant is extracted from the soil and solubilized in the flushing solution, and the ease with which the flushing solution moves through the contaminated soil. Generally, for fine grained soils, both the extraction of the contaminant from the soil and movement of flushing solution are less than that observed for large grained soils (i.e., sands). Thus, soil flushing is not always effective for remediating contaminated aquifers and the use of "pump and treat systems" on extremely long term basis is often required.

The improvement of flushing solution movement in low permeability soils (10^{-4} to 10^{-7} cm/s) is the subject of this research proposal. Specifically, the use of Prefabricated Vertical Drains (PVD), also referred to as wick drains, to decrease the flow path and travel time between flushing solution injection and extraction points will be investigated. The development of improved flushing agents (e.g., surfactant) is not within the scope of this proposal. Rather, several flushing agents will be selected based on literature and manufacturers' information and their effectiveness in extracting contaminants from soils will be evaluated in the laboratory. The most effective extracting agent(s) will then be employed to demonstrate the feasibility of using PV drains to improve the soil flushing process.

A creosote contaminated site has been selected as the object of remediation. The chemical composition of creosote is approximately 85 percent polycyclic aromatic hydrocarbons (PAHs), 10 percent phenolic compounds and 5 percent others (N, S, and O heterocyclic compounds). Thus, a single PAHs will be used as the study contaminant. Naphthalene will be used as the study contaminants.

In summary, the proposed research has as its objective the completion of the following three phases of study:

Phase 1:	Quantifying the parameters that govern the release and transport of PAHs by and through the subsurface.
Phase 2:	Development of a predictive mathematical model to simulate full-scale operation of PV drain-enhanced soil flushing systems.
Phase 3:	Operation of a mesoscale pilot facility to investigate the performance of the PV drain-enhanced soil flushing technique and to calibrate the predictive model.

Specific tasks for each phase of the research program are discussed in the Investigative Approach section of this proposal.

2.0 BACKGROUND

In this section background information on the conventional soil flushing system, the use of PV drains to improve liquid movement in the subsurface, and how PV drains will be used to improve the soil flushing system, will be presented. Because the focus of this research is on improving the movement and extraction of the flushing solution through the contaminated zone, the literature review will focus on liquid and mass transport in the subsurface. However, a brief discussion on PAHs contaminated sites, and the fate of PAHs in the subsurface (adsorption, desorption, biodegradation, and volatilization) is included.

2.1 Soil Flushing as a Remediation Technique

In soil washing/flushing water is the primary washing fluid; chemical additives are carried by the water to promote contaminant solubilization. Non-ionic and ionic surfactant, acids, and solvents are examples of chemical additives. While soil flushing is the focus of this research, much information can be gained by examining the effectiveness of chemical additives in extracting soil-bound contaminants in the soil washing process. Soil washing refers to the ex-situ remediation of soils, whereas soil flushing refers to the in-situ extraction of contaminants. Use of these two methods has been limited. However, of these two methods, there has been a greater amount of study conducted on soil washing systems, especially in Europe (USEPA, 1988a).

The conventional soil flushing process involves a number of steps. Each step must be considered separately when assessing the overall effectiveness. The four steps are:

1) contaminant solubilization by the wash fluid (surfactant),
2) extraction of the solubilized contaminants from the subsurface,
3) treatment of the spent flushing water, and,
4) disposal/reuse of the treatment residuals.

A general schematic of the first two steps, which defines the scope of this proposed investigation, is shown in Figure 1 (Holden et al. 1989). Conditions adversely affecting the success of soil flushing process are listed in Table 1. Hydrogeologic conditions of the contaminated area are extremely important to the success of the soil flushing process. USEPA (1988b) reported that soil flushing has been used at five Superfund sites for the removal of organics. The permeability of the soils at these sites was relatively high. Currently, the soil flushing option is difficult to implement at sites with low permeabilities.

Table 1. Characteristics Affecting the Soil Flushing Process

Characteristics	Reason for Potential Impact
Unfavorable Waste Characteristics Mixed waste types Variable Waste Composition	Washing solution difficult to formulate Frequent formulation of washing solution
Unfavorable Soil Characteristics Variable soil conditions Low permeability High soil humic content Soil-solvent interactions	Inconsistent flushing Movement of flushing solution hampered Desorption difficult Desorption inhibition
Unfavorable Flushing Solution Characteristics Difficult recovery of washing solution Poor treatability of washing solution Toxicity of washing solution Reduction of soil permeability	 High costs Replacement of washing solution Health risks Flushing chemicals reduce porosity.

Source: Technology Screening Guide for Treatment of CERCLA Soils and Sludges, U.S. EPA, 1988.

2.2 PV Drains and Subsurface Liquid Movement

Prefabricated vertical (PV) drains, also referred to as wick or strip drains, were originally developed as a substitute for the commonly used sand drains. They have been used extensively in the past for the expedient drainage and consolidation of low permeability soils under surface surcharge. The design of prefabricated vertical drains varies according to a specific application. Key parameters usually addressed in the design include:

1. Equivalent diameter of the drain which dictates the size of the inflow surface; and,
2. Discharge capacity of the drain .

As described by Anon (1988) PV drains consist of porous geotextiles wrapped around a plastic drainage core 3 to 4 inches wide and one quarter to 3/8 of an inch thick. PV drains are usually spaced in a manner to allow the dissipation of pore pressure generated due to the application of surcharge or hydraulic stresses on the system. They provide a conduit for flow under the induced hydraulic gradient. Typically they are arranged in a triangular or square grid pattern with 3 to 12 feet spacing. Installation rates reported in the literature are on the order of 1-3 feet per second excluding equipment mobilization and set-up time. Figure 2 illustrates the installation process of a typical PV drain configuration in a field situation.

The use of synthetic PV drains has evolved to many applications and several case studies were reported in literature. A theoretical study pertaining to the design and application of vertical drainage systems was conducted by Guido (1986). Recommendations for the selection of design spacing for band-shaped PV drains were examined. A comprehensive research program was carried out by New York State Department of Transportation (Suits et al 1986) to estimate the effectiveness of several types of PV drains. This research program included laboratory and field testing. Results indicated the suitability of using PV drains to accelerate the drainage of a given soil profile.

A successful implementation of PV drains was presented by Mattox (1987). In this project, construction of a 21.7 ft high embankment over weak marsh deposits in Mobile, Alabama, was accomplished through the use of geogrid reinforcing and PV drains. Installation of PV drains was necessary to reduce the time required for settlement of the embankment through accelerated drainage of the subsurface profile. Estimated savings due to the use of the innovative drainage technology was on the order of $600,000. In another application, Thacker et al (1988) presented a case in which PV drains were used in the construction of a coal refuse impoundment to allow complete pore pressure dissipation. Field measurements with pneumatic piezometers indicated that the use of PV drains in the drainage scheme was successful. The coal refuse impoundment met prudent engineering criteria with regard to stability even though a large portion of the dam was being built over hydraulically filled fine coal refuse. In a similar application, Saye et al (1988) presented a case in which PV drains, installed at spacing ranging from 3 feet to 5.5 feet, were used in order to facilitate drainage and strength gain of soft highly plastic clay deposited in a cutoff oxbow of the Missouri River.

In general, research work conducted to quantify the performance of the PV drains is mostly directed toward the drainage potential to accelerate the consolidation process, or compression of a soil profile due to expulsion of water. No research specifically addressed the quantity of flow being collected using a PV drainage scheme. Furthermore, no research was conducted to address the potential of using a PVD drainage scheme for the removal of pollutant substances from subsurface soils.

However, some research was conducted on the retrieval of tracers in agricultural applications through the use of subsurface drains. Everts and Kanwar (1990) presented the results of a study in which potassium bromide and calcium nitrate were used as tracers in sprinkler irrigation water. These tracers were applied to a field plot drained with a single subsurface drain line during two irrigations. Drain outflow was measured, and water samples were collected from drain discharge and analyzed for Nitrate (No^{-3}) and Bromide (Br^{-}) content. Results indicated that, transported on a mass basis, 24% and 12% of the bromide and 20% and 9% of the nitrate reach the drain, respectively, during the two sprinkler irrigations. Although not directly related to the scope of the proposed work, the results of this study indicates the promising potential of using subsurface drains for collecting subsurface pollutants.

In summary, PV drains shorten the drainage path of the flow and therefore would expedite the soil flushing process. Compared to conventional well fields and drains, the use of PV drains would reduce both labor and material costs. Because the installation process is relatively simple and inexpensive, fluid extraction using this process can prove to be practical and cost-effective. Figure 3 schematically shows a possible arrangement for the use of PVD system for recovery of subsurface pollutants in the field.

2.3 Examples of PAHs Contaminated Sites

There are over 2000 wood preserving sites in the United States requiring remediation with over 50 of these sites on the National Priority List (NPL), Stinson et al. (1991). The MacGillis and Gribbs Superfund site in New Brighton, Minnesota, is heavily contaminated with creosote, pentachlorophenol, and fuel oil. PAH concentrations as high as 407 mg/kg have been reported (Stinson et al. 1991). PAH concentrations of 2,800, 240, and 10 mg/kg for peat, soils, and sediments, respectively, have been reported at the Pine Street Canal Superfund site in Burlington, Vermont, (Weir and McLane 1991). Christiansen et al. (1991) reported PAH concentration exceeding 1900 mg/kg at an undisclosed Texas site. PAH concentrations exceeding 3,000 mg/kg and 20,000 mg/kg have been reported at the Bayou Bonfouca (Slidell, Louisiana) and the Jennison-Wright (Granite City, Illinois) sites, respectively, as stated by Halloran et al. 1991. In examining contaminated sites, a wide variety of PAHs (and other organic contaminants) are present in widely ranging concentrations. Thus, remediation research must address diverse conditions. However, because the main focus of this research project is the improvement of the liquid movement phenomenon of the soil flushing process, relatively simple PAHs (e.g., naphthalene) will be chosen as the study organics. It is tacitly assumed that the PV drain-enhanced soil flushing method will improve the efficiency of the pump and treat process regardless of the specific organic contaminant(s).

2.4 Use of Surfactant to Remove Soil-Bound Organics

Surfactant molecules have both a polar (hydrophilic) and nonpolar (hydrophobic) segment and thus they accumulate at polar-nonpolar interfaces. Above a certain concentration surfactant will form micelles (aggregates). The polar end of the molecule in the micelles is presented to the aqueous phase. The nonpolar end of the surfactant molecule faces inward, away from water molecules. The interior of the surfactant micelles is nonpolar and thus can solubilize nonpolar compounds that are sorbed onto soil particles. A large number of commercial surfactant that are environmentally safe and relatively inexpensive are available. Surfactant types can be categorized as ionic (anionic, cationic), nonionic, and amphoteric. Examples of surfactant and their characteristics are presented in Table 2 (USEPA 1985).

Table 2. Surfactant Types

Anionic	Cationic	Non-ionic	Amphoteric
Carboxylic acid salts	Long chain amines	Alcohol ethoxylates	pH sensitive
Sulfonic acid salts	Quaternary ammonium salts	Polyoxyethylenated alkylphenols	pH insensitive

The use of surfactant was first investigated by the Texas Research Institute (1979, 1985) as a method of recovering gasoline. Ellis et al. (1985) investigated the use of nonionic surfactant for removal of PCBs, chlorinated phenols, and petroleum hydrocarbons from soils. At surfactant concentrations of 1.5 percent (by volume) over 90 percent of the contaminants were removed from the soil. The use of surfactant increased removal by an order of magnitude over that observed for a water-only flush. A possible drawback to using nonionic surfactant in the soil flushing process is the difficulty encountered in separating the surfactant from the contaminated groundwater and subsequent surfactant reuse. Nash (1987) investigated surfactant enhanced soil flushing at the lab and field-scale using soil from the Volk Air National Guard Base, Wisconsin. Significant removal of organics in the lab-scale systems was reported. However, organic removal in the field-scale systems was less than that observed in the laboratory. The decrease in organic removal was attributed to the surfactant not penetrating the soil.

Liu et al. (1991) investigated the solubilization of several PAHs (anthracene, phenanthrene, and pyrene) by nonionic and anionic surfactant. Nonionic surfactant octyl- and nonyl-phenylethoxylates (9 to 12 ethoxylate units) were the most effective. A 1 percent (by volume) surfactant dosage was required to achieve 70-90 percent solubilization. Fountain and Hodge (1992) reported that several surfactant were able to increase the solubility of common chlorinated organics (e.g., perchloroethylene (PCE)) by several order of magnitudes. They also reported that, for PCE, several surfactant lowered interfacial tension between water and PCE to less than 1 dyne/cm causing downward vertical movement of the PCE. Thus, proper selection of surfactant mixtures is required if spreading of the contaminant downwards towards uncontaminated soils is to be minimized.

Dworkin et al. (1988) and Kuhn and Piotek (1989) reported favorably on the use of soil flushing for wood preserving contaminated sites. The relationship between the amount of contaminant that is solubilized and the surfactant concentration is approximately linear provided that the surfactant concentration is above the "critical" micelle concentration (CMC) as described by Gannon et al. 1989. At surfactant concentrations below the CMC contaminant solubilization does not occur. Gannon et al. (1989) reported that the CMC may be substantially reduced by the presence of a hydrophobic contaminant. However, Liu et al. (1991) reported that the solubilization of several soil-bound PAHs occurred at surfactant concentrations that were larger than the "clean-water" CMC.

In summary, a great deal of research on the development and use of surfactant to remove organic compounds from soils has been conducted. Based on results from lab-scale studies as well as full scale remediation systems, the use of surfactant in the remediation of contaminated soils appears to be promising. As mentioned previously, the focus of this research is not the development of improved surfactant but rather the improvement of the movement of the flushing solution through the contaminated zone. Thus, surfactant, such as those presented in Table 2, will be selected based on literature and manufacturers' information. Their effectiveness in extracting contaminants from soils will be determined in the laboratory and the most effective and environmentally safe agents(s) will then be employed in the demonstration of the PV drains enhanced soil flushing process.

2.5 PAH Adsorption and Desorption, Degradation, and Volatilization

The fate of contaminants in the subsurface is influenced by the extent with which the contaminant adsorbs and desorbs, degrades, and volatilizes. Each of these topics will be discussed separately. The majority of the review focuses on adsorption and desorption because during the conduct of the proposed research, steps will be taken to minimize degradation and volatilization.

2.5.1 Adsorption and Desorption

PAHs, the study contaminant, readily accumulates on soil particles. The concentration of the soil-bound contaminant can be related to the solution concentration through a number of isotherms (Freundlich, Langmuir, and B.E.T). In this study it is assumed that the soil has been contaminated thus, adsorption of the PAH will not be examined to a large extent. However, the adsorption of the surfactant-PAH onto clean soil will be investigated. It is conceivable that the contaminated flushing solution will pass through areas of the subsurface that are not contaminated and thus, it is possible that readsorption can occur. Desorption or solubilization of the contaminant from the soil in the presence of surfactant will be studied.

2.5.2 Biodegradation

A large number of organic compounds are subject to biochemical degradation. Biological treatment of contaminated sites has been named as the remediation technique in about 15 percent of the Records of Decision (ROD) (Christiansen et al. 1991). Naphthalene, the simplest PAH, is considered relatively degradable with a BOD5/COD ratio of < 0.2 (USEPA 1985). Christiansen et al. (1991), reported that the half-lives of total and carcinogenic PAHs in a soil-sludge slurry reactor were between 16 and 88 days. Weir and McLane (1991) reported that PAHs of low molecular weight (e.g., naphthalene and 2-methylnaphthalene) were biodegradable in soils, but higher weight PAHs were not. Berg et al. (1991) demonstrated that the composting of PAH contaminated soils was a viable treatment alternative. Total PAH soil concentration was decreased from approximately 300 mg/kg to less than 50 mg/kg in 14 weeks. Thus, it is apparent that PAHs, especially those with lower molecular weights, are susceptible to biochemical degradation. Measures to deter or account for biodegradation in laboratory experiments will be implemented.

2.5.3 Volatilization

PAHs are classified as semivolatile and generally have a Henry's constant lower than 10^{-4} atm/m^3 mol. Organic compounds having a Henry's constant greater than 3×10^{-3} atm/m^3 mol are candidates for air stripping (Holden et al. 1989). While volatilization of PAHs is possible, transfer of the contaminant to the gas phase is not an efficient process. However, during the conduct of this research, the loss of PAHs from the soil via volatilization will be accounted for by using a controlled experiments environment.

3.0 METHODOLOGY

The proposed research plan is the first phase of five year plan during which the major parameters affecting the efficiency of contaminant extraction using PV drains will be quantified, pilot scale study is performed and the project can move to field implementation. The research program for the current phase consists of column and batch studies to determine appropriate environmental and engineering parameters for the soils, contaminants, and surfactant under consideration. These experiments will be conducted during year one along with several pilot scale systems (Contaminant Recovery Cells, CRC) in which the recovery efficiency (hydraulic only) of the PV drains will be evaluated for uncontaminated soils.

3.1 Laboratory Testing

During the first year of the project, laboratory studies will be conducted to ascertain fundamental parameters of the soils, contaminant and surfactant. In addition, fundamental parameters of the recovery system will be evaluated. Laboratory work was conducted to evaluate the proper mix of the soil to be used in the testing program. A single polycyclic aromatic hydrocarbon (PAH), in this case naphthalene ($C_{10}H_8$), is chosen as the study contaminant. Preliminary laboratory work is conducted to evaluate the proper mix of the soil to be used in the testing program. Based on the results of compaction tests according to ASTM 698D and permeability tests according to ASTM D5084 a soil blend consisting of 80/20 percent by dry weight sand to kaolinite will be used.

On-going testing program includes performance of batch isotherms and flexible wall soil flushing permeability tests to estimate appropriate environmental and engineering parameters for the soils, contaminants, and surfactant under consideration. In addition, several pilot scale tests using Contaminant Recovery Cells (CRC) are underway. The recovery efficiency of the PVD system will be evaluated from these tests. Analysis to be conducted include naphthalene (by GC method 8100, USEPA, SW-846), and total organic carbon or chemical oxygen demand. Compaction tests according to ASTM 698D and permeability tests according to ASTM D5084 were conducted using blends of kaolinite and Ottawa sand to select the appropriate soil mix for use in the experiments.

3.1.1 Batch Isotherms

Batch isotherm studies are performed in order to evaluate the effectiveness of surfactant for contaminant removal from soil surfaces. A testing program was conducted to evaluate the solubilization of $C_{10}H_8$ using the study surfactant. Anionic aqueous solution of sodium dodecylsulfate (SDS) was chosen as the study surfactant. The anionic surfactant is negatively charged which will assist in minimizing sorption to the negatively charged kaolinitet particles.

Batch tests were conducted using surfactant concentrations of 0 to 0.5 M. The analysis was conducted using an HP Series II Gas Chromatograph (GC) with a capillary column and flame ionized detector. Solubilization as a function of naphthalene concentration as shown in Figure 4. As the SDS molarity increased the solubility of the naphthalene increased with a near linear relationship. This is due to the fact that the surfactant (its molecules are composed of hydrophobic and hydrophilic regions) forms micelles which solubilize with the hydrophic naphthalene compound. Naphthalene solubility of 500 mg/l was measured for SDS concentration of 0.05 Mol and approximately 3300 mg/l for SDS concentration of 0.5 Mol.

A suite of tests will be performed resulting in a matrix consisting of surfactant type and concentration, and soil contact time versus percent of contaminant removed from the soil. This information will lead to the selection of a surfactant for application in the column studies and in the contaminant recovery cells. Soils will be contaminated with Naphthalene by dissolving Naphthalene in Methanol, mixing the solution with soil, and allowing Methanol to evaporate. The initial soil/Naphthalene concentration will then be determined.

Equilibrium isotherms will be estimated for the adsorption of naphthalene on the study soil. Also, re-adsorption of naphthalene, in the presence of the SDS surfactant, by the clean soil will be assessed.

3.1.2 Column Studies

A series of column studies were conducted on clean soil with water and with surfactant solution to evaluate the hydraulic properties of the study soil. Clean soil studies will be used to obtain permeability characteristics of the soil types both for water and for surfactant as permeating liquids. Similar tests are underway for contaminated soil. The studies on contaminated soil columns will be used to ascertain the effectiveness of the SDS surfactant in removing contaminants under a flow type situation and estimate the dispersion/advection characteristics of the system.

Sample preparation for the columns study was as follows:

1. Samples were prepared from a mixture of 80% ottawa sand and 20% kaolinite.

2. Sieve analyses were conducted as a baseline to check the final integrity of the soil upon completion of a test.

3. Samples were compacted using standard proctor according to ASTM 698D. The samples were prepared at water content range of ion will be done at a water content of approximately 6% to 11% to achieve a permeability on the order of $1\text{x}10^{-5}$ cm/sec.

4. Flow tests are conducted to a duration necessary to provide discharge of minimum of 5-7 pore volumes of permeant fluid.

Figure 5 (a and b) shows the variation of permeability as a function of effluent pore volume. The flexible wall permeability test was conducted according to ASTM 5084 standards. The molding moisture content plays a significant role in controlling the density, and therefore the permeability, of the compacted soil. This can be explained by the diffuse double layer theory. At low water content, clay particles develop flocculated structures which lead to low compaction density. As the water content is increased, the structure of the soil matrix tend to disperse and high compaction densities are achieved.

The relationship between compaction density and water content for the study soil is shown in Figure 6. Maximum density of approximately 125 pcf was achieved at a moisture content of 9.5%. The variation of the permeability as measured from the flexible wall test, as a function of the molding water content is shown in Figure 7. Soils compacted dry of optimum tend to have high permeability while soils compacted wet of optimum tend to have low permeability. Measured permeabilities for the study soil decreased from $3\text{x}10^{-4}$ for water content of 7% to approximately $2\text{x}10^{-5}$ for molding water content of 11%.

Figure 8 shows the effect of surfactant on the permeability characteristics. In this case, permeability tests were performed using water as a permeant and then SDS solution with concentrations between 0.0022 and 0.008 Mol. The introduction of the SDS solution resulted in reduction of the permeability value. At this time, it is speculated that this effect is due to the change in the viscosity of the permeant fluid. More investigation and tests are underway to ascertain the effect of the SDS on the hydraulic behavior of the study soil.

3.1.3 Procedure for Soil Extraction

The extractor procedure outlined below is based on EPA Method 3540 Soxhlet Extraction. Due to financial considerations and the scope of this project, minor alterations have been made to accommodate the University laboratory.

Materials:

Soxhlet Extractor: 37mm ID, with 250ml boiling flask and Allihn condenser (the cooling fluid will be the laboratory supplied cold water).

Kuderna-Danish Apparatus:
Concentrator Tube: 10ml graduated, with ground glass stopper.
Evaporator Flask: 250ml
Snyder Column: Three ball macro.
Boiling Chips: PTFE, 10/40 mesh.

Water Bath: Temp controlled bath under hood.

Paper Thimbles: 33mm x 80mm cellulose.

Reagents:

Distilled Water: Laboratory supplied.

Sodium Sulfate: Granular Anhydrous.

Methylene Chloride: Pesticide grade.

Methanol: Pesticide grade.

Methods:

1. Mix 10g of sample with 10g of anhydrous Sodium Sulfate and place in the extractor thimble.
2. Place 175ml of Methylene Chloride into a 250ml boiling flask with boiling chips and attach to the Soxhlet extractor.
3. Attach an Allihn condenser to the extractor and install the cold water lines to the hose barbs.
4. Heat the solvent and allow to extract for 16 hrs.
5. After the extract has cooled, place the remaining solvent in to a Kuderna-Danish (K-D) concentrator.
6. Prewet the Snyder column with approx. 1ml of Methylene Chloride.

7. Place the concentrator in a water bath and allow the extract to evaporate until the volume left is 1ml. The temperature should be adjusted so this takes 15 min.
8. Remove the K-D concentrator from the bath and allow to cool.
9. Adjust the volume if necessary with Methylene Chloride to 2ml.

3.1.4 Contaminant Recovery Cells

Three contaminant recovery cells (CRC's) were constructed and are currently used to assess the efficiency of the PV drain contaminant recovery system. The CRC's include a central section (0.67m X 0.67m X 1.0m - length/thickness/depth of soil) which is filled with the study soil. An upstream reservoir supply a base inflow into the soil while the downstream reservoir collect the base outflow. The reservoirs are used to pre-saturate the soil and to apply a constant base flow during water and contaminant recovery tests. For contaminant recovery purposes, PV drains will be installed into the soil. In order to quantify recovery efficiency, single and multiple drains will be used. Two systems of fluid recovery will be evaluated. These include applying a vacuum to the drains and applying a stress on the surface of the soil. Both systems provide a driving force for fluid transport from the soil.

A list of the CRC's and associated test parameters is given in Table 3. Drain efficiencies for the removal of fluids from the soils will be quantified. The time required for construction and preparation of the cells including saturation of the soils is expected to be on the order of two to three months.

Table 3. Contaminant Recovery Cells and Operating Parameters

CELL No.	% SAND/ KAOLINITE	No. DRAINS	CONTAMINANT RECOVERY	
			VACUUM (psi)	APPLIED PRESSURE (psi)
			10	2 - 10
1	80/20	1	It is estimated that each recovery step will require 2-3 months	
2	80/20	2		
3	80/20	MULTIP		

The three CRC are constructed and are in operation. Figure 9 shows a picture of one of the cell. Integrity testing was conducted to confirm that the cells are leak-proof. Bentofix (clay/geotextile mating) was used as lining material to minimize side wall leakage. Soil samples were compacted in the CRC's and dye was introduced to trace the flow path. No side wall leakage was observed. Saturation of the soil samples in the CRC's took approximately six weeks to complete.

Figure 10 shows the distribution of the in-place density measured using the sand cone test. The uniformity of density distribution increased as work crew gained experience with mixing and preparing the soil samples. At this stage of the research it was decided that a density on the order of 110 pcf is desirable in order to allow the installation of the PVD with minimum disturbance. Therefore, and as shown in Figure 10, the molding water content was increased in preparing the sample for CRC #3 in order to achieve the target density of 110 pcf. The permeability values measured from the CRC's are indicated on Figure 7. The permeability values measured from the CRC's show an excellent agreement with the values evaluated from the flexible wall column. Permeability values measured from the CRC's are on the order off $5\mathrm{x}1^{-5}$ cm/sec.

4.0 Liquid Retrieval Using PVD: Model Development

Analysis techniques for performance evaluation of the PVD focus on the ability to induce consolidation and therefore accelerate the rate of settlement at a given site with soft clay soils. However, the use of PVD for this project is to improve the soil washing process through the efficient retrieval of subsurface liquid in fine grained soils that may contain appreciable amount of cohesionless material. As shown in Figure 12, the installed PVD has a zone of influence with a radius r_{eq}. The governing differential equation for the solute transport assuming full saturation and no decay:

$$\frac{\partial C}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}(D_r r\frac{\partial C}{\partial r}) + D_z\frac{\partial^2 C}{\partial z^2} - \frac{1}{r}\frac{\partial}{\partial r}(\frac{r\ v_r C}{n}) - \frac{1}{n}\frac{\partial}{\partial z}(v_z C) - \frac{1}{n}\frac{\partial(\rho_d K_d C)}{\partial t} \tag{1}$$

where:

C= concentration
r =equivalent radius
D_r and D_z = coefficient of vertical and radial dispersion: f(v_r and v_z)
v_r and v_z= radial velocity and vertical velocity
k_d=equilibrium distribution coefficient
ρ_b = bulk density
n= porosity of soil

Analytical solution of above second order, four-variable partial differential equation is as follows: Based on Carribo's solution (1952) for a similar model, C can be expressed as:

$$C(z,r,t)=C_z(z,t)\cdot C_r(r,t)=C_z\cdot C_r \ldots\ldots \tag{2}$$

$$\frac{\partial C}{\partial t}=C_z(z,t)\frac{\partial C_r(r,t)}{\partial t}+C_r(r,t)\frac{\partial C_z(z,t)}{\partial t}=C_z\frac{\partial C_r}{\partial t}+C_r\frac{\partial C_z}{\partial t} \ldots\ldots \tag{2.1}$$

$$\frac{\partial^2 C}{\partial z^2}=C_r\frac{\partial^2 C_z}{\partial z^2} \qquad (2.2)$$

$$\frac{\partial C}{\partial r}=C_z\frac{\partial C_r}{\partial r} \qquad (2.3)$$

$$\frac{\partial(r\frac{\partial C}{\partial r})}{\partial r}=C_z\frac{\partial(r\frac{\partial C_r}{\partial r})}{\partial r} \qquad (2.4)$$

$$\frac{\partial(rC)}{\partial r}=C_z\frac{\partial(rC_r)}{\partial r} \qquad (2.5)$$

$$\frac{\partial C}{\partial z}=C_r\frac{\partial C_z}{\partial z} \qquad (2.6)$$

Substituting equations above into Eq.1:

$$(1+\frac{\rho_d K_d}{n})(C_r\frac{\partial C_z}{\partial t}+C_z\frac{\partial C_r}{\partial t})=\frac{D_r}{r}C_z\frac{\partial(r\frac{\partial C_r}{\partial r})}{\partial r}+D_z C_r\frac{\partial^2 C_z}{\partial z^2}-\frac{v_r}{nr}C_z\frac{\partial(rC_r)}{\partial r}-\frac{v_z}{n}C_r\frac{\partial C_z}{\partial z} \qquad (3)$$

i.e.:

$$C_r(\frac{\partial C_z}{\partial t}-\frac{D_z n}{n+\rho_d K_d}\frac{\partial^2 C_z}{\partial z^2}+\frac{v_z}{n+\rho_d K_d}\frac{\partial C_z}{\partial z})=C_z(\frac{\partial C_r}{\partial t}-\frac{D_r n}{n+\rho_d K_d}\frac{1}{r}\frac{\partial(r\frac{\partial C_r}{\partial r})}{\partial r}+\frac{v_r}{n+\rho_d K_d}\frac{1}{r}\frac{\partial(rC_r)}{\partial r}) \qquad (4)$$

Equation (4) can be separated to two equations(Eq.5 and Eq.6) as follows:

$$\frac{\partial C_z}{\partial t}=\frac{D_z n}{n+\rho_d K_d}\frac{\partial^2 C_z}{\partial z^2}-\frac{v_z}{n+\rho_d K_d}\frac{\partial C_z}{\partial z} \qquad (5)$$

with initial and boundary condition:

$$\begin{aligned} &C_z(z,0)=C_{z0}, && z\geq 0 \\ &C_z(0,t)=0, && t>0 \\ &C_z(\infty,t)=0, && t>0 \end{aligned} \qquad (5\alpha)$$

And,

$$\frac{\partial C_r}{\partial t}=\frac{D_r n}{n+\rho_d K_d}\frac{1}{r}\frac{\partial\left(r\frac{\partial C_r}{\partial r}\right)}{\partial r}-\frac{v_r}{n+\rho_d K_d}\frac{1}{r}\frac{\partial(rC_r)}{\partial r} \qquad (6)$$

with initial and boundary condition:

$$\begin{aligned} &C_r(r,0)=C_{r0}, && r\geq r_0 \\ &C_r(r_0,t)=C_{r_0}, && t>0 \\ &C_r(\infty,t)=0, && t>0 \end{aligned} \qquad (6\alpha)$$

Using Laplace Transformation and Laplace Inverse Transformation as described by Marino (1974a) Eq.5 can be solved utilizing initial conditions and boundary conditions as follows:

$$C_z(z,t)=\frac{C_{z0}}{2}\left[1-erfc\left(\frac{z-\frac{v_z t}{n+\rho_d K_d}}{2\sqrt{\frac{D_z n t}{n+\rho_d K_d}}}\right)\right] \qquad (7)$$

where

$$erfc(x)=\frac{2}{\sqrt{\pi}}\int_x^{\infty}e^{-\xi^2}d\xi \qquad (8)$$

For Eq.6, if neglecting the spreading of element of pollutant (Raimondi, 1959), following equation can be obtained:

$$\frac{\partial C_r}{\partial t}=\frac{D_r n}{n+\rho_d K_d}\frac{1}{r}\frac{\partial(\frac{\partial C_r}{\partial r})}{\partial r}-\frac{v_r}{n+\rho_d K_d}\frac{1}{r}\frac{\partial C_r}{\partial r}\ldots\ldots \qquad (9)$$

Similar form of Equation 9 has been discussed by Bear (1972) and Tang and Babu (1979). Using Laplace Transformation and utilizing initial and boundary conditions, a solution for Eq.9 is as follows:

$$C_r(r,t)=C_{r0}-C_{r_0}\frac{erfc(h)}{erfc(h_0)}\ldots\ldots \qquad (10)$$

where

$$h=\frac{\frac{r^2}{2}-\frac{v_r t}{n+\rho_d K_d}}{\sqrt{\frac{4}{3}\frac{D_r n r^3}{v_r}}}\ldots\ldots \qquad (11)$$

and

$$h_0=\frac{\frac{r^2}{2}-\frac{v_{r_0} t}{n+\rho_d K_d}}{\sqrt{\frac{4}{3}\frac{D_r n r_0^3}{v_r}}}\ldots\ldots \qquad (11\alpha)$$

Substituting Eq.7 and Eq.10 into Eq.2:

$$C(z,r,t)=C_z(z,t)\cdot C_r(r,t)=\frac{C_{z0}}{2}[1-erfc(\frac{z-\frac{v_z t}{n+\rho_d K_d}}{2\sqrt{\frac{D_z n t}{n+\rho_d K_d}}})][C_{r0}-C_{r_0}\frac{erfc(h)}{erfc(h_0)}]\ldots\ldots \qquad (12)$$

h, h_0 and function erfc are expressed by Eq.11, 11a and 8. The movement of the subsurface liquid for retrieval can be induced using applied surface surcharge or injection and vacuum system. The theoretical model to estimate the maximum discharge (q_{max}) to be recovered from the PVD in clay under surface surcharge is as follows:

$$q_{max} = \pi r^2_{eq} \; dU/de \; L \; \varepsilon \tag{13}$$

$$U = 1 - \exp^{-} \frac{2T_R}{f(n)} \tag{14}$$

$$F(n) = \frac{n^2}{(n^2 - 1)} \ln(n) - \frac{3n^2-1}{4n^2} \tag{15}$$

where:
U= average degree of consolidation
ε = strain due to consolidation
Cr= coefficient of radial consolidation
n = r_{eq}/r_{st}

Modeling of the vacuum system can be achieved using the theory of wells. This effort is currently underway and is a part of the ongoing effort on model development.

5.0 CONCLUSIONS

In summary, the proposed work is progressing on budget and on time. Literature review was conducted to investigate the existing theories dealing with applications of PVD and their applicability to the soil type to be used in the project. More laboratory tests are planned to estimate the physical and engineering properties of the test soil including Atterberg Limits, grain size distribution and compressibility characteristics. In parallel, columns and the recovery cells are being performed to characterize the mobility of the study contaminant and analyze the contaminant-soil interaction.

A contact was established with the NILEX corporation, one of the largest installers of the PVD in the U.S. The Nilex Corporation indicated strong interest in the project and discussion is underway regarding their involvement as industrial partners. In addition to contaminant recovery, results from this research program will indicate the feasibility of using PVD system for collection and detection of leachate in cases where waste was placed in unlined areas. Furthermore, the feasibility of using the PVD system to deploy micro-organisms for in situ bioremediation will be postulated from the results of this research.

While major strides in the hazardous waste management field have been made in minimizing the risks associated with the disposal of wastes being generated, hundreds of inactive and/or abandoned hazardous waste sites exist that require remediation. The required remediation approach varies from site to site, depending on the hazardous constituents and site conditions present. The proposed study is an initial step in what will be a continuing effort to develop an in situ method, namely PV drain-enhanced soil flushing, to remove PAHs and other organic compounds from the contaminated subsurface. Because there is little or no experience with using PV drains as part of the soil flushing process, the proposed study will provide fundamental and basic information on performance characteristics of the DESF process as a mean of removing contaminants from sites containing fine grained soils.

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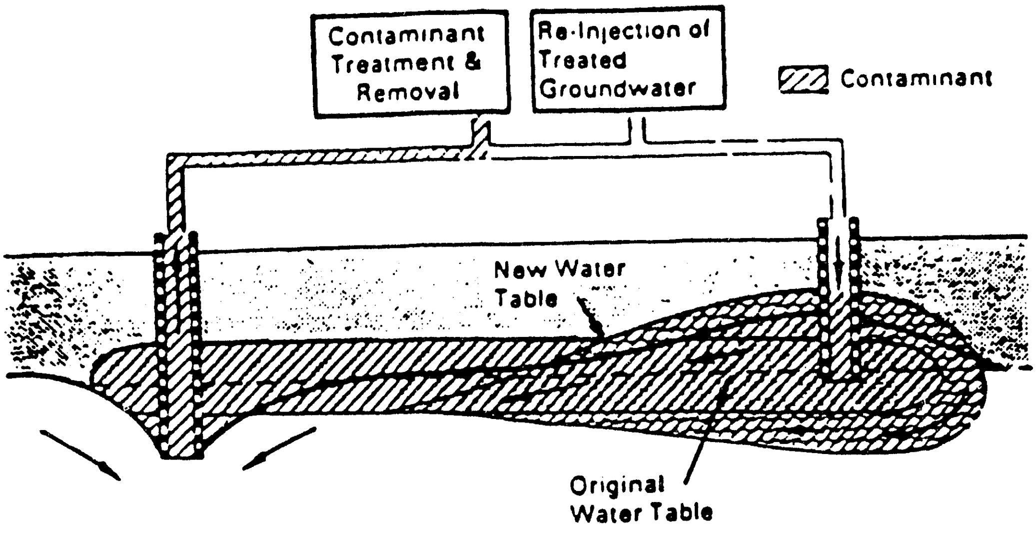
FIGURES



Source: EPA/540/2-86/003(f)

Figure 1. Schematic of Conventional Soil Flushing Process

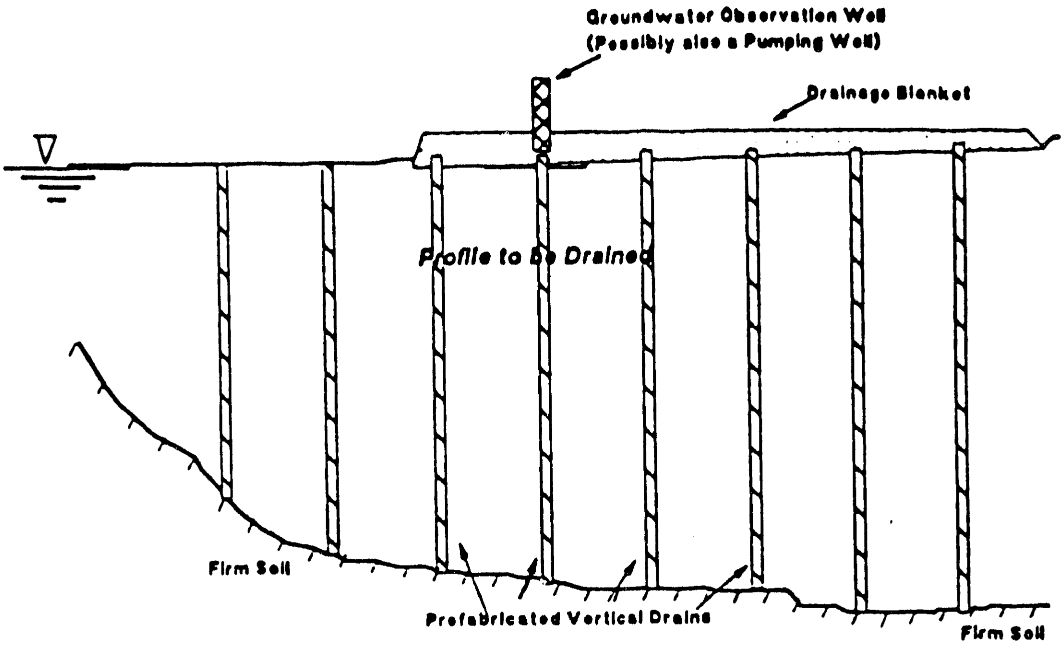


Figure 2. Field Installation Scheme of PVD System

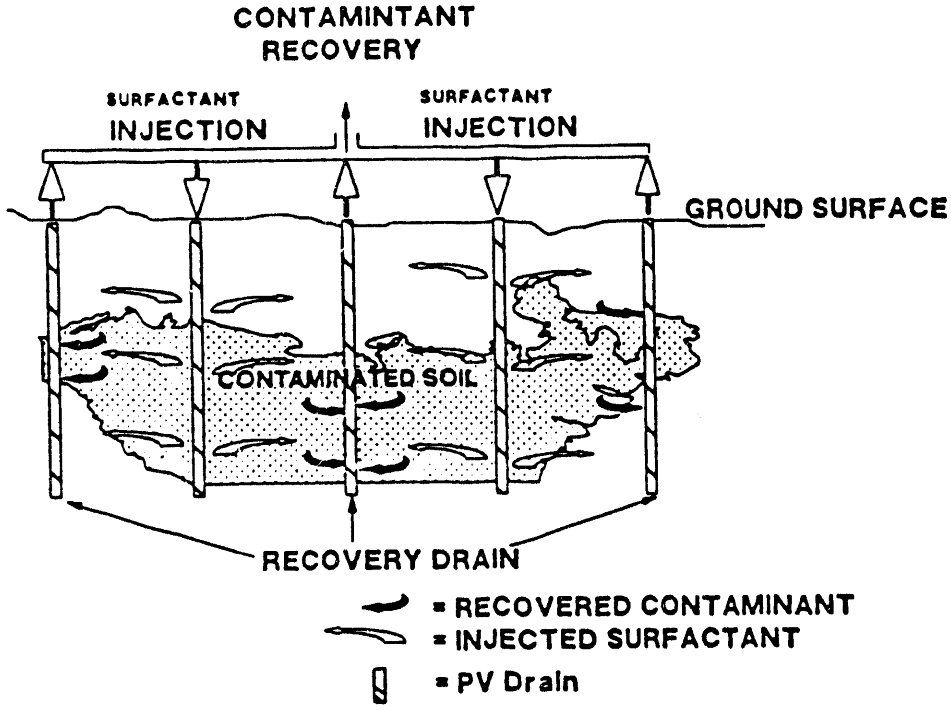


Figure 3. Proposed Field Installation Scheme for Contaminant Recovery

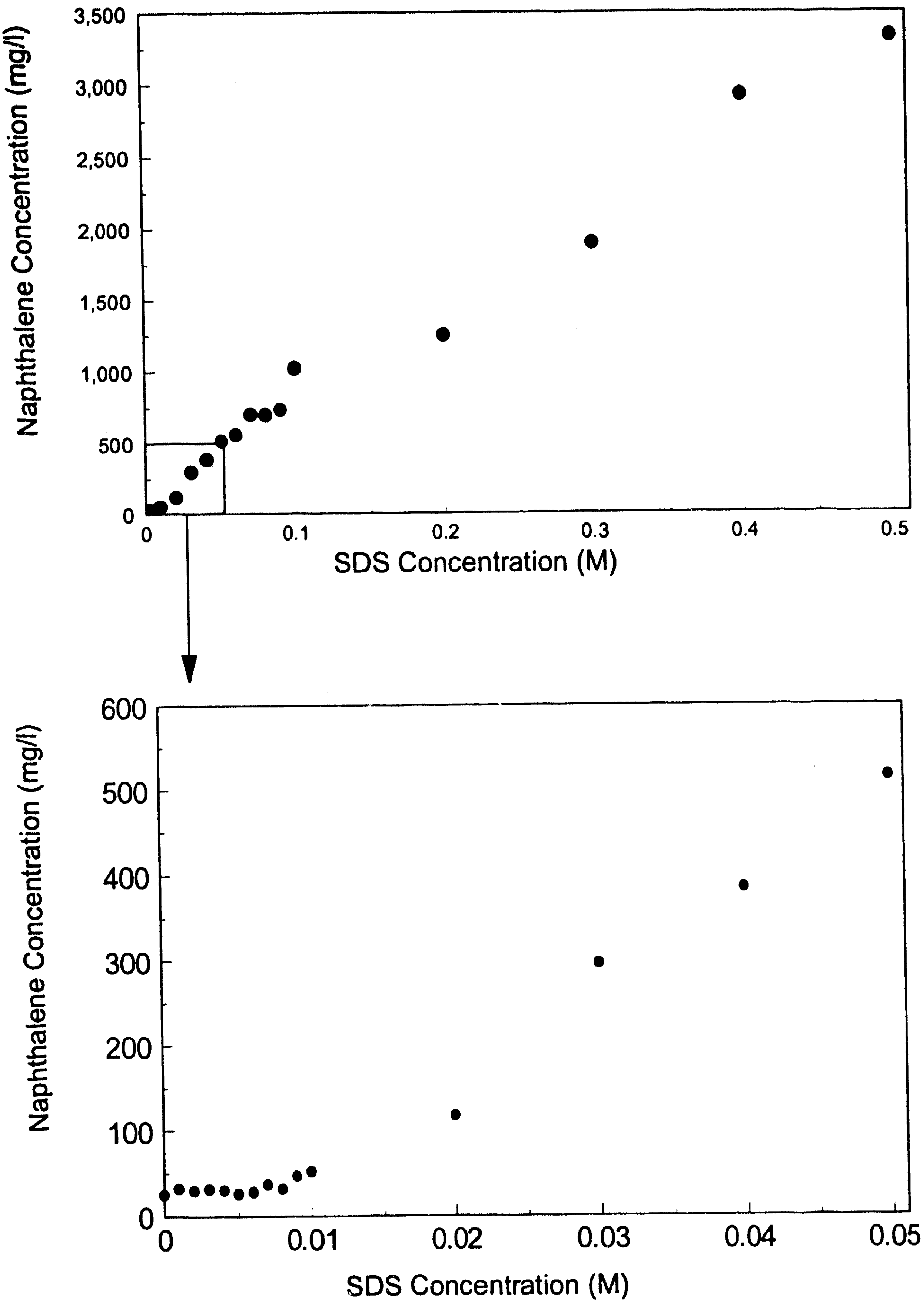
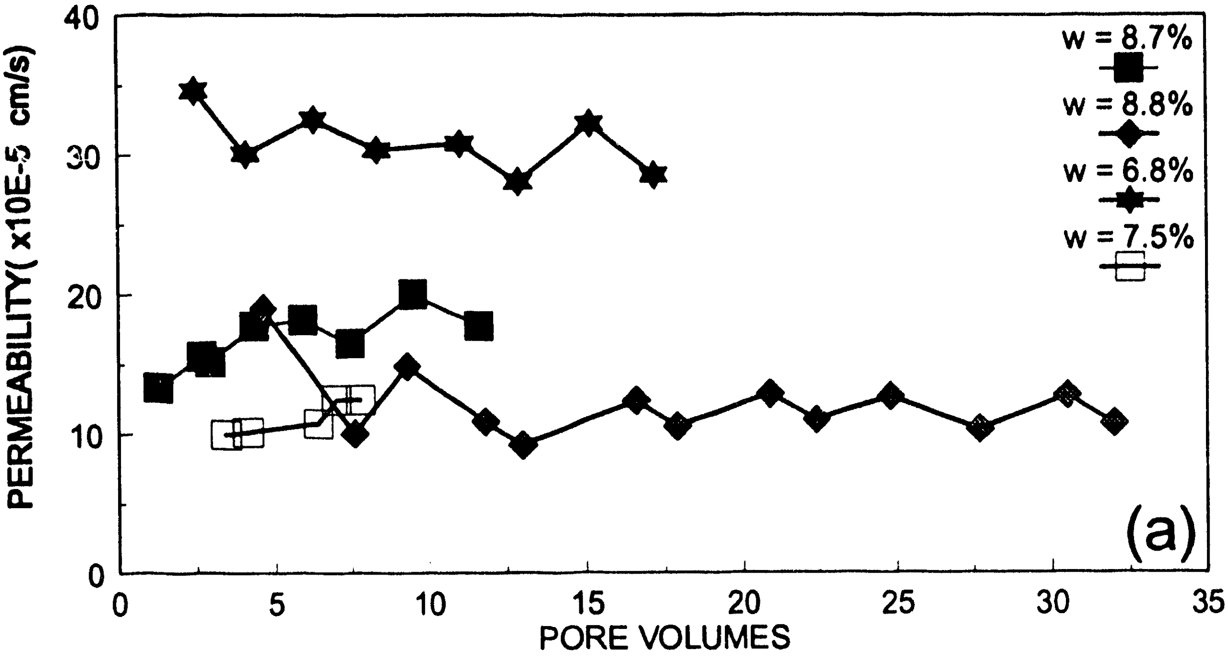
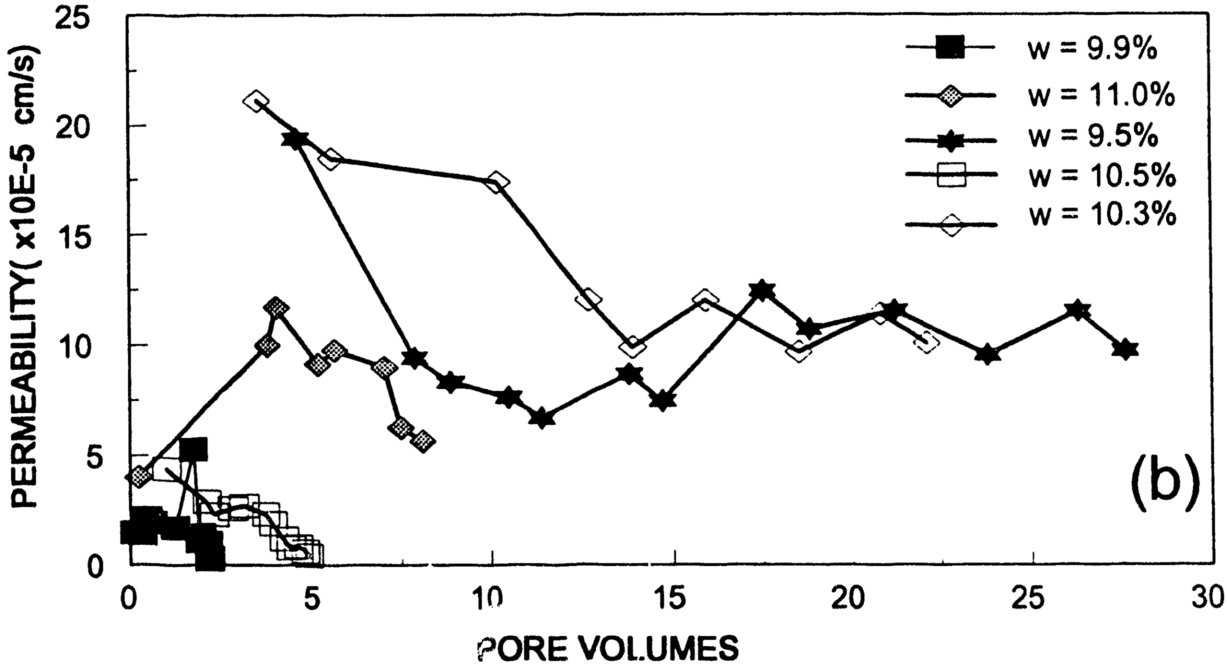


Figure 4. Soluability of Naphthalene Using SDS Surfactant Solution



PERMEABILITY vs PORE VOLUMES for w=6-9%



PERMEABILITY vs PORE VOLUMES for w=9-11%

Figure 5. Results of the Flexible Wall Peremability Tests: a) w range of 6%-9% and b) w range of 9% to 11%

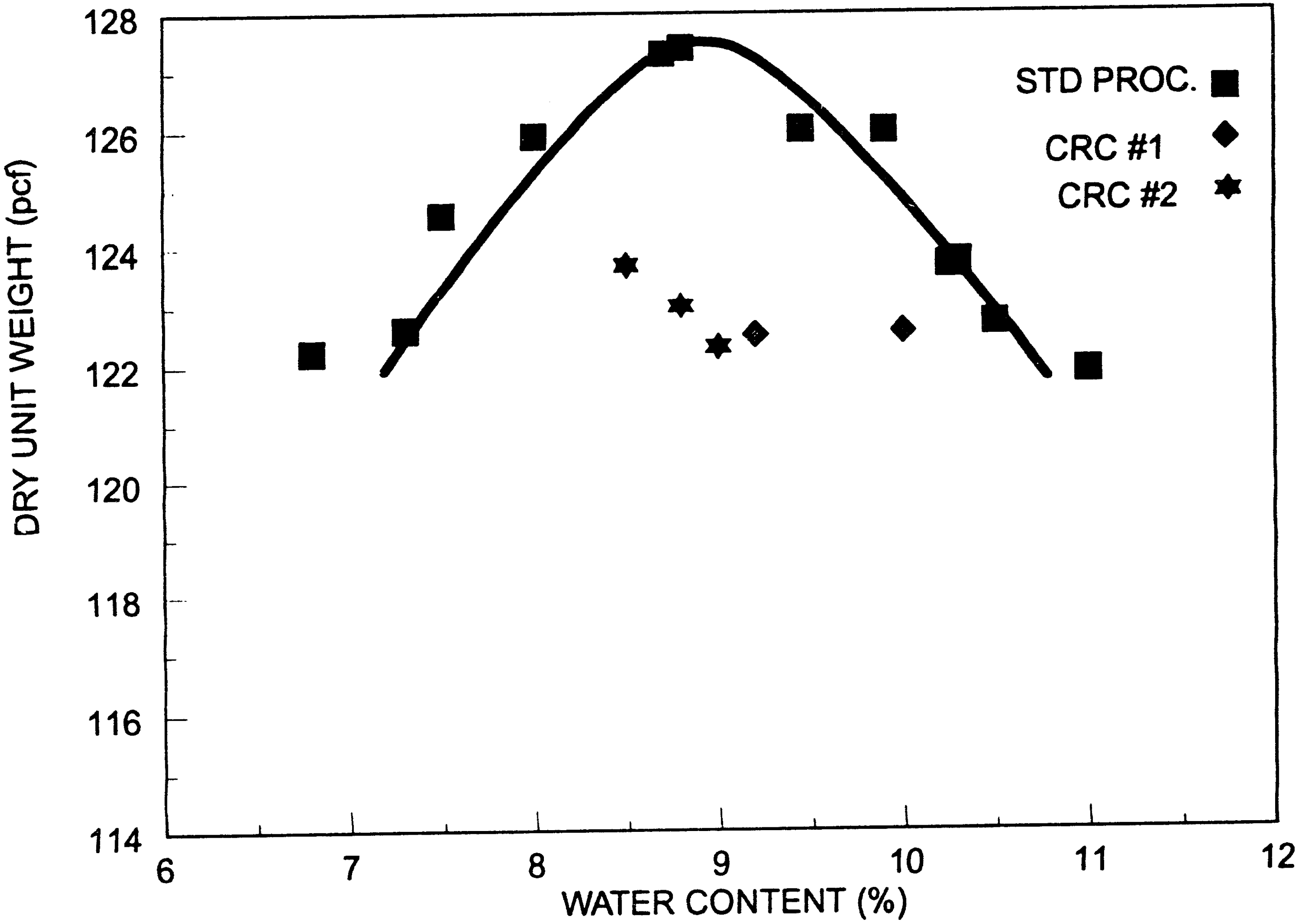


Figure 6. Dry Unit Weight vs Molding Moisture Content

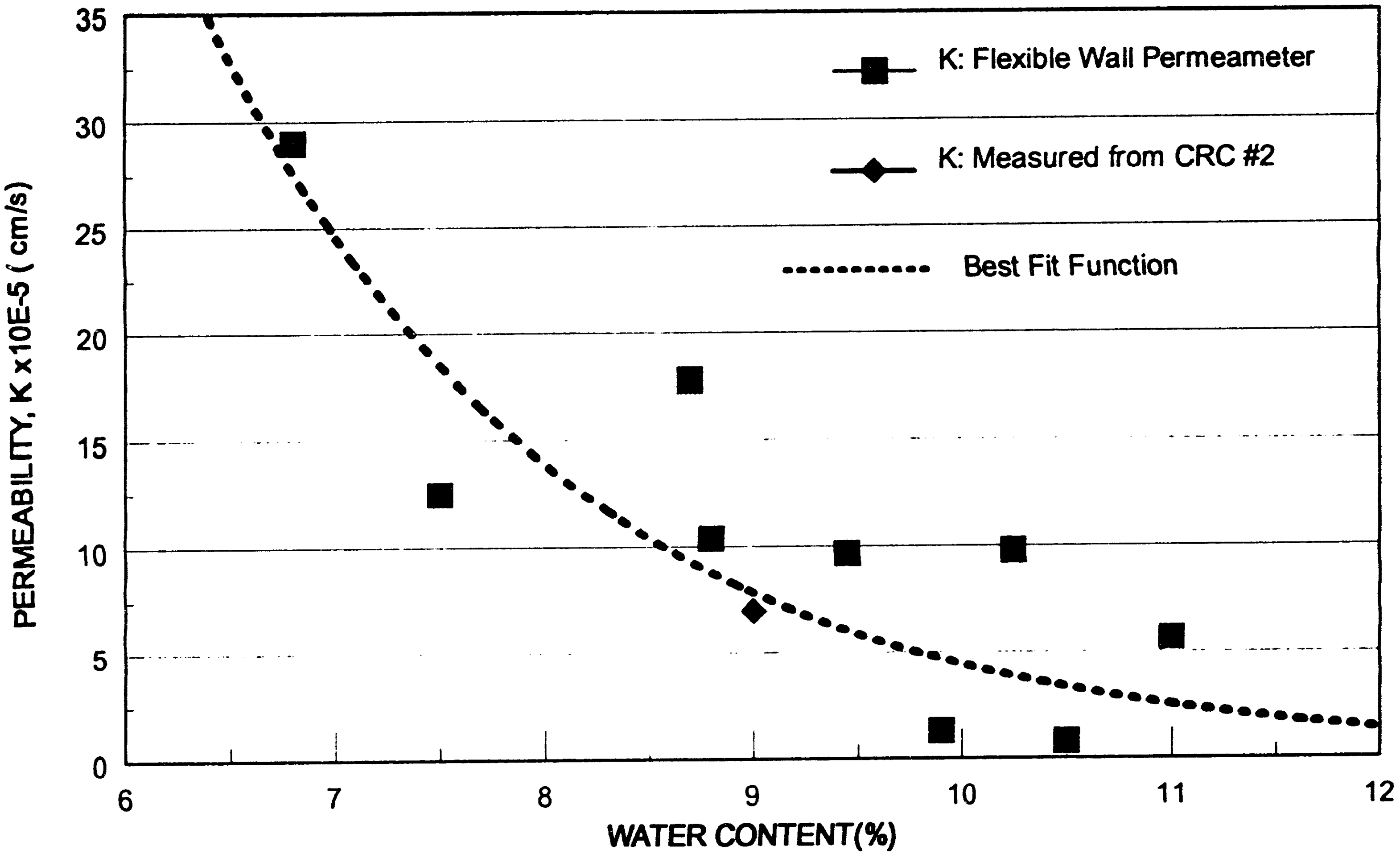


Figure 7. Variation of Peremability as a Function of Molding Water Content (w)

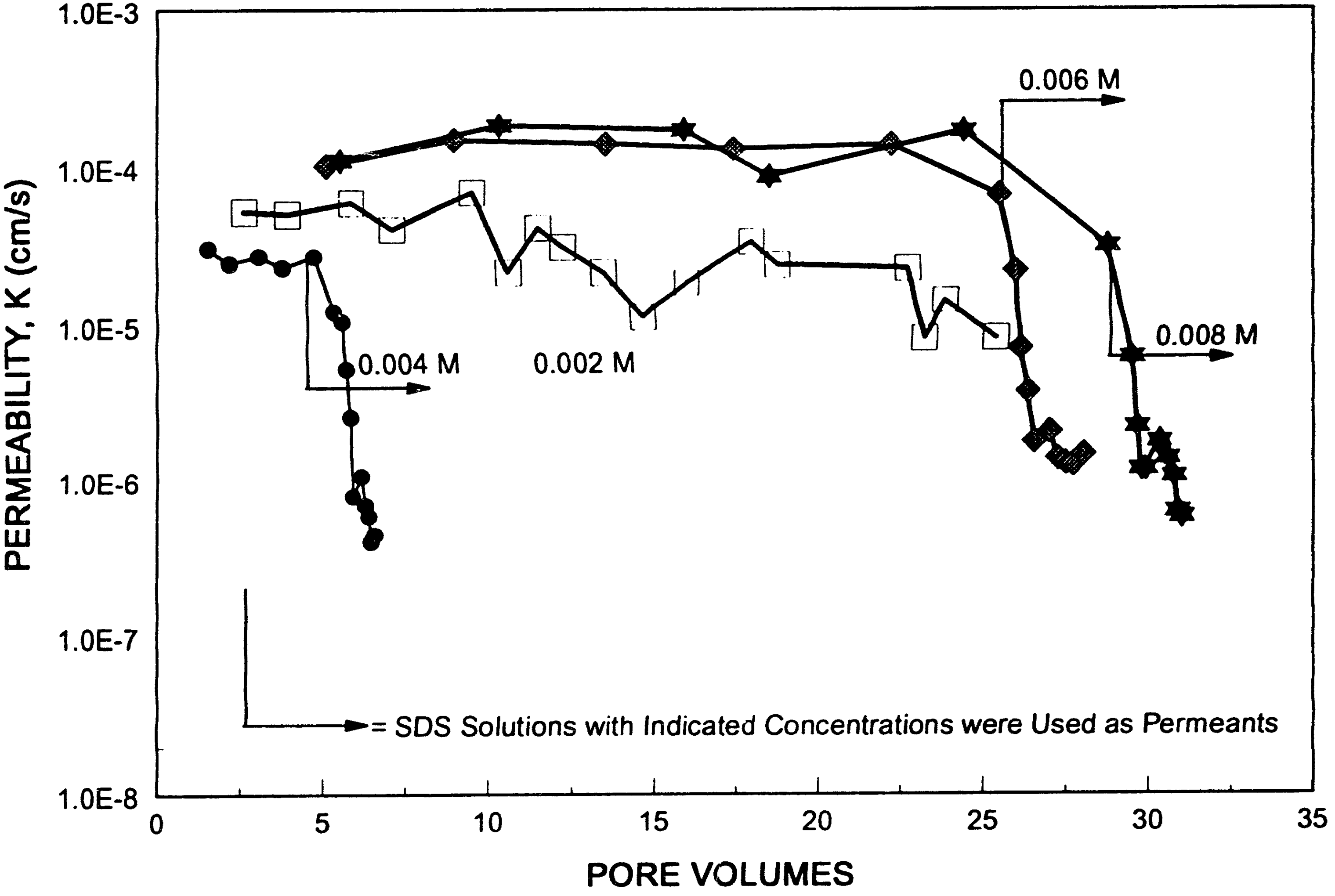
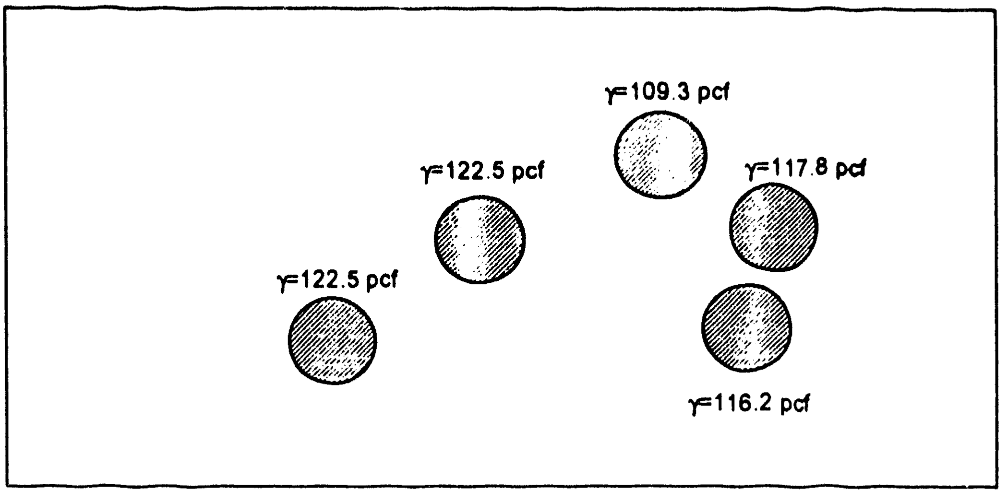
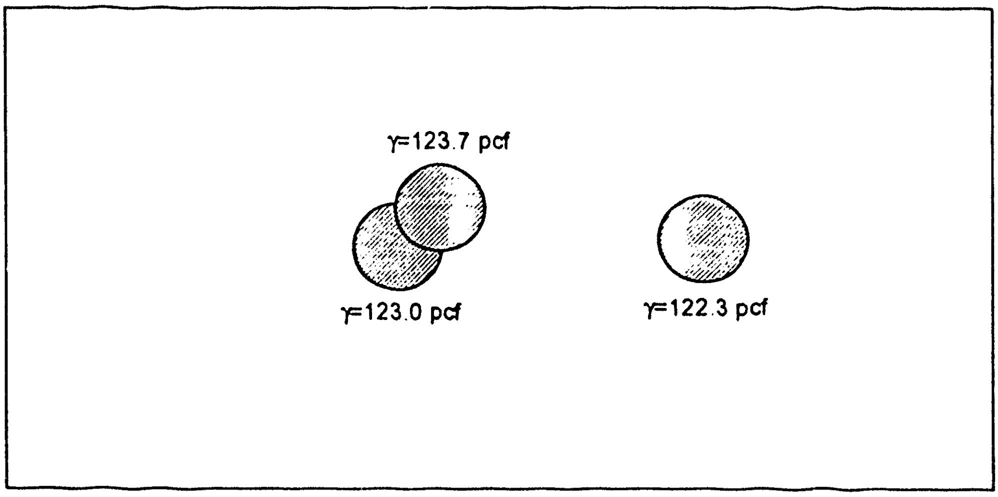


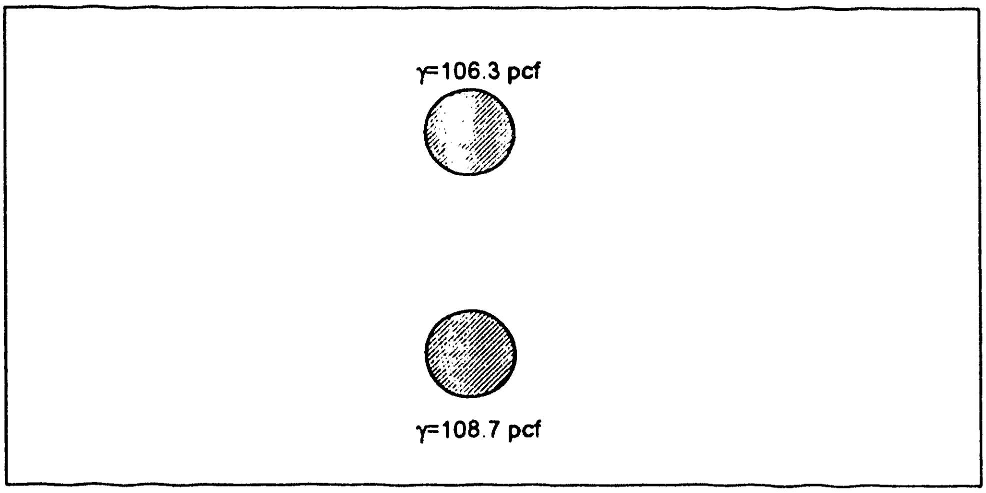
Figure 8. Effect of SDS Surfactant on Measured Permeability



CRC #1

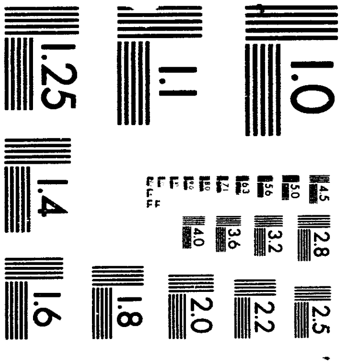


CRC #2



CRC #3

Figure 9. Measured Densities from In Place Sand Cone Test


1.0
1.1
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6.3

2 of 4

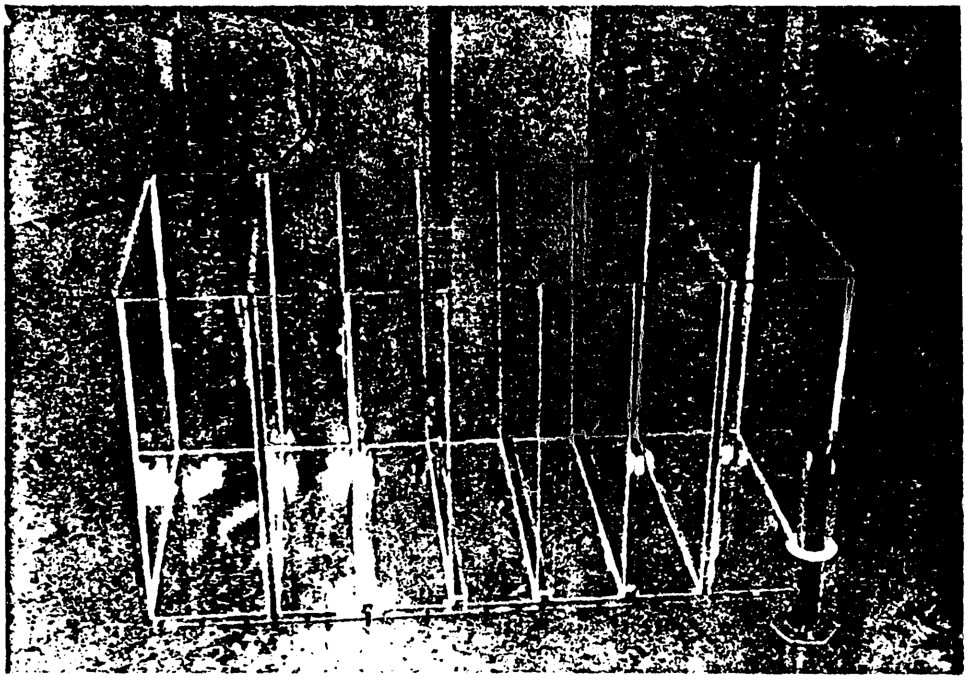

Figure o. Photograph of the Contaminant Recovery Cell (CRC)

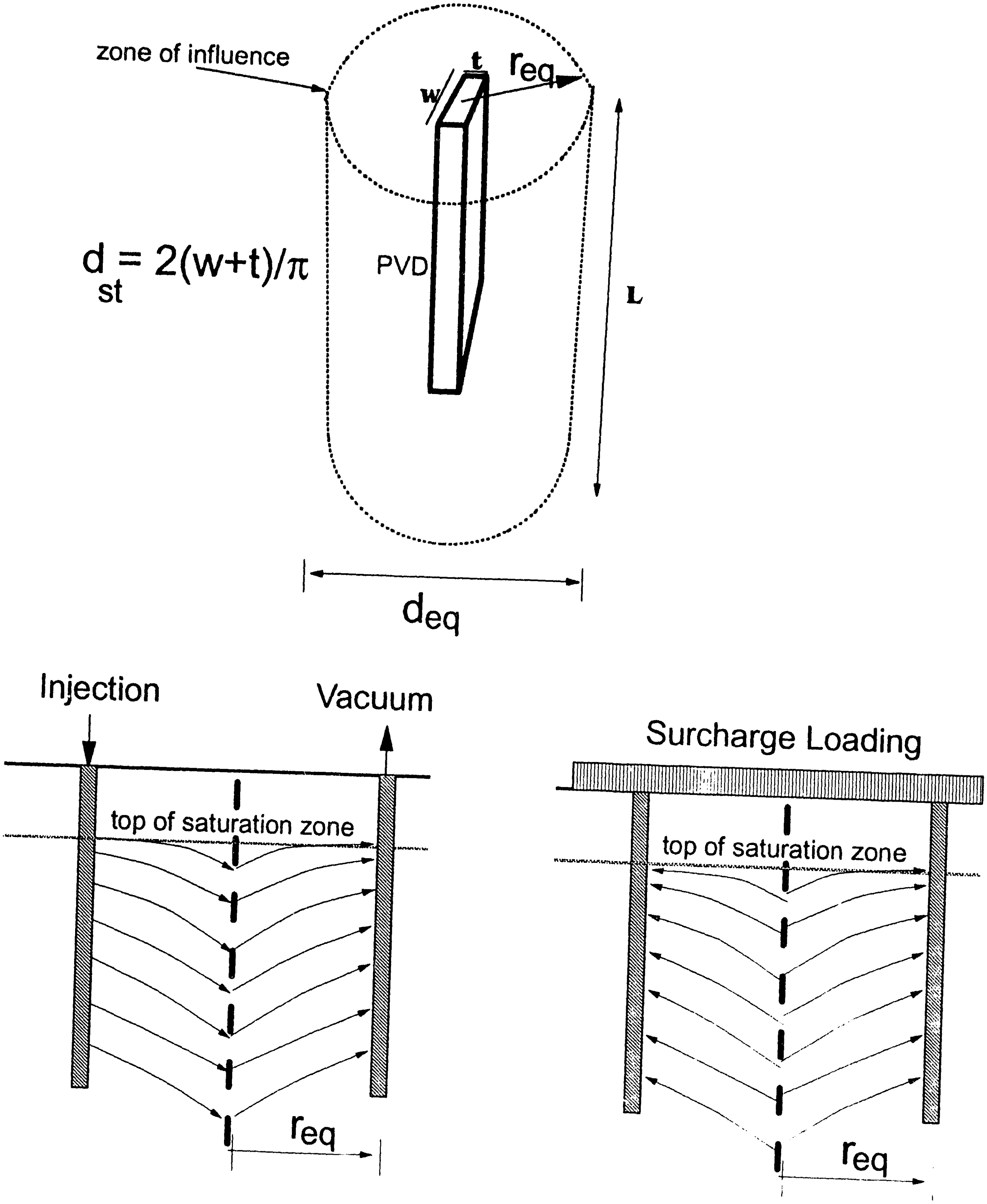

Figure 11. Modeling Configuration for the PVD

Site Remediation Technologies:
In Situ Bioremediation of Organic Contaminants

Quarterly Technical Progress Report
for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92M29467

For
U.S. Department of Energy
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ABSTRACT

In situ bioremediation offers a number of advantages over other processes for destruction of organics in groundwater. Advantages include the potential for complete or near complete destruction of contaminants in place, avoidance of transfer of the pollutants to another medium, less risk of health hazards due to human exposure and cost-effectiveness in many cases. The objective of this research is to evaluate and optimize the ability of methanotrophic, methanogenic, and other selected bacteria for cost-effective biotransformation of a mixture of chlorinated solvents as often found at DOE sites. A five phase workplan is utilized which involves the systematic manipulation of environmental conditions to enhance the rate and extent of biodegradation of the candidate VOC's. It is planned to take advantage of the natural symbiotic relationship between the methanogenic and methanotrophic bacteria so as to promote sequential anaerobic/aerobic mineralization of the chlorinated solvents.

Both the aerobic and anaerobic phases of the research are well underway. Aerobic investigations in this quarter focused on evaluation of growth enhancing agents for the aerobic oxidation of TCE and determination of the suitability of hydrogen peroxide as a replacement for oxygen. The suitability of 3-hydroxybutyrate as an energy source was evaluated at concentrations up to 25 mM with four different methanotrophs. Only one of the organisms showed any significant response and it was concluded that methanol and formate are probably the most promising exogenous energy sources for aerobic TCE degradation by methanotrophs.

Experiments performed with hydrogen peroxide as a replacement for oxygen were encouraging. At the peroxide concentrations evaluated thus far (up to 666 ppm), the organisms seem to be able to adapt rapidly to the presence of the peroxide. Work at higher concentrations of peroxide is planned.

An anaerobic maintenance reactor was setup and is being operated to provide organisms for evaluation of reductive dehalogenation. The maintenance reactor was seeded with a mixed group of organisms from digesting municipal sludge. Good methane production is being achieved indicating a healthy population of methanogens. After reviewing a number of possible procedures, it was decided to use 160 ml serum bottle microcosms for the Phase 2 reductive dehalogenation studies. Shakedown of the gas chromatograph and purge and trap systems is underway in order to measure various VOC's. Plans are being formulated for the column and lysimeter studies which will investigate the sequential anaerobic/aerobic mineralization of mixed solvents.

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1.0 INTRODUCTION

A variety of toxic organic contaminants are found at DOE sites including fuel hydrocarbons, polychlorinated biphenyls (PCB's) and volatile organic solvents such as trichloroethylene (TCE), perchloroethylene, and carbon tetrachloride. These compounds may occur as single contaminants, but are often found in conjunction with heavy metals or in mixed wastes containing radioactive components.

In-situ bioremediation has a number of advantages for destruction of organic contaminants in groundwater. Other processes such as sorption and volatilization do not destroy contaminants, but rather just concentrate them or transfer them to another medium. Abiotic (chemical) transformation is not normally cost-effective in groundwaters and may even result in production of more toxic chemical species.

Clean-up methods often involve soil flushing to mobilize the contaminants for transport to the surface for treatment. However, because many organic contaminants sorb to soils, they are not readily leached from the soils often leaving toxic residuals in place even after flushing. Furthermore, bringing the contaminants to the surface increases the risk of health hazards due to human exposure. There is increasing recognition that bacteria are present and active in the subsurface and that *in situ* biotransformation offers a potentially more effective and economical method of contaminant destruction.

2.0 PURPOSE

The purpose of the research is to evaluate and optimize the ability of methanotrophic, methanogenic, and other selected bacteria for cost-effective biotransformation of TCE and other volatile organic compounds (VOC's) found at DOE sites. The approach outlined involves the systematic manipulation of environmental conditions in the subsurface for the purpose of enhancing the rate and extent of biodegration of candidate (VOC's). This approach takes advantage of the ubiquity of methanotrophic and methanogenic bacteria and introduction of non-native organisms should not be necessary. Also, only relatively benign enhancing compounds will be added in non-toxic concentrations. It is envisioned to take advantage of the natural symbiotic relationship between the methanogenic and methanotrophic bacteria so as to promote sequential anaerobic/aerobic mineralization of the chlorinated solvent contaminants.

3.0 BACKGROUND

A number of exciting developments are occurring in the field of environmental biotechnology (engineering applications of microbial ecology). For example, while trace concentrations of some organic contaminants cannot support microbial growth as the sole electron donor, they can still be biotransformed by engineering the system so that the microbial population obtains the majority of its energy and carbon from a different compound that serves as the primary substrate. This is sometimes referred to as *secondary utilization*. There are also many organic contaminants that are biotransformed in the environment for which no microorganisms have been found which are able to use them as sole carbon source. This is a special case of secondary metabolism often termed *cometabolism*. Cometabolism has been defined (Dalton, 1982) as the "transformation of a non-growth substrate in the obligate presence of a growth substrate or another transformable compound". As an example, halogenated methanes, ethanes, and ethylenes are poor growth substrates for bacterial growth but may be degraded by methanotrophs growing aerobically on methane (Henson et al., 1988).

4.0 METHODOLOGY

The principal focus of the investigation is to develop methods which will enhance bacterial metabolism of organic contaminants in sub-surface environments in order to increase the rate and extent of biodegradation. The methodology is presented in five phases below, however it is anticipated that modifications will be made to the workplan as the work progresses.

Phase 1: Literature Review

As noted above, it is planned that the work will focus on the use of methanotrophs for in-situ VOC destruction. However, a complete review of the bioremediation literature will be carried out whether other classes of organisms also appear attractive and the research plan may be modified. The information gained from the literature review will be utilized both in this project and in the systematic study (METC/MC-1).

Phase 2: Batch Studies to Evaluate Optimum Concentration of Growth Enhancing Agents in Both Liquid and Soil Cultures

In order to enhance microbial activity, a variety of chemical compounds will be investigated for addition to areas of sub-surface VOC contamination. However, some of the compounds to be investigated are toxic in high concentrations (for example hydrogen peroxide). Thus, the maximum allowable and optimum concentrations of each of the candidate enhancing compounds will be evaluated. Several different methanotrophic species will be tested to determine if one is significantly more hardy than others. Liquid cultures of bacteria containing various concentrations of the test compound will be monitored for the rate of growth to determine the optimum concentration to promote growth and the concentration at which inhibition occurs.

These experiments will only offer a first approximation of the optimum concentrations because liquid cultures do not closely mimic the conditions found in sub-surface soils. Thus, additional experiments will involve inoculating soil samples containing various concentrations of test compounds (peroxide, acetate, formate, EDTA, etc.). Several methods will be evaluated to monitor cell growth such as the rate of oxygen or methane uptake, measurement of CO_2 production, microscopic cell counting, or isolation and quantification of DNA. In this way, we will be able to determine the maximum non-toxic concentration of potential biodegradation enhancing compounds.

Phase 3: Column Studies to Evaluate the Rate and Extent of Degradation of Candidate VOC's

At this stage, the work will begin to examine the effect of promising compounds on the actual rate and extent of degradation of TCE. This work will be performed using glass columns containing soil, TCE, and methanotrophic bacteria. The columns will be flushed with a slow stream of methane to provide a source of carbon. A control column using nitrogen gas will also be examined to insure that the gas is not volatilizing the TCE.

To test the ability of hydrogen peroxide to serve as a source of oxygen, the gas phase will contain little or no oxygen, and a dilute solution of hydrogen peroxide will be added, either as a steady stream or in periodic aliquots. At various times, samples will be taken and analyzed for TCE and bacterial growth. In this way, the relationship between rate of growth, and rate of TCE oxidation, as a function of peroxide concentration may be determined. Similar experiments will be performed for other compounds such as formate, formaldehyde, and EDTA.

Phase 4: Comparison of TCE Biotransformation by Particulate and Soluble Methane Monooxygenase

Some species of methanotrophic bacteria are able to express two distinct forms of methane monooxygenase: a soluble form (sMMO) located in the cytosol, or a particulate form (pMMO) located in the cell membrane. Only one of the two forms is expressed at any given time, with the amount of available copper serving as the metabolic switch controlling expression. The sMMO is expressed only when the amount of available copper is extremely low, and this is enhanced by excess iron, a necessary cofactor of sMMO. Thus it appears that in most subsurface environments, the membrane-bound form of MMO will be expressed. Indirect evidence suggests that sMMO is the more effective form for degradation of TCE and other VOC's. Thus,by reducing the amount of available copper in the environment, it may be possible to enhance expression of sMMO, and thereby increase the rate of contaminant degradation. Various metal chelators will be used to reduce the level of available copper to evaluate the potential benefit of sMMO expression.

Phase 5: Investigation of the Utilization of the Symbiotic Relationship Between Methanogenic and Methanotrophic Bacteria for VOC Degradation Without Addition of Exogenous Methane

In order to investigate the possibility of enhancing the symbiotic relationship between methanogenic and methanotrophic bacteria, a two-part column will be used. The lower section will contain acetate and a consortia of methanogenic and other anaerobic bacteria; the upper portion will contain TCE and the methanotrophs. In this way, methane produced by methanogenesis will provide the carbon source for the methanotrophic bacteria. No exogenous methane will be added, with either peroxide or air serving as the source of oxygen. The amount of oxygen added will be critical, since the methanogens are strict anaerobes. Thus the goal will be determination of the amount of oxygen needed to optimize methanotroph growth and TCE degradation without inhibiting methanogenesis. This will closely mimic the actual sub-surface conditions, with both an anaerobic zone where methane can be generated, and an aerobic zone where it can be oxidized and support growth of methanotrophs.

5.0 RESULTS AND DISCUSSION

A comprehensive literature review of biodegradation of chlorinated solvents was completed and submitted as part of the second quarterly report. As might be expected, information gained from the literature review served to modify and "sharpen" the focus of the remaining phases. In particular, the review highlighted the potential of developing the relationship between the methanotrophs (aerobic) and the methanogens (anaerobic) for mineralization of both highly chlorinated and less chlorinated compounds and additional emphasis was given to this approach in subsequent phases of the workplan as discussed below.

Our current understanding of the metabolic pathways utilized by methanotrophic and methanogenic bacteria for degradation of volatile chlorinated solvents suggests that the efficiency, reliability and extent of bioremediation could be greatly improved if the symbiotic relationship between the two were encouraged. It appears that a consortium of methanogenic and methanotrophic bacteria working together under the right conditions would be effective for mineralization of PCE, TCE and other chlorinated solvents.

The methanotrophs have an obligate requirement for methane, which is complimented by the methane production of methanogenic organisms. Furthermore, the methanogens ability to dehalogenate more oxidized (more halogenated) pollutants, generating vinyl chloride, is complimented by the ability of the methanotrophs to mineralize vinyl chloride and other small mono-chlorinated hydrocarbons. The rate limiting step of mineralization under anaerobic conditions is the dehalogenation of vinyl chloride. Thus, it might be advantageous to induce methanotrophic growth at the point where all (or most) of the more chlorinated compounds have been dehalogenated to vinyl chloride. The number of chlorines dramatically effects the rate of anaerobic degradation: the more chlorines the faster the rate of degradation (Sims et al., 1990). A higher number of halogen substituents results in a more oxidized compound making it more susceptible to biological reduction. The relative reduction and oxidation rates of chlorinated organic contaminants are depicted in Figure 1. It may be seen that they are complimentary in nature.

Although methanogenic bacteria will not grow in the presence of oxygen, the reductive dehalogenation reaction is somewhat oxygen tolerant. The rate of TCE degradation is reduced under micro-aerophilic conditions, but not completely blocked (Freedman and Gossett, 1989). Under these conditions a suitable source of reducing equivalents must be provided (eg. methanol, hydrogen, acetate, and formate). It is interesting to note in this regard that Kastner (1991) reported that an aerobic enrichment culture's ability to dechlorinate cis-1,2-dichloroethylene was shown to be dependent on a cyclic transition from aerobic to anaerobic conditions and limited oxygen supply. A schematic depicting a possible sequential degradation process is shown in Figure 2. It may also be possible to increase biodegradation rates by alternating methanogenic and methanotrophic growth conditions, thus limiting the accumulation of potentially toxic byproducts, as well as optimizing the alternating production of methane rich and oxygen rich conditions.

In order to accomplish project objectives in a timely manner, the research is being conducted in two complimentary paths as will be discussed in detail in the following sections. Studies to enhance the aerobic degradation of target compounds by methanotrophs are being performed by Shiemke (biochemistry) while Sack (environmental engineering) is working on anaerobic reductive dehalogenation using methanogens. Information gained from the separate aerobic and anaerobic research studies will then be combined to optimize sequential anaerobic/aerobic mineralization of the chlorinated solvents.

5.1 (Phase 2) Aerobic Batch Studies Using Methanotrophs to Evaluate Optimum Concentration of Growth Enhancing Agents in Both Liquid and Soil Cultures (Shiemke)

Degradation of TCE by methanotrophs is initiated by the methane monooxygenase (MMO) enzyme (Little et al., 1988). The rate-limiting step in the biotransformation of TCE by methanotrophs appears to be the oxidative reaction catalyzed by this monooxygenase. Thus, one method to improve the efficiency of aerobic degradation of chlorinated solvents by methanotrophs is to adjust conditions to achieve the optimum reaction rate for MMO. MMO has an obligate requirement for oxygen and energy, in the form of reducing equivalents. Methanotrophs obtain this energy from the oxidation of methanol, formaldehyde, and formate; all of which can be obtained from the sequential oxidation of methane as shown in Figure 3 (Anthony, 1986). In the subsurface it is likely that oxygen and methane will be rapidly depleted, and introduction of these substrates will be a difficult engineering problem, due to their low mobility. However, substances such as methanol and formate can provide energy to the organism for TCE oxidation (Henry and Grbic-Galic, 1991), and are likely to have significantly greater mobility in the subsurface than methane. Likewise, hydrogen peroxide can be converted to oxygen in the subsurface, and is also likely to have greater mobility than O_2. However, due to the possible toxicity of these substances we first need to determine the maximal non-lethal concentrations that the organism can withstand. That is the goal of this phase of the project.

Other labs have shown that liquid cultures of methanotrophs will oxidize TCE with either methane, methanol or formate as the energy source (Henry and Grbic-Galic, 1991). TCE degradation is faster in the presence of methanol or formate, relative to methane, probably because methane and TCE compete for the same substrate-binding site on MMO. Another potential source of energy for methanotrophs is 3-hydroxybutyrate. Some species will produce polymers of 3-hydroxybutyrate when growth substrates are in excess (Anthony, 1986). The polymers are later broken down and the 3-hydroxybutyrate monomers are oxidized to provide energy in times of starvation. Thus, we have investigated the effectiveness of 3-hydroxybutyrate as an exogenous energy source, relative to formate.

These experiments were performed on liquid suspensions of pure methanotroph cultures, using an oxygen electrode to measure the extent that respiration is stimulated in response to addition of the energy source (formate or 3-hydroxybutyrate). It is assumed that compounds such as formate and 3-hydroxybutyrate will contribute to the total energy pool of the cell, and that this energy pool can be utilized for either respiration or substrate oxidation (Anthony, 1986). Measurement of respiration is faster, and easier than measurement of substrate oxidation rates, and serves as an indirect indication of the extent that a given compound contributes to the energy pool of the cell.

To perform these experiments 3.0 ml of a dilute suspension of bacteria (~0.25 mg/ml of cell paste) were added to each chamber of the oxygen electrode. The basal respiration rate was measured for approximately 5 minutes. After this time a measured amount of either formate or 3-hydroxybutyrate was added as a small volume of a concentrated solution. The stimulation of the respiration rate was then measured as the rate of oxygen usage, minus the basal respiration rate. Our results show that *Methylocystus, Methylomonas* and *Methylococcus* species were unable to use 3-hydroxybutyrate. Addition of 3-hydroxybutyrate at concentrations up to 25 mM did not stimulate respiration at all. In contrast, formate had a dramatic effect on the respiration rate at concentrations as low as 1.0 mM. Respiration of *Methylosinus trichosporium* was stimulated by 3-hydroxybutyrate. However, the extent of stimulation was much less for 3-hydroxybutyrate than for formate, as shown in Figure 4. Thus, methanol and formate appear to be the best exogenous energy sources for aerobic TCE degradation by methanotrophs. Experiment are planned for the future to determine the relative utility of these compounds to provide energy for TCE oxidation in liquid cultures and soil columns (see Section 5.4.1).

We have also initiated studies to determine if hydrogen peroxide can replace oxygen in the oxidative degradation of TCE by methanotrophs, and if so what concentration of peroxide is optimal. Peroxide is known to be a potent bactericide in high concentrations, so we are first determining the maximum non-lethal concentrations of peroxide that the methanotrophs can withstand. For these experiments an initial "seed" culture is grown and used to inoculate several side-arm flasks containing a range of peroxide concentrations. In this way we ensure that each flask starts with the same initial concentration of bacteria. Methane is added to the head-space of each flask and they are shaken at 37°C for several days. During this growth phase methane and oxygen are added to the head space (20% each) every 24 hours, and growth is monitored by measuring the turbidity at several different wavelengths using a spectrophotometer. In this way we will determine the approximate range of peroxide concentrations that can be tolerated by these organisms. At a later date we will determine if peroxide can replace oxygen in the degradation of TCE by methanotrophic bacteria (see Section 5.4.1).

To date we have done three sets of experiments in which peroxide was added at concentrations from 0 to 666 ppm. The culture containing no peroxide showed an immediate increase in turbidity that leveled off after approximately 20 hours. Additional growth occurred after each subsequent addition of methane and oxygen. In contrast the cultures containing peroxide all showed an initial lag phase of ~10 hours during which no growth occurred. After this lag period growth of the peroxide-containing cultures paralleled that of the control culture (no peroxide). Thus the bacteria seem to adapt rapidly to the presence of the peroxide. In the near future experiments will be initiated in which the peroxide concentration is increased to several thousand ppm. If these concentrations are tolerated we will then move on to measurement of TCE oxidation in the presence of peroxide.

5.2 (Phase 2) Anaerobic Batch Studies Using a Mixed Consortia of Methanogens and Other Organisms to Accomplish Reductive Dehalogenation (Sack)

As noted earlier, after completion of the literature review (Phase 1), it was decided to give additional emphasis to evaluating the potential of a combined anaerobic/aerobic process to mineralize a spectrum of chlorinated solvents. Hence anaerobic batch studies were added to Phase 2 to accomplish reductive dehalogenation using a mixed consortia of methanogens and other organisms.

An initial objective of the anaerobic biodegradation studies was to identify and establish sound anaerobic culturing and transferring techniques in order to successfully demonstrate reductive dechlorination. Some of the organisms involved are strict anaerobes and care must be exercised to exclude oxygen. Anaerobic culturing methods and transferring techniques were developed based on methods utilized by a number of authors (Freedman and Gossett, 1989; Holdeman, et al., 1977; ASTM, 1993. A Coy anaerobic environmental chamber will be utilized to aid in maintaining anaerobic conditions during transfers. As discussed below, a maintenance reactor (MR) was first established in order to provide organisms for the reductive dehalogenation studies. Other Phase 2 activities in this quarter included planning for the use of serum bottle microcosms to evaluate reductive dehalogenation and work to measure VOC's with the gas chromatograph as will be discussed below.

5.2.1 Maintenance Reactor-Setup and Operation Actively digesting sludge from the Morgantown Wastewater Treatment Plant (MWTP) was used to seed a 15 liter maintenance reactor (anaerobic) which will serve as the inoculum source during the anaerobic microcosm studies. Sludge from the digester was chosen rather than a pure methanogenic culture in order to assure a mixed culture of obligate anaerobes (including methanogens) as well as other organisms such as facultative anaerobes. As noted earlier, a mixed consortia of organisms are preferred in order to carry out reductive dehalogenation on a mixture of solvents (Freedman and Gossett, 1989; Distefano, et al., 1991).

Figure 5 shows the layout of the laboratory maintenance reactor and the various gas measuring and sampling devices. The 15 liter maintenance reactor is a stirred, batch-fed anaerobic unit operated at 22-25° C with a hydraulic residence time of 30 days. The MR was initially seeded with 5 liters of actively digesting sludge from MWTP and batch-fed every other day a substrate consisting of (per liter of tap water): Ensure, 31.5 ml; methanol, 0.317 g; acetate, 0.350 g;

$NaHCO_3$, 3.36 g; K_2HPO_4, 0.25 g; $MgSO_4{*}\ 7H_2O$, 0.20 g; $FeCl_2{*}6H_2O$, 0.012 g; and $CoCl_2$, 0.007 g. A stock solution of the MR substrate inorganics was prepared and sparged with N_2 gas to obtain an oxygen free solution (D.O. ~ 0.20 mg/l). The organics are added individually along with the inorganics. MR feedings are performed after first initiating a flow of N_2 gas into the reactor headspace to maintain anaerobic conditions. Next, 1 liter of solution is withdrawn from the bottom outlet port, and finally 1 liter of MR substrate is introduced through top inlet lines.

Gas production and composition in the MR is estimated in order to assess general system health and the level of methanogenic activity. A Mariotte flask system is utilized to quantify gas production. As shown in Figure 5, the Mariotte flask system consists of two 20 liter bottles, one of which is placed at a higher elevation and is filled with a brine solution. The brine solution was prepared (Standard Methods, 1992) by adding 200 g Na_2SO_4 and 30 ml of concentrated sulfuric acid to 800 ml of distilled water. As the MR produces gas, it flows into the upper Mariotte bottle and displaces brine into the lower bottle. The volume of gas produced is determined by measuring the change in brine levels in the graduated bottles. The brine solution has a very high total solids concentration and low pH so that very little of the gas produced is absorbed. The high dissolved solids concentration of the brine minimizes the solubility of the gases, while the low pH prevents the absorption of CO_2. Therefore, the volume of the displaced liquid closely approximates the volume of gas produced. Table 1 displays typical gas production data obtained during various times of MR operation.

Table 1. Typical Gas Production Data

DATE	GAS PRODUCTION (ml/hr)
6/16/93	167
6/17/93	179
6/18/93	363
6/22/93	357
6/23/93	283
6/24/93	600
6/25/93	374
6/28/93	612

The percentage of methane produced by the maintenance reactor is currently being measured using a combustible gas indicator (MSA GASCOPE Model 60) equipped with a thermal conductivity detector. The unit is calibrated using 2 % and 100% CH_4 Good methane production has been established with values reaching over 60 % methane. For comparison, it might be noted that digestion of municipal sludge typically produces about 2/3 methane and 1/3 carbon dioxide. However, the percentage of methane in the gas depends on the chemical composition of the substrates being degraded.

In addition to using the combustible gas indicator to detect methane in MR gas, plans are underway to set-up and use a N-CON Comput-OX respirometer which can assess the amount of gas evolved by using the ideal gas law. The third approach for analysis of MR gas composition, as well as, microcosms headspace analysis will involve the use of a GOW-MAC 550-Series Gas Chromatograph equipped with a thermal conductivity detector. Specifics regarding the later two approaches for gas analysis will be further discussed in future progress reports.

5.2.2 Choice of Microcosms for Evaluation of Reductive Dehalogenation After a review of the literature, it was decided to perform testing for reductive dehalogenation of solvents in microcosms consisting of 160 ml serum bottles. Details of the testing protocol will be discussed in Section 5.4, "Research Planned for Next Quarter".

5.2.3 Measurement of VOC's Via Gas Chromatography Analysis of VOC's such as PCE, TCE and vinyl chloride will be carried out using a Hewlett Packard MP 5890 Series II GC with an electron capture detector and a porapak Q column. EPA methods 601, 5030, and 8010 will be utilized as appropriate. A local industry donated a used Tekmar purge and trap (P & T) apparatus for use with the GC which will greatly improve sensitivity. Currently, both the GC and P & T units are in place and undergoing shakedown in order to obtain suitable data. After starting up the P & T unit, difficulty was experienced in cleaning out the apparatus so as to obtain a good base line. A new trap has been installed and the system has been flushed with methanol and water as per manufacturer's instructions. In addition, a leak between the sample port and the trap was noted and we are awaiting a technician from the donor company to assist in repair of the leak and final shakedown of the unit.

5.3 Other Project Activities

During the 3rd quarter, a number of other project related activities were accomplished. On May 27, an oral and a brief written progress report were presented at a progress review meeting held at METC/DOE. A Management Plan for the project was prepared and submitted to NRCCE on June 15th. In addition, a technical paper reviewing bioremediation of chlorinated solvents was prepared for presentation at the 25th Mid-Atlantic Industrial and Hazardous Waste Conference to be held at the University of Maryland, July 7 to 9, 1993.

5.4 Research Planned for the Next Quarter(s)

5.4.1 Optimization of Aerobic TCE Degradation Rates Once we have determined the maximum non-lethal peroxide concentration for methanotrophs we will begin assessing the ability of peroxide to replace oxygen in TCE degradation. These experiments will be done using dilute bacterial suspensions in septum-sealed serum bottles containing approximately 1.0 ppm TCE, an energy source (methanol or formate), and either oxygen or peroxide. The optimal concentration of either methanol or formate will first be determined by measuring the rate of TCE degradation as a function of the concentration of the energy source. The TCE concentration will be determined by injecting a small aliquot of the sample into the GC, using either a flame ionization or electrolytic conductivity detector (depending on the desired level of sensitivity). The ability of the organisms to use peroxide will be determined in a similar fashion. In this case the solutions will be sparged with argon or nitrogen to remove dissolved oxygen. Peroxide and TCE will then be added, and the concentration of TCE degradation measured over time, using the GC, as above. A range of peroxide concentrations will be used in order to determine the optimal concentration.

The information determined from the above experiments regarding optimal concentrations of energy source (methanol or formate) and peroxide will then be used as the starting point for our soil column studies (Phase 3). The goal of these studies is to optimize concentrations of energy source and peroxide for TCE degradation in an environment that more closely resembles that of the subsurface. An inoculum of methanotrophic bacteria will be added to a soil column and a solution of TCE, formate or methanol, and peroxide will be pumped slowly through the column. The concentration of TCE in the effluent will be monitored to determine the degree of biotransformation. The concentrations of peroxide, and energy source will be varied independently of each other to determine optimal levels of each. It is likely that higher concentrations of peroxide will be tolerated in these studies, since some may react with components of the soil matrix rather than the bacteria. Some of these latter reactions should lead to production of oxygen, through disproportionation of peroxide.

The soil column would also be used for studies to determine if we can control expression of the two forms (Phase 4) of MMO (DiSpirito et al., 1992). Low concentrations of EDTA would be added to chelate free copper, in order to favor expression of the soluble form of MMO. If the bacteria switch to expression of the soluble MMO we should see a dramatic decrease in TCE concentration, since the rate of degradation is much faster with this enzyme (DiSpirito et al., 1992). To verify that the soluble MMO is being expressed we would isolate the bacteria and test for oxidation of naphthalene. Only the soluble MMO is capable of oxidizing this compound (Brusseau et al., 1990).

Results of these studies will then lead into planned experiments using mixed aerobic/anaerobic environments (Phase 5). In these experiments the environment will switch between aerobic and anaerobic, either temporally or spatially. The aerobic environment will contain concentrations of peroxide, and methanol or formate that are optimal for the aerobic transformation of TCE, as determined in experiments above. The method of converting between aerobic and anaerobic environments has yet to be determined.

5.4.2 Evaluation of Reductive Dehalogenation Using Serum Bottle Microcosms As noted in an earlier section, it was decided to carry out microcosm experiments to evaluate reductive dehalogenation of highly chlorinated solvents in 160 ml serum bottles. The serum bottles will contain 100 ml of liquid and will be sealed with teflon-lined, gray butyl rubber septa and aluminum crimp caps. The bottles will be stored in the dark at 25^0 C, under quiescent conditions, with the liquid in contact with the septa (to minimize loss of volatiles). Degradation of TCE will be initially achieved by anaerobically transferring 100 ml mixed-liquor samples directly from the laboratory maintenance reactor to the 160 ml serum bottles. Initial doses of TCE will be 0.75 mg/l and when the initial dose is degraded the bottles will be repetitively respiked by adding TCE saturated stock solution. During each respiking, 4.0 ml of well-mixed liquid will be removed and replaced with fresh basal salts medium (containing 50 mg of methanol and 50 mg acetate substrate per liter) plus the TCE stock solution. The basal salts medium will consist of (per liter of distilled deionized water): NH_4Cl, 0.20g; $K_2PO_4*3H_2O$, 0.10 g; KH_2PO_4, 0.055 g; $MgCl_2*6H_2O$, 0.20 g; trace metal solution (per liter, 0.1 g of $MnCl_2*4H_2O$; 0.17 g of $CoCl_2*6H_2O$; 0.10 g of $ZnCl_2$; 0.20 g of $CaCl_2$; 0.019 g of H_3BO_4; 0.05 g of $NiCl_2*6H_2O$; and 0.020 g of $Na_2MoO_4*2H_2O$, adjusted to pH 7 with NaOH or HCl), 10 ml; resazurin, 0.001 g; Na_2S*9H_2O, 0.50 g; $FeCl_2*4H_2O$, 0.10 g; $NaHCO_3$, 5.0 g; and yeast extract, 0.050 g. The basal medium will be prepared by boiling the first six components, cooling under an N_2 purge, adding the remaining components, switching the gas to a mixture of 30% CO_2 and 70% N_2, and adjusting the pH to ~7.5.

Each set of experiments will be performed in triplicate, accompanied by duplicate water controls (100 ml of distilled deionized water plus the chlorinated compound), and duplicate inoculated bottles which will be autoclaved, cooled and spiked with the chlorinated compound plus 2-Bromoethanesulfonic acid (an inhibitor of methanogenesis). Once RD has been evaluated in liquid microcosm, column and lysimeter work will be begun as discussed briefly in the following section. It is planned that construction of the anaerobic columns be initiated during next quarter depending on completion of the liquid microcosm studies.

In order to accomplish project objectives, results obtained in the liquid/soil culture microcosms will be expanded into both aerobic and anaerobic sand/soil columns (Phase 3). Planning is underway for setup and design of the columns. Results of the aerobic and anaerobic testing will then be combined (Phase 5) in columns and lysimeters to accomplish alternating anaerobic and aerobic mineralization of the solvents.

The sand columns used for RD in Phase 3 will be operated to accomplish both RD of the chlorinated aliphatic hydrocarbons (CAHs) to end products such as vinyl chloride and the aerobic oxidation of these end products to environmentally acceptable products. The actual column design is still under study. However, the columns will be designed to simulate the subsurface with an anaerobic lower stratum and an upper aerobic section. PCE and TCE will be slowly fed upflow through the column allowing RD in the lower section. The environment will be controlled in the upper zone of the column to create an aerobic zone by addition of hydrogen peroxide or air. A primary substrate such as methanol and nutrients will be fed into the bottom of column along with the CAH compounds. Hydrogen peroxide or air could be delivered continuously or pulsed to the upper zone via ports in the side of the column or by prefabricated vertical drains (Pads) built into the column. The column will be designed to allow recirculation in both the anaerobic and aerobic zones including the unsaturated zone.

After gaining satisfactory experience in the columns, lysimeters will be utilized to better mimic the horizontal flow pattern in the field. It is planned to use lysimeters similar to the contaminant recovery cells utilized by Gab et al. (1993). It is planned to manage the environment by installing a series of PVD's as shown which will be used for delivery of amendments and possibly for vertical recirculation within the lysimeter. It is proposed to create a vertical gradient across the lysimeter so that the profile is entirely anaerobic at the entrance and completely aerobic as reaches the exit. However, a number of other configurations are also under consideration to accomplish the desired sequential anaerobic/aerobic mineralization of the CAH compounds.

6.0 CONCLUSIONS

Both the aerobic and the anaerobic testing is well underway (Phase 2). Additional studies to achieve reductive dehalogenation of the CAH compounds were added to the original workplan based on the literature review.

Four different methanotrophs were fed 3-hydroxybutyrate at concentrations up to 25 mM to determine if the compound could serve as a suitable energy source. Only one of the organisms showed any response. In contrast, formate had a dramatic effect on respiration rate at very low concentration. It was concluded that methanol and formate appear to be the best exogenous energy sources for aerobic TCE degradation by methanotrophs.

Experiments performed with hydrogen peroxide as a replacement for oxygen were encouraging. At the peroxide concentrations evaluated thus far (up to 666 ppm), the organisms seem to be able to adapt rapidly to the presence of the peroxide. Work at higher concentrations of peroxide is planned.

An anaerobic maintenance reactor was setup and is being operated to provide organisms for evaluation of reductive dehalogenation. The maintenance reactor was seeded with a mixed group of organisms from digesting municipal sludge. Good methane production is being achieved indicating a healthy population of methanogens. After reviewing a number of possible procedures, it was decided to use 160 ml serum bottle microcosms for the Phase 2 reductive dehalogenation studies. Shakedown of the gas chromatograph and purge and trap systems is underway in order to measure various VOC's. Plans are being formulated for the column and lysimeter studies which will investigate the sequential anaerobic/aerobic mineralization of mixed solvents.

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8.0 FIGURES

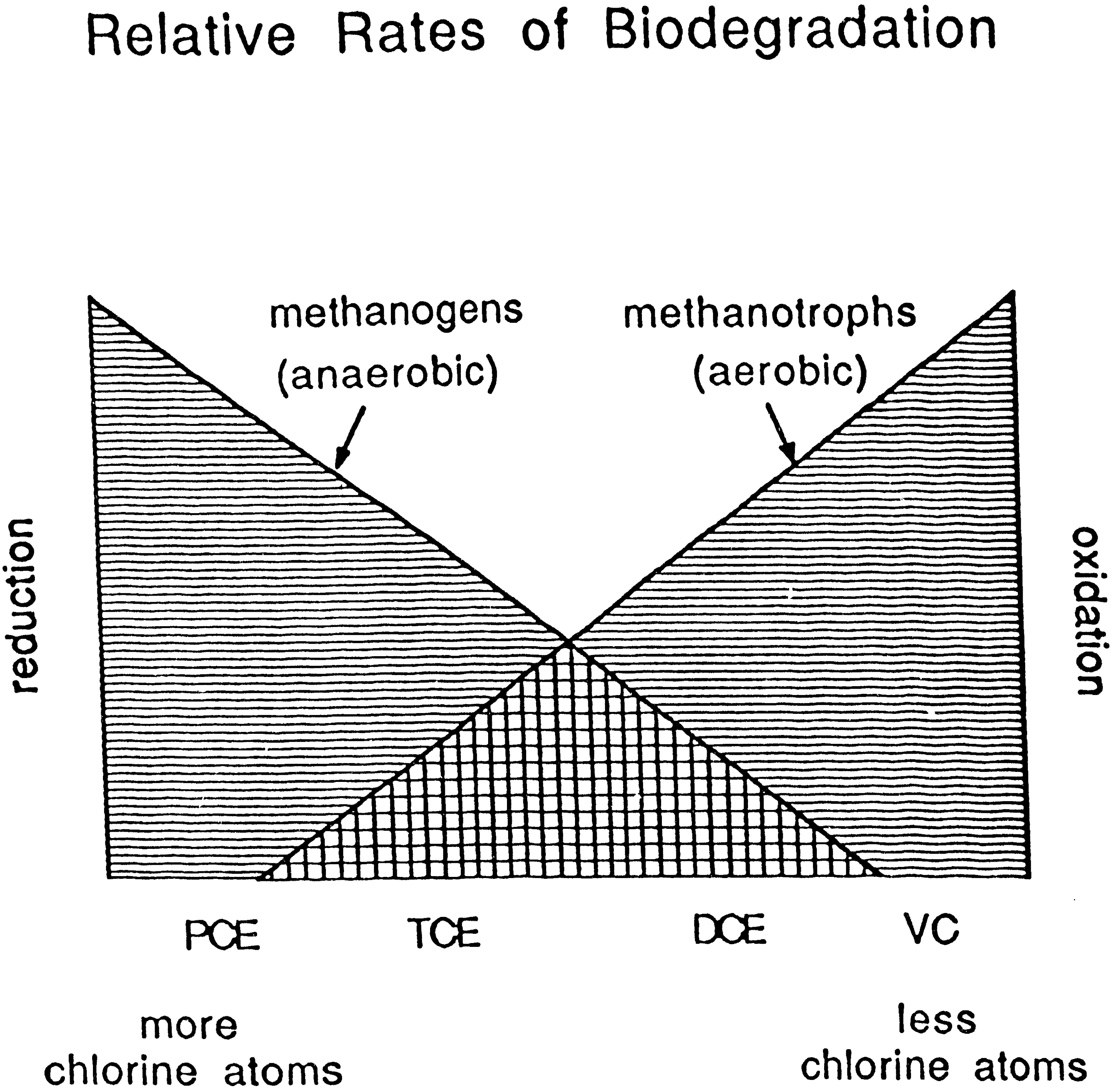

Figure 1. Relative redox rates of chlorinated organic contaminants.

SEQUENTIAL ANAEROBIC/AEROBIC TRANSFORMATION OF SOLVENTS

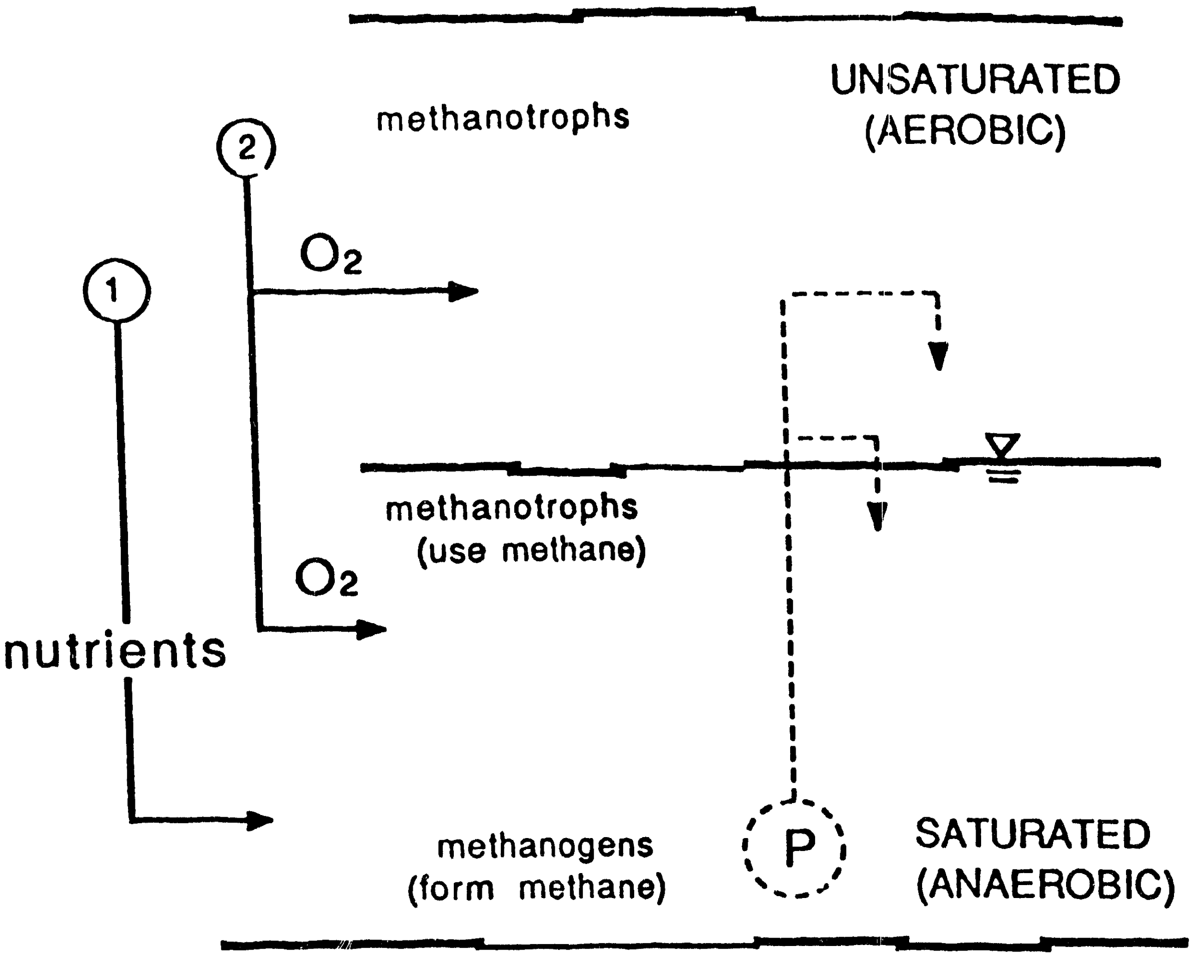

Figure 2. Sequential degradation of solvents.

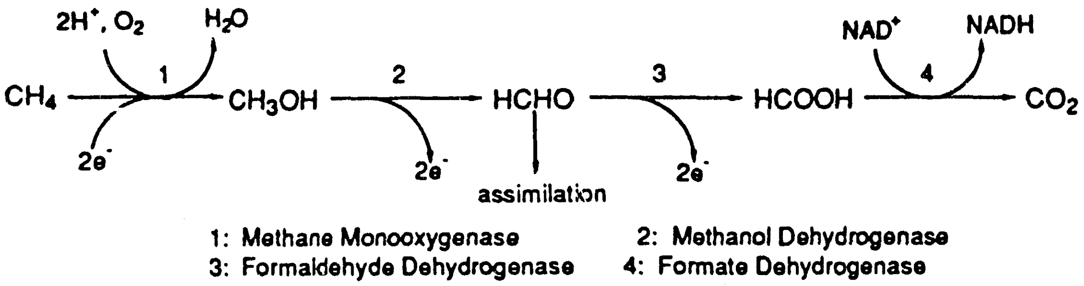

Figure 3. Metabolic pathway for methane oxidation in methanotrophic bacteria. The numbers above the arrows refer to the enzymes listed below the pathway.

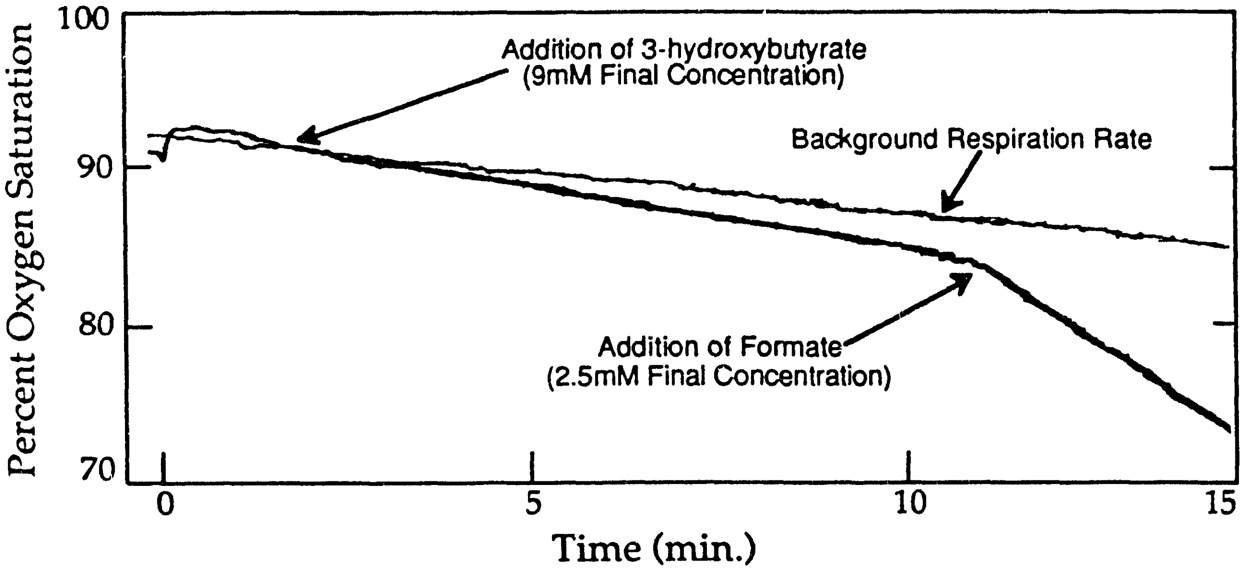

Figure 4. Relative effects of formate and 3-hydroxybutyrate on the respiration rate of *Methylosinus trichosporium*.

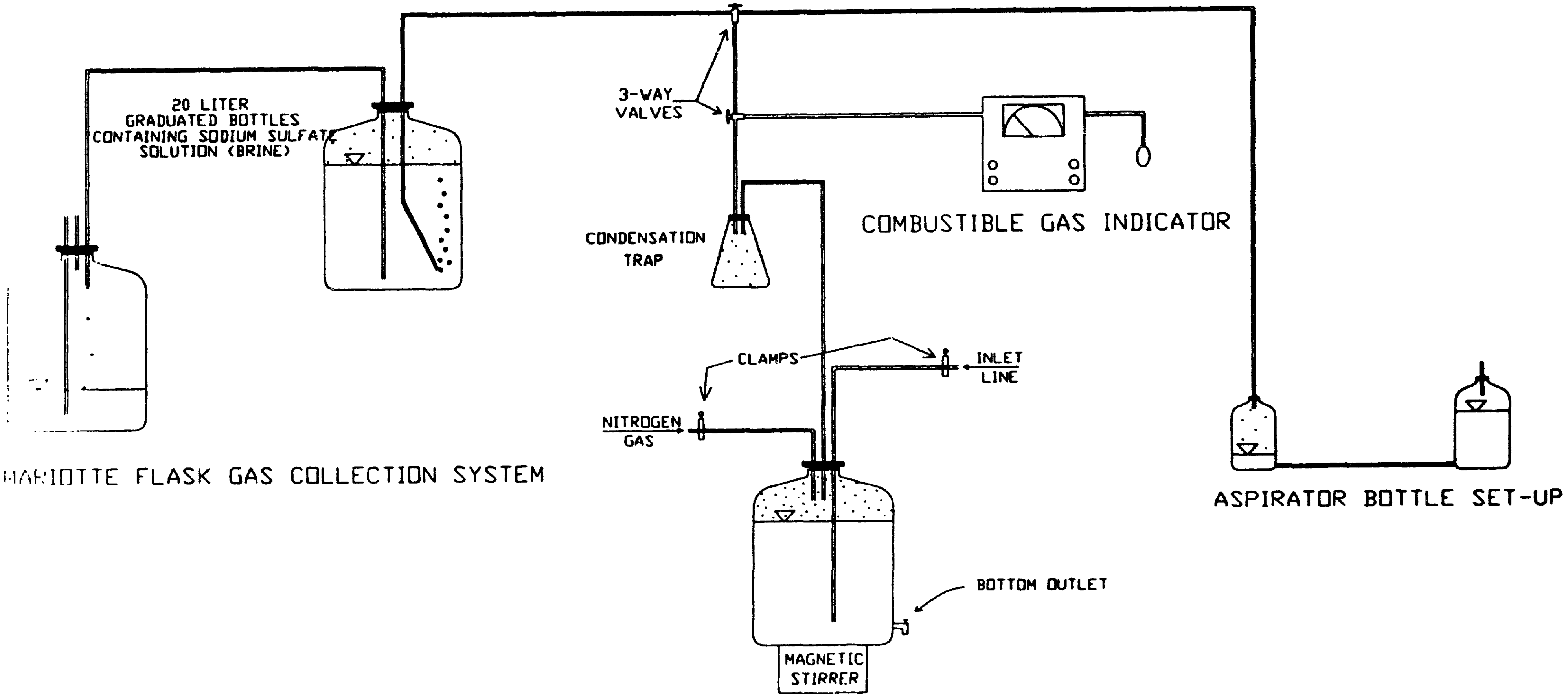

Figure 5. Maintenance reactor system.

EXCAVATION SYSTEMS FOR HAZARDOUS WASTES SITES
Dust Control Methods for In-Situ Nuclear Waste Handling

Quarterly Technical Progress Report
for Period April 1 through June 30,1993

Work Performed Under Contract
No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By

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ABSTRACT

This report covers the period of activity from April 1, to June 30 1993 for the research project No. DE-FC21-92MC29467. A main portion of this reporting period has been devoted to continuously build up the necessary information for designing the excavation system and process flowsheet alternatives with minimum hazardous waste dust in the following tasks: 1) to survey the literatures and contact the potential manufactures directly for the equipment used in transportation, classification, size and volume reduction, loading/storage, and personal protection; 2) to establish a list of foams for vapors and dust control based on the functional groups and types of wastes, and to establish a guideline for selecting the foams; 3) to compile the in-situ recovery techniques for hazardous vapors and gaseous products; and 4) to establish a list of techniques for decontamination and demolition of the buildings, equipment and structures.

A large number of excavation, transportation and size reduction equipment is available in mining and processing industry. The lists of equipment are established. The guidelines for equipment selection and designing the excavation system and process flowsheet alterna-tives are established. The factors that affect the selection of equipment for excavation and process flowsheet alternatives depend on the characteristics of wastes, site geological conditions, meteorological conditions, and specifications of downstream remediation treatment methods.

For dust control, the prevention and suppression techniques may be applied. The prevention technique is to extract the excessive VOCs vapors and radioactive gases by applying in-situ recovery techniques prior to excavation activity. During the excavation activity, water may be sprayed to control the dust. A more effective way of dust control during excavation is the application of foams which may control the vapors, gases and particulates simultaneously. Foams have been used in the mining industry, fire extinguishers and chemical spills, but not many foams have been used at hazardous waste sites. A list of foams based on the functional groups of the wastes has been established. The foams can be formulated with selected surfactants, stabilizers and/or additives for dust control at the waste sites. To avoid the health risk as a result of the interaction between the wastes and foams, the foams must not be applied to any unknown wastes without prior laboratory testings.

The hazardous waste sites may have buildings, equipment and structures which may need to be decontaminated and demolished before a site clean-up can be more effectively performed. Literature review related to decontamination and demolition techniques are in progress and will be extended to the next reporting quarter.

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1. INTRODUCTION

Cleaning up the Nation's abandoned hazardous organic and nuclear waste sites is a top environmental priority of the decades. Those hazardous waste sites contain the contaminated soils, liquid sludge, concrete blocks, buildings, structures, equipment, weapons, arsenals, etc. Currently, more than 1200 sites are included in the National Priorities List and many more have been proposed for inclusion on the list. Many remedial technologies can be used to clean up the hazardous waste sites. A site clean up may require on-site material handling and processing techniques including soil excavation and transportation (Church, 1981), decontamination and/or demolition of the contaminated buildings and structures as well as size reduction. In many cases, the excavated waste materials and demolished structures require additional preparation (Weiss, 1985, Dosani and Miller, 1992) including classification, size/volume reduction, transportation and re-storage to prepare the waste materials suitable for further remediation treatments, i.e., soil washing, photo-catalytic water treatment, biological degradation process, incineration, etc.

Excavation, removal and transportation of the in-situ wastes materials generate considerable dust in each step. If those activities are applied to the handling of the hazardous organic/nuclear wastes, in-situ VOCs and radioactive gases recovery must be applied, and proper selection of equipment and operation procedures with dust control techniques must be implemented to eliminate toxic vapors, radioactive gases and dust exposure to all workers involved. Thus, the objectives of this project are 1) to survey the techniques of in-situ VOCs vapor and radioactive gases recovery, and 2) to survey and select the existing or any other novel equipment employed in the mineral/coal mining and processing industry and design the excavation system and process flowsheet alternatives by emphasizing on the dust control for cleaning up the hazardous waste sites.

2. EQUIPMENT FOR PROCESSING, TRANSPORTATION AND OTHERS

The selected equipment used for excavation under three excavation systems was summarized in the Second Quarterly Report for the period from January 1 through March 31, 1993. In this report, the equipment for transportation, classification, size and volume reduction, loading, re-storage and personal protection are surveyed and summarized below:

2.1 Equipment for Transportation

After the hazardous/nuclear wastes are excavated, the destination of the excavated wastes depends on the downstream on-site or off-site remediation, i.e., for re-storage and/or further treatments. The equipment of transportation on site can either be parts of the excavation equipment themselves such as the front-end loader or selected transportation equipment. Various sizes of trucks or conveyor belts may be considered depending upon the transporting distance, required capacity and surrounding condition on site. Off-site transportation is for long distance movement of processed or unprocessed excavated materials from the waste sites to designated treatment or disposal sites. The highway truck is often used for off-site transportation. Some manufacturers which produce or deal with front-end loaders and trucks are listed in Table 1.

2.2 Equipment for Processing--Mechanical Classification, and Size/Volume Reduction

Equipment selection for classification as well as size/volume reduction depends on i) waste types; ii) moisture content of wastes; iii) initial size of the feeding wastes and size reduction ratio; iv) volume of waste to be processed, and; v) specifications of the downstream remediation processes. Multistage crushing & grinding circuits may be needed if a large reduction ratio is required. The location of crushing/grinding plants including equipment for classification and size and volume reduction should be on-site or relatively closer to the excavation sites. Although mobile plants can be setup either on-site or off-site, on-site waste processing including sorting, classification, crushing/grinding plants are generally more favorable, because on-site classification and reduction processing are more economical and efficient to avoid unnecessary transportation, loading/unloading and further dispersion of the contaminants. Some manufacturers which make the equipment for mechanical classification and size/volume reduction, particularly for wood, papers, rubber and plastic types of wastes are shown in Table 2. For the wastes containing contaminated clay soils, rocks, concrete blocks, bricks, etc., none of the shredder types of equipment are suitable. Wear would be unacceptable. Conventional and innovative types of crushers, mills and pulverizers used in the mineral/coal processing plants should be considered and selected. A large list of equipment and their auxiliary equipment are in the handbook of Mineral Processing (Weiss, 1989). However, not all the equipment used in the mineral/coal processing industry are suitable for waste processing. Thus, guidelines for the selection of processing equipment have been established based on the characteristics of the initial wastes and specifications of the wastes products. Some manufacturers who produce or deal with the equipment for mechanical classification, feeders, hoppers and others are exhibited in Table 3, while some manufacturers who produce and deal with the equipment for size reduction is given in Table 4, respectively.

2.3 Equipment of Loading/Storage

Under the following situations, certain loading, feeding and storage equipment may be needed, which may include cranes, portable or special types of conveyors such as screw conveyor and product/recycle conveyors, chutes, feeders, grizzly scalpers, vibrating screens, etc: i) when the excavated wastes are loaded onto transportation equipment or directly fed into a classification and/or size/volume reduction equipment, and ii) after size/volume reduction, the wastes need to be transported to a designated destination for treatment and/or storage.

Except for some excavation equipment such as the front-end loader, the rough terrain forklifts, skid-steer loaders and draglines can be used as parts of the loading/storage equipment. Other excavation equipment can also serve this purpose. Table 5 shows examples of feeders and other special types of equipment for loading and storage of the hazardous wastes.

2.4 Equipment for Personal Protection

Proper selection and use of a personal protective equipment are crucial to the workers' safety and health. According to Subpart I of OSHA regulation 29 CFR 1910, the protective equipment shall be provided, used, and maintained wherever it is necessary by reason of hazardous of processes or environment. Thus, a personal protective equipment is designed to permit for safe work and operations by preventing i) skin contact, ii) dermal absorption and inhalation, and iii) inadvertent ingestion of potentially toxic agents. It is also designed to protect the worker from physical injuries such as eye wounds, bruises, abrasions and lacerations.

Based on the waste types and dust distribution on sites, the personal equipment necessary to protect the body against contact with known or anticipated chemical hazards can be divided into four different categories. Each affording a different level of protection (EPA 1982). When conditions are uncertain, the maximum level of personal protective equipment should be used. The applicable conditions for four classified personal protective equipment are: 1) Level A is for the highest level of respiratory, skin, and eye protection; 2) Level B is for the highest level of respiratory protection but a lesser level of skin protection. Level B is the minimum level recommended on initial site entries until the hazards are further defined; 3) Level C is selected when the airborne substance is known and the criteria for an air purifying respiration are met, as in the case of most buildings and equipment decontamination operation; and 4) Level D is selected when there are no respiratory or skin hazards. The lists of the components of personal protective equipment are given in Table 6, and the guidelines for selecting the personal protective equipment are established according to the above mentioned four classifications.

Table 1 Equipment Used for Transporting the Waste Materials

Manufacturer	Front-end Loader	Truck
Caterpillar Tractor Co.	Wheel mounted 65-690 FWHP 1.5-36 cu. yd.	Rear dump, 640 - 1200 FWHP 35-85 tons cap.
Dart Truck Company	Wheel mounted 700-818 FWHP 7-30 cu. yd.	Rear dump, 640-1100 FWHP 65-120 tons cap. Bottom dump 635-1100 FWHP 100-160 tons cap.
John Deere & Company	Wheel mounted 71-260 FWHP 1.25-7 cu. yd.	
DJB Sales, Inc.		Rear dump, 235-450 FWHP 27.5-5 tons cap.
Euclid, Inc.		Rear dump, 228-1520 FWHP 25-170 tons cap. Bottom dump, 300-1050 FWHP 30-150 tons cap.
Fiat-Allis Construction	Wheel mounted 80-335 FWHP 1.5-6.5 cu. yd.	
International Harvester, Inc. Construction Equipment Group	Wheel mounted 51-1075 1.5-6 cu. yd.	Rear dump, 395-600 FWHP 36-50 tons cap.
Hitachi construction Machinary Corp. Kawasaki Heavy Industries Ltd.	Wheel mounted 67-305 FWHP 1.5-6.5 cu. yd.	
T & J Industries, Inc.		Rear dump, 160-575 FWHP 13-65 tons cap.
WABCO Construction & Mining Equip., Div. of American Standard Inc.		Rear dump, 420-2250 FWHP 35-250 tons cap. Bottom dump, 1000-1450 FWHP 150-170 tons cap.

Table 2 Shredders/Compactors for Waste Processing

NAME	MANUFACTURER	FEATURE
Mobile Shear	LaBounty Manufacturing Inc.	High tensile, high alloy, abrasion-resistant steel; processing steel beams, reinforced steel pipe, rail cars, tree stumps and tires; 360° continuous rotation; high performance cylinders; angle actuators; range in sizes to fit from skid-steer loaders to excavators.
Shredders	MAC/Saturn Corp. Shredding Systems, Inc. Hi-Torque Shredder Co. Jersey Stainless, Inc. Eidal International Sales Corp.	Hydraulic-driven rotary shear-type shredder; low noise; low dust; automatic reverse, non-jamming capability; low speed and high torque; replaceable cutters, spacers; cutting accomplished by drawing material past interfaces of 2 counter-rotating blades in close tolerance; can handle hazardous/nuclear wastes, tires and rubber, ferrous and non-ferrous materials, soil waste and batteries.
Shredder/compactor System Rip-shear Shredder	MAC/Saturn Corp. S & G Enterprises Corp. Compaction Technologies, Inc. Consolidated Balers & Compactor William Patent Crusher and Pulverizer Co., Inc.	Shear-type shredder combined with a high density compactor; automatically shreds and compact metals (including drums and conduits), wood, cardboard, rubber, cloth, paper, etc; bales are 15 in. x 30 in. by variable lengths; 3 bales automatically loaded into a 45 cu. ft container.
Shredder-Mixer Earth Materials Processor/Composer	Powerscreen of America, Inc. Royer Industries Compost System Co.	Conveyor and stone grate; hydraulic brakes; highway tires; shredding belt; lump breakers; trash-away conveyor; variable sweep and deflector.
Drum Grappler Barrel Handler	LaBounty Manufacturing, Inc. Gensco Equipment Co. Ltd. Mack Manufacturing, Inc. Downs Crane & Hoist Co., Inc.	Specially designed barrel handlers for moving barrels, including those of hazardous wastes; 360° rotating turntable mechanism; 3/4 in. sparking neoprene lining; made with high-alloy, high-tensile, abrasion-resistant steel; heat-treated alloy pivot bearings; fits most excavators and backhoe.

Table 3 Feeders, Mechanical Classifiers and Other Auxiliary Equipment for Waste Processing

Item	Manufacture	Description
Portable Belt Conveyors	FMC Corp, Material Handling Div.	
Stationary/Vibrating Grizzlies	Fuller Company, F. L. Smith-Fuller Engineering Group Nordberg, Inc. Stephens-Adamson, a McNally Wellmen Co.	For preliminary scalping purpose (material larger than 6") grizzlies should be selected prior to using the crusher
Portable Vibrating Screens	Allis Mineral Systems, Sala Machine Work Div. FMC Corp. Power Screen of America, Inc. Kason Corp. Read Corp. Simplicity Engineering Stephens-Adamson, a McNally Wellmen Co.	Screen powered by a 47 hp air-cooled diesel hydraulic unit; twin road wheels, heavy-duty tow bar and hydraulic jacking leg; screen mesh sizes range from 1/4 in. to 4 in.; screening angle adjusts from 12° to 25°
Feeders, Chutes, Hoppers, Tarp, Others	Allis Mineral systems, Sala Machine Work Div. FMC Corp. Simmons-Rand Co.	

Table 4 Size Reduction Equipment for Waste Processing

Item	Manufacture	Description
Reversible Impactors (Impact) Twin Rotor Impactors	Fuller Co. McLanahan Corp. Nordberg Inc. Pennsylvania Crusher, Inc. Williams Patent Crusher and Pulverizer Co., Inc.	These impactors are capable of handling wet and sticky materials that would clog most other crusher. They produce maximum of fines and is widely used in brick and clay plants as a secondary crusher, but they can be used as the primary tailing crushers. Multistage cushing circuit may be needed for high size reduction ratio.
Autogenous Grinding Mills Semi-Autogenous Grinding Mills Non-Reversible Hammer Mills (Impact and Scrubbing)	Allis Mineral Systems, Grinding Div., Svedala Industries, Inc. Gruendler Crushers Nordberg Inc. Stedman Machine Co.	Variety of grinding mills which are used in hardrock processing plants can be selected for high size reduction ratio depending on the feed conditions, capital investment and product specifications. Single stage grinding circuit may be sufficient for high size reduction ratio. The hammermills which is operated based on dynamic impact, attrition and shear forces have high reduction ratios for handling dry materials.

Table 5 Equipment for Loading and Storage

NAME	MANUFACTURER	FEATURE
Crane	Grove Manufacturing Co. National Crane Demag Cranes Abell-Howe JLG Cranes	Truck-mounted rough terrain hydraulic crane; telescopic swing away extension (maximum 30° angle); loads moment and anti-two block system with audio-visual warning and control level lockout; electric display of boom angel, length, radius, tip height, relative load moment; ball bearing swing circle with 360° audio-visual warning system; hoist mirrors.
Mixer Mini-Maxcrete	Maxon Industries Philadelphia Mixers Corp. VFL Technology Corp. Davis Pugmill Inc.	Mixer-agitator with double reduction chain drive with high pressure orbital hydraulic motor driving heavy-duty shaft with 8 urethane paddles; tilt-away grid top for loading, visual mixing inspection; 3-position mixer control (change/stop/discharge); gate has double-acting cylinder with inching control for metered discharge.
Mobile Belt-Loader	General Motors Corp.	Associated with excavation in flat or gently rolling area, where cuts are long and materials haulers function well.
Movable Belt-Loader	Holland Co. Athey Products Corp.	Suitable for hilly and mountainous terrain, where cuts are short and haulers are stationary at the loading location.

Table 6 Personal Protective Equipment

COMPONENTS	LEVEL A	LEVEL B	LEVEL C	LEVEL D
Pressure-demand, self-contained breathing apparatus approved by NIOSH and MSHA	x	x		
Full-face, air-purifying, canister-equipped respirator approved by NIOSH and MSHA		x	x	
Fully encapsulating chemical-resistant suit	x			
Chemical-resistant clothing (coveralls, hooded, two-piece chemical-splash suit; chemical-resistant hood and apron; disposable chemical-resistant coveralls)		x	x	
Coveralls	*	*	*	x
Long cotton underwear	*			
Gloves (outer), chemical-resistant	x	x	x	x
Gloves (inner), chemical-resistant	x	x	x	x
Boots, chemical-resistant, steel toe and shank	x	x	*	*
Hard hat (under suit)	*	*		
Disposable protective suit, gloves and boots (over fully encapsulating suit)	x			
2-way radio communication (intrinsically safe)	x	x	x	
Escape mask			*	*
Safety glasses or chemical-splash goggles				*
Hard hat (face shield)		*	*	*

Notes: x - required
* - optional

3. IN-SITU VAPOR AND RADIOACTIVE GASES RECOVERY AND OTHER REMEDIATION TECHNIQUES

Many sites with organic and nuclear wastes contain a high concentration of hazardous organic vapors and radioactive gases. The concentration of the hazardous vapors and gases will impose a high risk of inhalation by the workers at the clean-up sites. There are nineteen innovative recovery or delivery technologies for in-situ remediation of waste sites. The recovery or delivery technologies are the processes that facilitate the transportation of materials either into or out of the subsurface. For prevention and control of organic vapors and radioactive gases, the following in-situ recovery and/or prevention techniques should be evaluated and considered for each specific waste site to be cleaned-up. Reduction of excessive hazardous vapors and radioactive gas emission during or prior to the excavation activities are very much needed for the workers' health and safety. The selected in-situ techniques are described below:

1) **Vapor/Gaseous Extraction Technique**

A vapor extraction system (VES) (Tera Vae, Inc. 1989) involves the recovery of vapor-ladened air from unsaturated soils by applying a vacuum to the extraction wells. The process appears to be limited to those contaminants that exhibit significant volatility at ambient temperatures.

2) **Modified Air Flushing Technique**

In the above-mentioned technique, if the soil hydraulic conductivity is low, the effect of vacuum extraction may decrease. The modified air flushing technology is designed to accelerate the movement of vapors or gaseous materials through the contaminated soils by using the soil flushing method to increase the hydraulic conductivity prior to vacuum extraction.

3) **In-Situ Steam Stripping Technique**

In situ steam stripping (Toxic Treatment, 1991) is a method intended to recover not only highly volatile but also moderately low vapor pressure organic compounds from the contaminated soils. The rate of vaporization and transport of these compounds increase as a result of the increasing soil temperature following contact with the steam. The steam has two main functions: it vaporizes the contaminants and becomes the transport medium for the vaporous materials. A partial vacuum (under pressure) can accelerate the rate of volatilization and speed the transport of contaminants to the collecting points.

4) **Ground Freezing Technique**

This technique is based on the potential to migrate the concentrate solutes. When pore water freezes slowly, crystals of nearly pure ice form, and any dissolved species are concentrated in pockets or form thin films of liquid around the solid particles. The film around the particles can be very mobile allowing ion movement to occur through diffusion. Ground freezing has a potential for remediation because contaminants apparently can be concentrated ahead of the freezing fronts. By concentrating on the contaminants, artificial ground freezing can be used to reduce the volume of the contaminated soils at a site and thereby facilitate remediation.

5) **Freezing Soil Technique**

The freezing soil technique has been applied in mining and petroleum industries for well and shaft drilling by freeing the ground water . This technology can be used in low degree freezing of the soil during excavation to lower the vapor pressure of the hazardous organic wastes and minimize the formation of radioactive gases.

Other techniques including cyclic pumping, radial-well drilling, hydraulic fracturing, carbon dioxide injection, jet-induced slurry method, ultrasonic application, kerfing technique, electro-kinetics osmosis technique, etc., to increase the hydraulic flow barriers can be considered to enhance the delivery and recovery and to improve the implementation of the technologies for in-situ recovery.

4. VOCS VAPORS AND DUST CONTROL

Superfund and other hazardous waste sites in the United States are organic wastes or contain organic wastes, even in some nuclear waste sites. Volatile organic compounds (VOCs) are often encountered in organic wastes. VOCs may continuously volatilize into air, or react with other substances to produce gaseous emissions during excavation. These gases, in addition to being potentially hazardous, also may carry radioactive particles into the air. Details concerning the determination of vapor emission rate will be reported in the next quarterly report.

The most common practice in the mining industry is the application of liquid spray for dust control, i.e., water spray or water with selected surfactants (Charlton, 1984; Chander, et al., 1991) by air spargers. This method may not be very effective when they are applied to dust control in hazardous waste remediation. Foams may be a better choice to reduce or halt the generation of toxic or flammable vapors from volatile liquids or solids. These foams may also effectively suppress the particulate emission during excavation. Although foams have been used to control the vapors of chemical spills (Hiltz and Gross, 1980; (Gross, 1978, 1980); Hiltz, 1983 a, b), fire, and coal/mineral dusts (Hiltz and Friel, 1973; Bhaskar and Gong, 1992), not many foams have been applied for dust control at hazardous waste sites.

4.1 Types of Foams

There are six basic types of foams available for use on controlling VOCs.

1) Regular Protein Foams (RPFs). RPFs are composed of an animal protein (keratin hydrolyzate) with polyvalent cations and other stabilizing elements. They are effective for control of some hydrocarbons such as toluene, ethylbenzene, gasoline, etc.

2) Fluoroprotein Foams (FFs). FFs are designed for control of some ester (such as n-butyl acetate, vinyl acetate, etc.), and some hydrocarbons (such as toluene, cyclohexane, etc.).

3) Surfactant Foams (SFs). SFs are made of surfactants, water and air, and can be used to control hydrocarbons (aliphatic, aromatic and industrial) and some liquified organic gases.
4) Aqueous Film Forming Foams (AFFFs). AFFFs are made from mixtures of fluoroprotein surfactants and conventional surfactants and are designed for control of hydrocarbon vapors.
5) Alcohol Type Foams (ATFs). ATFs consist of an AFFF, regular protein, surfactants, or fluoroprotein base with a metal stearate additive (salt of stearic acid) or a polymeric additive. They are made to control hydrocarbon and polar solvent (water miscible) vapors
6) Special Foams (SFs). In addition to the above mentioned types of foams, there are at least three foams that were specifically formulated to control hazardous vapors. These are Hazmat NF #1, Hazmat NF #2, and MSA Type V. Hazmat NF #1 and Mazmat NF #2 are designed to be deal with alkaline and acid vapors, respectively. MSA Type V is used to control vapor hazards from water-reactive volatile chemicals, and has a pH tolerance between 2 and 10. These foams have special additives that allow them to be used on materials that destroy other foams.

4.2 Foam Quality

1) Expansion ratio

The expansion ratio is a dimensionless number that expresses the ratio of the volume of foam to the volume of foam concentrate that produces the foam. Expansion ratios are defined as follows: i) high-expansion foam has an expansion ratio greater then 250 and lasts for one hour or more; ii) a medium expansion foam has an expansion ratio of 20-250 and lasts about 30 minutes; and 3) a low expansion foam has an expansion ratio of less than 20 and lasts about 15 minutes or less. If a dense foam is preferred, then low expansion forms should be selected. High expansion foams generally produce more thinner foams which may have less suppression effect.

2) Quarter Drainage Time

Quarter drainage time refers to the time it takes for a foam to release 25% of the total liquid incorporated into the foam. Long quarter drainage times are indicative of stable foams which are capable of suppressing vapor from chemicals for long time period before reapplication is necessary (assuming the foam is compatible with the chemicals). High-expansion foams exhibit the longest quarter drainage time.

4.3 Applications and Considerations of Utilization of Foams During Excavation

There have not been many applications of foams in hazardous sites. IT corporation (1992) used vapor-suppressing foams to control vapors during excavation of hazardous organic wastes. The vapor-suppressing foams were made by combining a foaming agent (FX-9162) and a stabilizer (Fx-9161) with water and air, using an eductor system, and spraying this solution through an air-aspirating nozzle. Each agent is proportioned into the water line at a concentration of 6%. The foam "sets-up" (makes the transition from a fluid to a flexible solid foam) in about 2 minutes. The effectiveness of the stabilized foam as a vapor-suppressing medium is influenced by foam variables such as formulation, foam depth, expansion ratio, and age, as well as the nature of the particular hazards. Laboratory and field tests were conducted with aqueous stabilized foam to investigate the effects of foam variables and the nature of the hazards on vapor suppression performance (Alm et al., 1987). The following trends were noted:

(1) For a period of days, the percentage suppression of hydrocarbons did not change significantly. In a 12-day laboratory experiment with cyclohexane and a 7-day field trial with JP-5 fuel, the suppression was greater than 97%, even after the foam had dehydrated to form a membrane.

(2) With high-polarity VOCs such as acetone and MEK, suppression was in the 90 to 100% range for the first several hours, decreased to the 80 to 90% range after 10 hours for foam application weights of at least 0.62 g/cm^2. The higher polarity allows these VOCs to diffuse faster than other hydrocarbons through the aqueous matrix of the foam.

(3) In general, the vapor-suppressing properties of the stabilized foams were not greatly affected by variation in concentration of the FX-9162 foamer and Fx-9161 foam stabilizer components. Some improvement in suppressing acetone vapors was noted when FX-9161 stabilizer concentration was doubled from 6% to 12%, whereas a slight decrease in suppression of cyclohexane vapor was noted when the FX-9162 foamer concentration was increased.

(4) The application weight of the stabilized foam used should be determined by the nature of the hazards. Lowering the application weight of 4:1 expanded foam from 0.62 to 0.31 g/cm^2 did not significantly hurt performance on cyclohexane; however, doubling the application weight of the stabilized foam from 0.62 to 1.24 g/cm^2 on acetone cut emissions by more than 50%.

(5) Both laboratory and field tests showed that vapor suppression performance was affected by the foam expansion ratio, particularly with nonpolar VOCs such as cyclohexane. Foams of low expansion (4:1 to 8:1) provide the best control of many VOCs. In case of extremely toxic emissions, low-expansion foams are recommended. In some field situations, highly irregular surfaces makes a somewhat higher foam expansion a more practical choice.

The observations during trial excavation of the McColl Superfund site (IT Corp., 1992) showed that the foam vapor suppressants could control the vapors during excavation, but they were not as effective as expected. The foam appeared to react with the highly acidic waste and the reaction reduced the effectiveness of the foam. Because the foam contained more than 90% of water, which resulted in formation of a layer of mud on the surface of the wastes. The mud made traction difficult for the loaders and personnel worked at the site.

4.4 Selection of Foams

According to the literature survey, many experiences of the application of the foams were derived from the mining industry. However, many existing foam types are for the purpose of controlling silicates and coal dust particulates. Those foam types are not necessarily appropriate for the hazardous vapors, radioactive gases and dust control at the waste sites. There is a lack of information and technologies of using the foams in the control of hazardous vapors at the waste sites. Careful selection of the appropriate foam types for the hazardous wastes are crucial for the workers at the clean-up sites. After having selected the form types for the given specific wastes, laboratory tests should be conducted before deciding to adopt the foams for application. Possible risks exist, if the inappropriate foam types are selected for the given nuclear wastes/volatile organic compound wastes. They may cause i) vapor ignition, ii) explosion, iii) toxic effects, and iv) undesirable risk associated with unfavorable foam-chemicals interactions. Foams should **never** be applied for vapor control on materials that have not been tested. Table 7 shows some appropriate foam types for controlling vapors produced by specific compounds.

Table 7 Foam Selection for Hazardous Vapors Control

Group	Chemicals	Recommended Foam Types
Alcohol	Butyl Alcohol	Alcohol
	Methanol	Alcohol
	Octanol	Alcohol
	Propanol	Alcohol
Aldehydes and Ketones	Acetone	Alcohol
	Methyl Butyl Ketone	Alcohol
	Methyl Ethyl Ketone	Alcohol
Amines	Ethylamines	Alcohol Hazmat NF #1 MSA Type V
	Ethylene Diamine	Alcohol Hazmat NF #1 MSA Type V
	Hydrazine	Alcohol Hazmat NF #1 MSA Type V
	Methylamines	Alcohol Hazmat NF #1 MSA Type V
Ethers	Ethyl Ether	Alcohol
Esters	n-Butyl Acetate	AFFF Alcohol Fluoroprotein Protein Surfactant
	Methyl Acrylate	Alcohol
	Vinyl Acetate	Alcohol Fluoroprotein
Hydrocarbons (Aliphatic)	Ethane	Surfanctant
	Ethylene	Surfanctant
	Heptane	Alcohol Fluoroprotein Protein Surfactant
	Hexane	Alcohol
	Octane	Alcohol
Hydrocarbons (Aromatic)	Benzene	Alcohol
	Ethylbenzene	AFFF Alcohol Fluoroprotein Protein Surfanctant
	Toluene	Alcohol Fluoroprotein Protein

Table 7 Foam Selection for Hazardous Vapors Control (Continued)

Group	Chemicals	Recommended Foam Types
Hydrocarbons (Alicyclic)	Cyclohexane	Alcohol Fluoroprotein Protein
Hydrocarbons (Industrial)	Gasoline	Alcohol Fluoroprotein Protein Surfanctants
	Kerosene	Alcohol Fluoroprotein Protein Surfactants
	Naphtha	Alcohol Fluoroprotein Protein Surfactants
	Paint Thinner	Alcohol Fluoroprotein Protein Surfactants
Liquefied Organic Gases	Ethylene Oxide	Alcohol
	Liquefied Natural Gas (Methane)	Surfactants
Inorganics	Carbon Disulfide	Mazmat NF #2 MSA Type V
	Hydrochloric Acid	Hazmat Nf #2 MSA Type V
	Hydrogen Chloride (Anhydrous)	Hazmat NF #2 MSA Type V
Inorganic (continued)	Nitric Acid	Hazmat NF #2 MSA Type V
	Silicon Tetrachloride	Surfactant
	Sulfur Trioxide	Hazmat NF #2 Surfactant MSA Type V
	Titanium Tetrachloride	Hazmat NF #2 MSA Type V
	Ammonia	Surfactant
Inorganic Cryogens	Bromine and Chlorine	Hazmat NF #2 Surfactant MSA Type V

5. METHODS FOR DECONTAMINATION AND DEMOLITION OF BUILDINGS, STRUCTURES AND EQUIPMENT

For decontamination or demolition of contaminated buildings, equipment and structures (PEI Associate, Inc. and Battelle Columbus Lab, 1985), the special procedures and methodology to minimize the dispersion of hazardous waste dust into to the air are required. In the event of cleaning, dismantling and demolition, a large quantity of contaminated debris may expose the workers and/or nearby residents through airborne contamination. There are twenty one methods being proposed (PEI, Inc, 1985) to perform the decontamination and demolition of buildings, equipment and structures.

The decontamination and demolition methods include: 1) asbestos removal and encapsulation, 2) absorption of liquid contaminants, 3) physical dismantling, 4) demolition, 5) dusting/vacuuming/wiping methods, 6) contaminants encapsulation and enclosure, 7) gritblasting the surface of the abrasive materials, 8) hydroblasting/water washing, 9) Scalification the contaminants from concrete materials, 10) steam cleaning, 11) Sealant application to immobilize the contaminant in place, 12) photo-degradation of the contaminant, etc. A literature survey and evaluation of the methods for decontamination and demolition of the contaminated buildings, equipment and structures are in progress. It will be extended to the next reporting quarter in which more detailed results will be reported.

6. FUTURE WORK

A specific hazardous nuclear/organic waste site will be selected for conceptual design of the excavation system and process flowsheet alternatives. The selection of the specific site will be discussed with technical managers, as well as project and task managers of this project. Based on the selected waste sites, site information and characteristics of the waste will be collected.

The excavation and processing activities produce considerable secondary dusts when they are applied to handle the hazardous nuclear/organic waste materials to prepare the soils for further treatments, i.e., soil washing, adsorption and incineration. The efficacy of those equipment with secondary dust generation will be taken into account. Even in some nuclear waste sites, volatile organic compounds (VOCs) are often encountered in the organic wastes. VOCs may continuously volatilize and may carry radioactive particles into the air. Thus, the estimation methods of VOCs vapors and radioactive gaseous emissions/dispersion will be developed. In addition, dust emission/dispersion to the air from each excavation/transporting equipment will also be estimated by incorporating the air flow velocity once the waste sites are specified.

Decontaminating the buildings, structures, and equipment, as a special case for remediation of the hazardous/nuclear waste sites, is required in the clean-up of nuclear facilities and military arsenals. A literature survey for building/structure decontamination and demolition is in progress and will be continued. Some of the methods will be selected, evaluated, and upgraded with current techniques and improved equipment for the specified waste sites.

A large number of alternative equipment for the excavation and processing as well as technical information for dust control are needed to design the optimum excavation system and process flowsheets alternatives for minimization of dust during the remediation 4activities at the hazardous waste sites. To effectively design and transfer the information and technology to the end users in the university and industry, the establishment of a computer based information system for the design of the site-specific excavation and process flowsheet alternatives is very much needed. A continuation proposal for this work has been submitted.

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Chemical Destruction of Polychlorinated Biphenyls

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ABSTRACT

The general objective of this research is to first evaluate the existing technologies for destruction of polychlorinated biphenyls (PCBs) by chemical methods. Development of new chemical treatment procedures for dechlorination of PCBs will also be a major focus of this research project. The detailed reaction pathway for the dechlorination process will be carefully probed so as to gain fundamental understanding of the reaction mechanism. Such information will be invaluable in providing guidelines for designing an efficient and economical system.

In the first part of this report, the main focus will be on the assessment of the current technologies and the discussion of the basic chemical reactions behind these treatment procedures. The commercial processes as well as procedures recently published in the literature will be reviewed, including dechlorination of PCBs by sodium and other alkali metals, by the use of strong base, by catalytic dechlorination, and by photochemical degradation.

In the second part of this report, experimental results obtained from dechlorination of aromatic halides, including chlorobenzene, 4-chlorobiphenyl, Aroclor 1242, and Aroclor 1254, by sodium 1-dimethylaminonaphthalide (NaDMAN) will be discussed. The easy recovery of 1-dimethylaminonaphthalene from the reaction mixture offers a significant advantage for its use as an electron carrier for sodium metal during the dechlorination process.

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1. EXECUTIVE SUMMARY

It is the objective of this research to evaluate the existing technologies for destruction of polychlorinated biphenyls (PCBs) by chemical methods. We will also focus on establishing chemical treatment procedures for dechlorination of PCBs. We will probe into the detailed reaction mechanisms of various dechlorination processes so as to gain fundamental understanding of the reaction pathway. Such information will provide insight in designing an efficient and economical system.

In the first part of this report, the main focus will be on the assessment of the current technologies and the discussion of the basic chemical reactions behind these treatment procedures. Three commercial vendors listed with the Environmental Protection Agency (EPA) for their involvement in chemical dechlorination of PCBs have been contacted: (1) Trinity Environmental Technologies, Inc., (2) Chemical Waste Management, Inc., and (3) Roy F. Weston, Inc.

The Trinity Environmental Technologies, Inc. utilizes sodium metal to dechlorinate PCBs to inert biphenyl and sodium chloride. A general discussion of dechlorination of PCBs by sodium and other alkali metals is included in this report.

The Chemical Waste Management, Inc. utilizes a nucleophile-based process (the KGME process) that enables the destruction of halogenated aromatic compounds through the successive replacement of one or more halogen atoms with 2-methoxyethoxy moiety. A demonstration of this process was given at the ReSolve Superfund site at North Dartmouth, Massachusetts in the summer of 1992 under the sanction of EPA. Destruction of PCBs by nucleophilic displacement of chlorine atoms with a strong base is also reviewed in this report.

The procedure employed by Roy F. Weston, Inc. involves the use of zinc and a mild organic acid to generate nascent (atomic) hydrogen, which replaces aromatic halogen atoms in toxic organics in the presence of gentle heat and an unspecified catalyst. This process has been tested only in the laboratory in gram quantity and has not been scaled up to pilot plant level. Other catalytic dechlorination processes are also discussed in this report.

The direct photodegradation of PCBs with UV or sunlight irradiation proceeds with low efficiency. However, the efficiency of photodegradation can be dramatically enhanced with appropriate photo-sensitizers and other additives. The basic reaction mechanism of the photodegradation process is discussed in this report.

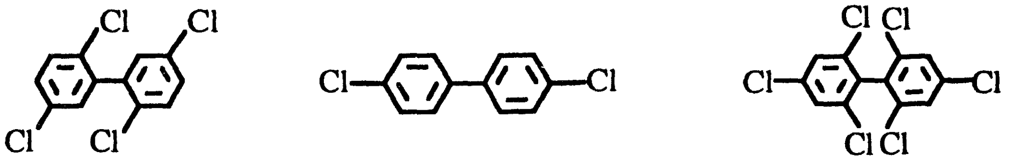
In the second part of this report, experimental results obtained from dechlorination of aromatic halides, including chlorobenzene, 4-chlorobiphenyl, Aroclor 1242, and Aroclor 1254, by sodium 1-dimethylaminonaphthalide (NaDMAN) will be discussed. The easy recovery of 1-dimethylaminonaphthalene from the reaction mixture offers a significant advantage for its use as an electron carrier for sodium metal during the dechlorination process.

2. INTRODUCTION

2.1 Background

Polychlorinated biphenyls, commonly referred to as PCBs, are one of the major organic pollutants in the environment. The chemical structures of three representative polychlorinated biphenyls are shown in Figure 1. The large scale use of PCBs for a variety of purposes, especially as a dielectric material in capacitors and transformers as well as plasticizers and solvents in plastics and printing inks, coupled with the chemical stability of PCBs against degradation have resulted in their worldwide accumulation in the environment.

Figure 1. Chemical Structures of Three Representative Polychlorinated Biphenyls



The total worldwide production of PCBs through 1980 is estimated to be approximately 2.4 billion pounds. Of the 1.25 billion pounds of PCBs estimated to have been produced in the United States, mainly by Monsanto under the registered trademark of Aroclor, about 24 million pounds are believed to have been released to the environment.

The toxic effects of PCBs have been well documented. One of the most famous cases occurred in Japan in 1968 when PCBs from a defective heat exchanger were leaked into rice oil which was then consumed by more than 1000 people.[1] For those who consumed more than 0.5 grams (average consumption was 2 grams), severe acne, darkened skin, and eye damage developed. Recovery was slow and these symptoms were still present even after three years. Numerous studies have also reported the toxic effort of PCBs to a wide range of wildlife, including mink, some species of shellfish, shrimp, and fish, and especially those birds that are at the top of the food chain, such as eagles, hawks, falcons, and pelicans.[2] The chronic (long-term) toxicity to humans and other species is yet to be fully realized.

2.2 Destruction of PCBs

Because of the thermodynamic stability of PCBs, destruction by incineration and other chemical degradation processes are difficult. Disposal of untreated PCBs by landfill is virtually banned by the Resource Conservation and Recovery Act (RCRA). Currently, incineration is still the most widely used method for treating many hazardous wastes, including PCBs. Incinerators are strictly regulated to assure effective destruction of PCBs. For example, the regulation requires 99.9999% (six-9's) efficiency for the degradation of nonliquid PCBs by incineration. However, despite such strict regulations it is possible that trace amounts of PCBs as well as other combustion byproducts, including the much more toxic polychlorinated benzofurans and dioxins, could still be released to the environment through stack emission. Concerns about the health impact of PCBs, dioxins, and other organic compounds formed and emitted into the environment have on surrounding communities have created many controversies and strong opposition from various environmental groups. It is now typical to take more than ten years and prolonged legal battle before an incinerator for industrial hazardous wastes could be constructed and operated. One recent example involves the Waste Technologies Industries (WTI) facility in East Liverpool, Ohio which will soon begin its test burn only after 13 years of planning and construction, more then 20 court cases, and even the intervention of the Vice President of the United States. In a recent article of the *Chemical and Engineering News*, many issues concerning hazardous waste incineration were raised and discussed.[3] It is clear that there is a need to continue research and development of alternative chemical processes for treating hazardous wastes in general and PCBs and other chlorinated aromatic compounds in particular.

2.3 Purpose and Scope of Report

It is the purpose of this report to first evaluate the existing technologies for the destruction of PCBs by chemical methods. We will focus mainly on the current commercial processes as well as procedures recently published in the literature, including dechlorination of PCBs by sodium and other alkali metals, by the use of strong base, by catalytic dechlorination, and by photochemical degradation. The basic chemical reactions behind these dechlorination processes will also be discussed. Experimental results obtained from dechlorination of aromatic chlorides by sodium 1-dimethylaminonaphthalide will also be discussed.

3. LITERATURE REVIEW OF CHEMICAL DESTRUCTION OF PCBS

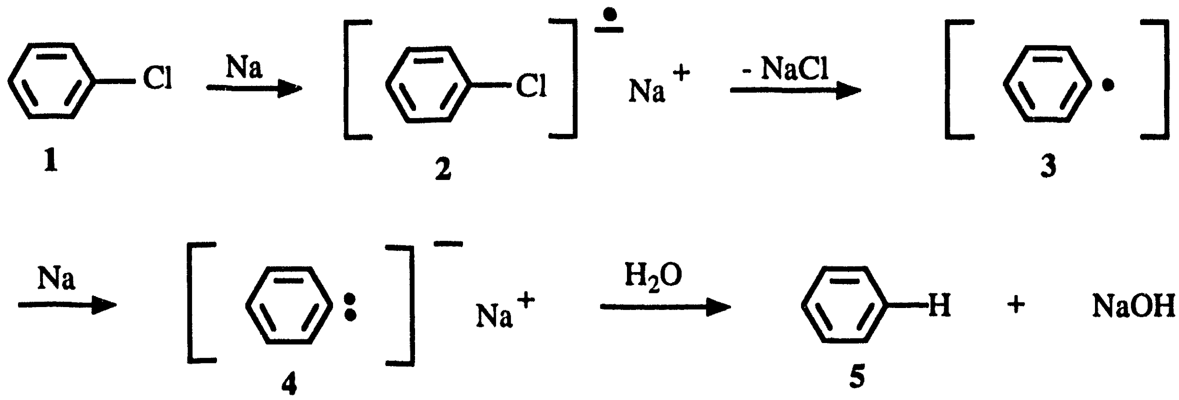
Development of chemical process for the destruction of PCBs and other chlorinated aromatic compounds continues to be a research area of intense interest. Limited success has been achieved in some specific cases. Excellent review articles of the chemical processes are available in the literature.[4] In addition, a recent monograph by Mitchell D. Erickson covered broad issues concerning PCBs, especially the analytical procedures.[5] In this report, four general methods for chemical destruction of PCBs will be reviewed.

3.1 Dechlorination of PCBs by Sodium and Other Alkali Metals

The Goodyear Tire and Rubber Company patented a sodium-naphthalide process for PCB destruction in 1981 and later released it for public use.[6] This process removes chlorine atoms from the PCBs and combines them with sodium to form sodium chloride (table salt).

The use of sodium metal for the dechlorination of aromatic compounds is well established in the literature.[7] The reaction mechanism is believed to involve first transferring an electron from sodium to the chlorinated aromatic compound, such as chlorobenzene (**1**) to form the corresponding radical anion, such as (**2**) (Fig. 2). The radical anion **2** then loses a chloride ion to form phenyl radical **3**, which then acquires an electron from sodium to form phenyl anion **4**. Subsequent quenching of **4** with water affords the dechlorinated adduct as benzene (**5**). In the case of PCBs, such reaction cycle is repeated several times until all the chlorine atoms are removed. The resulting anions then are quenched with water.

Figure 2. Dechlorination of Chlorobenzene by Sodium



Because sodium metal is not very soluble in organic solvents, the Goodyear process uses naphthalene as an electron carrier to improve the efficiency of electron transfer. The process normally takes 2 hours at 60°C for complete dechlorination. However, to effectively remove low levels of PCBs (ca. 100 parts per million, ppm) from contaminated oil down to ca. 3 ppm, far lower than the requirement set by the Environmental Protection Agency (EPA), a large excess of the reagent is required. Typically, the reagent to chloride molar ratio must be from 25 to 500 to obtain significant reduction of the PCB concentration. Quenching the excess sodium-naphthalide reagent with water must be conducted slowly and with extreme caution. This is because generation of hydrogen gas will occur if sodium is contacted with water, creating a potentially dangerous situation for explosion.

In 1984, Goodyear disclosed an improved process with the elimination of the water quench step.[8] The difficulties and disadvantages associated with a water quench of the alkali metal aromatic radical anion reagent are overcome by utilizing carbon dioxide (CO_2) as the excess reagent quenching material. No hydrogen gas is involved and at no time does water enter the system. The exclusion of water from the process allows for the recovery of the reaction solvent, such as tetrahydrofuran, in pure, dry form, eliminating additional process step, does not generate a waste water stream for disposal, and improves overall process safety.

The Goodyear process uses naphthalene, which has been classified as a priority pollutant by EPA, and its use is restricted. A number of processes have since been developed, utilizing other compounds as substitute for naphthalene.[9-11] The Sunohio, Inc. of Canton, Ohio developed proprietory compounds to replace naphthalene in a sodium-based process for reclamation of transformer oils containing PCBs. The Sunohio procedure was reviewed preciously.[9]

In a recently patented procedure, ammonium salt was used to accelerate the reductive cycle of dechlorination and to serve as a proton source to hydrogenate and quench the dehalogenated polyhaloaromatics.[10] It was also reported in a separate patented procedure that liquid hydrosiloxane could facilate the reductive dechlorination so that it will proceed to completion at room temperature in relatively short times.[11] It was claimed that PCBs are dechlorinated to biphenyl and its higher molecular weight oligomers with greater than 99% efficiency.

Currently, the sodium-based process is employed by the Trinity Environmental Technologies, Inc., using a modified version of the Goodyear process. It is claimed that this process is cost competitive compared to incineration for the treatment of PCB oils. However, this process will not be able to treat PCB contaminated soil. A block diagram of the Trinity process is given in Figure 3.

3.2 Destruction of PCBs by the Use of Strong Base

The use of strong base to attack PCBs has been investigated. The KPEG process, which uses potassium metal (K) and polyethyleneglycol (PEG) to destroy PCBs, is an example of such a treatment procedure.[4a] Potassium metal reacts with polyethyleneglycol, such as diethyleneglycol (**6**), to form the correspond alkoxide (**7**), a strong base, which than attacks PCBs by nucleophilic displacement (Fig. 4).

Figure 4. Destruction of PCBs by the KPEG Process

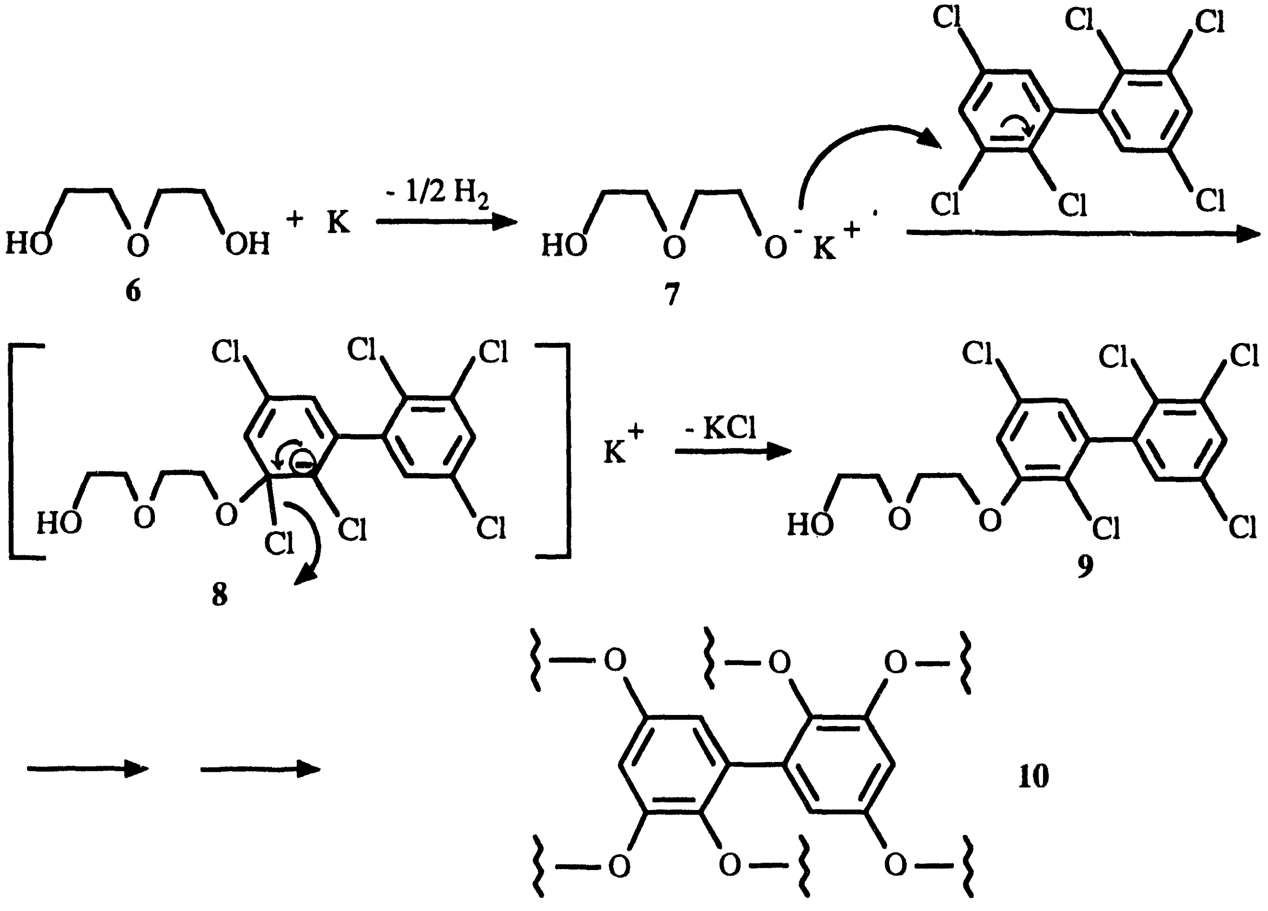
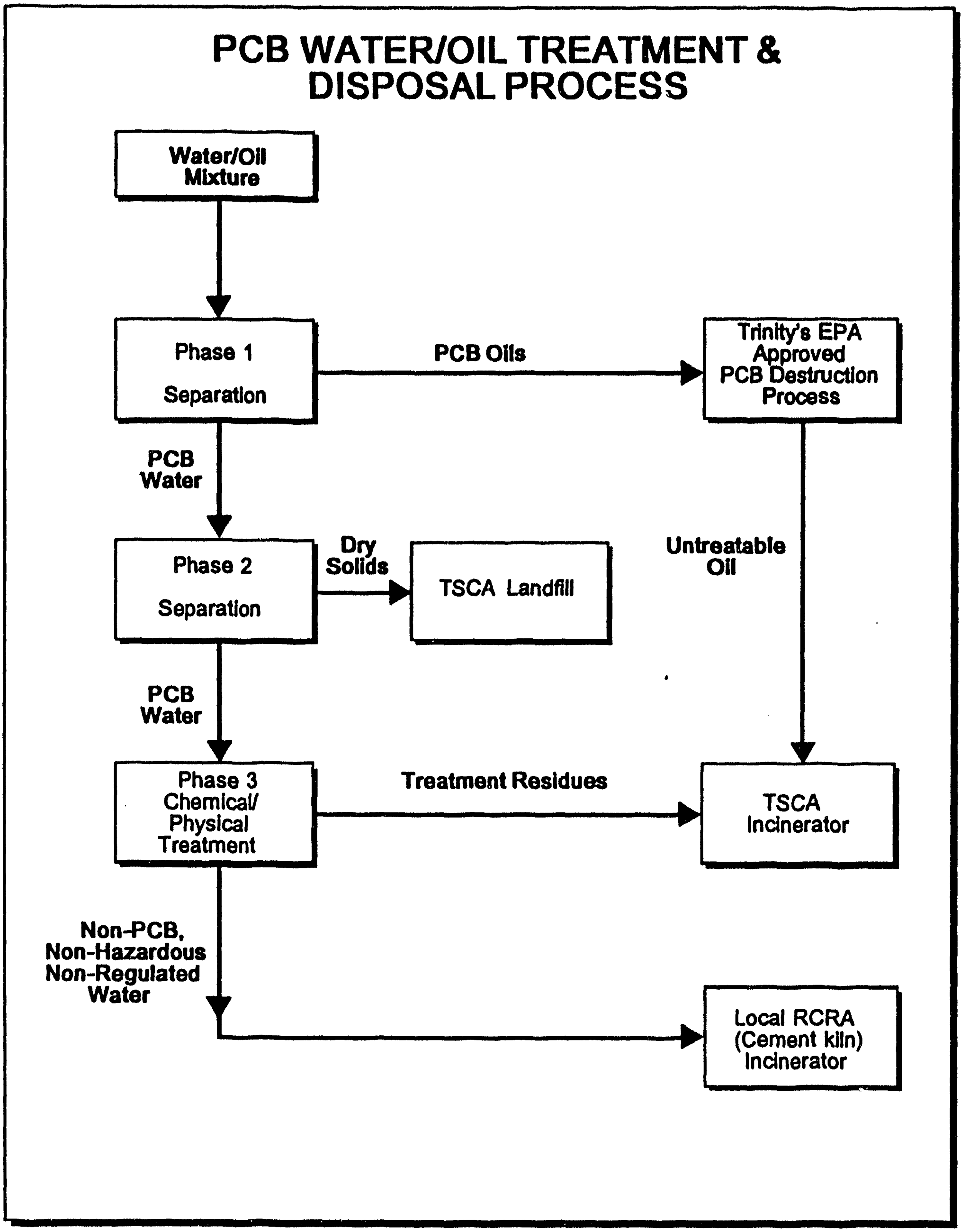


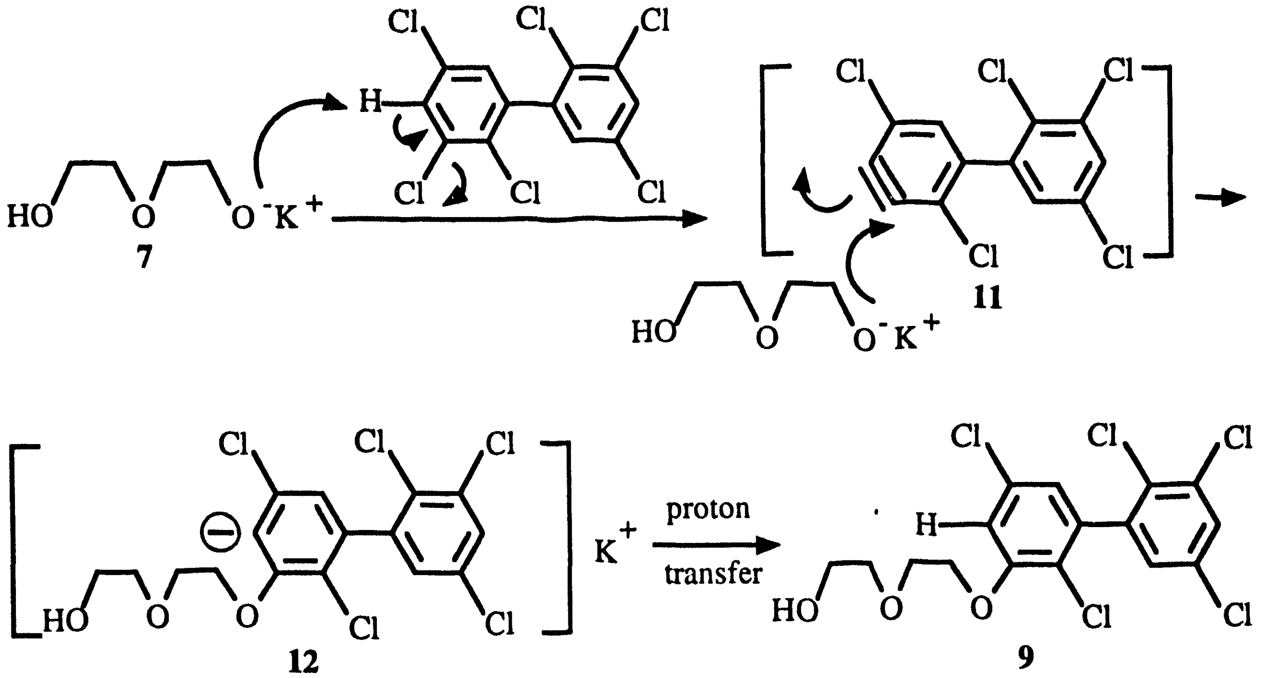
Figure 3. Block Diagram of the Trinity PCB Treatment Process



Although the exact reaction mechanism of the KPEG process probably has not been fully established. It can be speculated that for the highly chlorinated biphenyls, the electron deficient benzene ring could be attacked by **7** to form **8**. Subsequent loss of a chloride ion from **8** could lead to **9** with the net effect of replacing a chlorine atom with a polyethyleneglycol. After successive replacement of chlorine atoms with polyethyleneglycol, complete dechlorination to form polyhydroxylated biphenyls **10** could thus be achieved.

It is also possible that a competing reaction pathway involving the formation of a benzyne intermediate **11** may also be responsible for the dechlorination process (Fig. 5).[12]

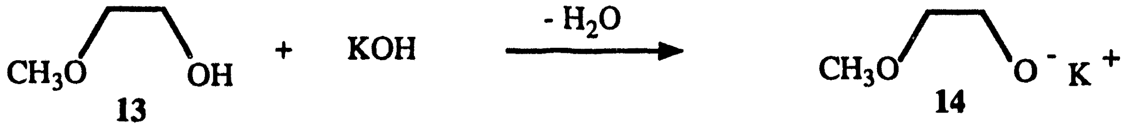
Figure 5. The KPEG Process via the Benzyne Pathway



Initial dehydrochlorination of PCBs to form benzyne **11** followed by the attack of **11** with an alkoxide would lead to **12**. Subsequent proton transfer could also result in the displacement of a chlorine atom by a polyethyleneglycol as shown in **9**.

Currently, a modified KPEG process is being utilized by the Chemical Waste Management, Inc. for the destruction of PCBs. The reagent, KGME (**14**), is generated in situ via the addition of KOH to 2-methoxyethanol (glycol methyl ether, GME, **13**), followed by azeotropic removal of water (Fig. 6). The use of KOH instead of potassium metal as in the KPEG process is an improvement which avoids the generation of hazardous hydrogen gas during reagent preparation.

Figure 6. Preparation of the KGME Reagent



A demonstration of the KGME process was conducted at the ReSolve Superfund sit at North Dartmouth, Massachusetts in the summer of 1992 under the sanction of EPA. Although a final report on the demonstration is not available at the present time, a private communication with Dr. Richard J. Ayen, Vice President and General Manager of the Chemical Waste Management, Inc., indicates that the KGME process is more expensive to operate than thermal desorption of PCB contaminated soil followed by off-site incineration of the resulting oil.

In early 1991, reports started to appear in the press indicating that quicklime, or calcium oxide (CaO), could destroy PCBs.[13] A success in such a process could mean a low cost remediation of PCB pollution. However, many researchers were skeptical of those reports because the basic chemical reaction between quicklime and water generates mainly $Ca(OH)_2$, which is a source of hydroxide ion. Hydroxide ion had not been shown to effectively destroy PCBs. Preliminary results from an independent study by the EPA's Risk Reduction Engineering Laboratory in Cincinnati suggest that the reduction of PCB content is mostly attributable to volatization and is not due to actual PCB destruction.[13,14]

3.3 Catalytic Dechlorination of PCBs

The catalytic dechlorination of PCBs at 180°C to biphenyl with 5% platinum or palladium on 60/80 mesh glass beads over hydrogen gas was reported by Berg *et al.* in 1972.[15] The use of 69% nickel on kieselguhr in the presence of sodium hydroxide and 50 atm of hydrogen gas at 115°C for 6 hours also effectively dechlorinated aroclor 1248.[16] It was later discovered that sodium borohydride could replace hydrogen gas as the reducing agent.[17] One example of the study showed that 0.3 mmol of Aroclor 1254 could be most effectively reduced to biphenyl (97%) by treating with 2.0 mmol of $NiCl_2$ and 60 mmol of sodium borohydride in 2-propanol at ambient temperature and pressure. The disadvantage of this process is that a rather large ratio of sodium borohydride to PCBs is required to reach complete dechlorination.

In a process patented by the Union Carbide Corporation in 1983,[18] 100 mg of a commercial Aroclor in 1 mL of methanol was treated with 0.03 g of $NiCl_2$, 0.5 g triphenylphosphine, 0.25 g NaI and 1.0 g of zinc dust in 10 mL of wet *N,N*-dimethyl formamide (DMF) at 60°C for 4 hours. The zinc dust in the presence of sodium iodide serves as the reducing means to keep the nickel in a zero valance state for effective catalytic dechlorination.

Currently, the Roy F. Weston, Inc. uses a catalytic dehydrochlorination procedure to remediate soils, sludges, and sediments contaminated with PCBs. The process uses zinc and a mild organic acid to generate nascent (atomic) hydrogen, which replaces aromatic halogen atoms in toxic organics in the presence of gentle heat and an unspecified catalyst. However, this process has been tested only in the laboratory in gram quantity and has not been scaled up to pilot plant level.

3.4 Photochemical Dechlorination of PCBs

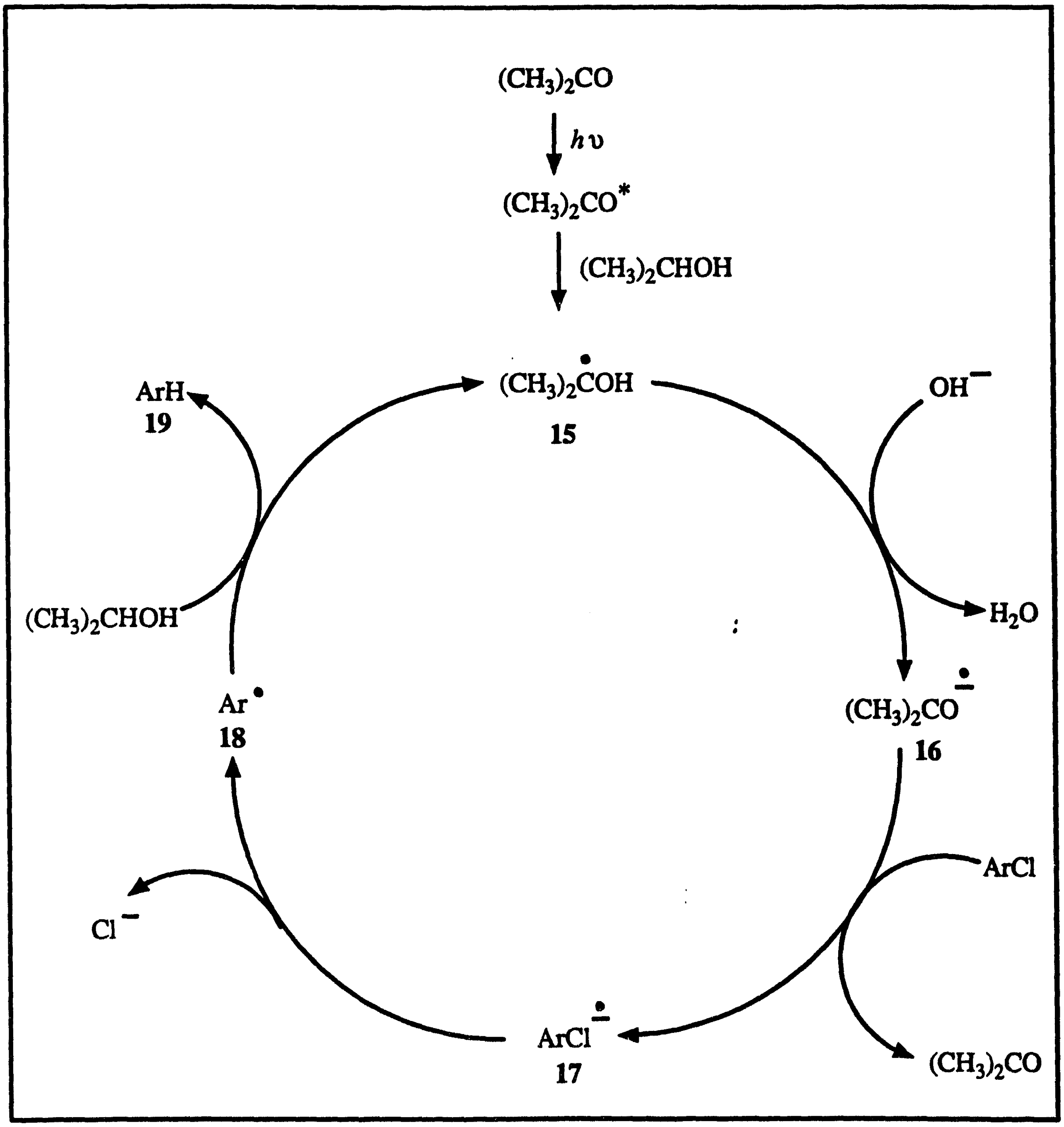
The use of photochemical methods for the destruction of PCBs have received considerable attention. The direct photodegradation of PCBs with UV or sunlight irradiation proceeds with low efficiency. This is because once the heavier chlorinated and more photo-sensitive biphenyls are depleted, the dechlorination process becomes very slow. Typically, only about 25% of Aroclor 1254 and 10% of Aroclor 1260 are reacted after 10 hours.[19a] However, the efficiency of photodegradation has been shown to be dramatically enhanced with appropriate photosensitizers and other additives. For example, it was reported that amines,[20] borohydrides,[19] alkaline alcohols,[21] and hydroquinones[22] greatly enhanced the rate of photodechlorination of PCBs in solution.

Recently, the use of acetone as a photosensitizing agent in alkaline 2-propanol has been shown to be particularly promising, allowing dechlorination of Aroclor 1254 at wavelengths compatible with those available from the sun.[23] Total disappearance of Aroclor 1254 and the formation of biphenyl occurred in less than 25 minutes.

A free radical chain reaction has been proposed to be the pathway of the photodechlorination process (Fig. 7). The acetone molecule is excited by irradiation to a high energy triplet state, T_1 (n,π^*), which then abstracts a hydrogen atom from 2-propanol to give the ketyl radical **15**. The ketyl radical then loses a proton to the alkaline medium, producing the ketyl radical anion **16**. The Aroclor in turn reacts with the ketyl radical anion through an electron-transfer process given unstable aryl radical anion **17** which releases a chloride anion, producing the aryl radical **18**. The aryl radical then abstracts a hydrogen atom from 2-propanol to furnish dechlorinated biphenyls **19** and the ketyl radical **15**, allowing the propagation cycle for dechlorination of PCBs to continue until all of the chlorine atoms are removed.

The acetone-induced photodegradation of PCBs is a very attractive method because of the low costs of the reagents. Unfortunately, under similar conditions photodechlorination of extracts of Aroclor 1254 contaminated soil proceeded with low efficiency. Clearly, continued research is needed to bring the photodegradation method to practical use.

Figure 7. Acetone-Induced Photochemical Degradation of PCBs

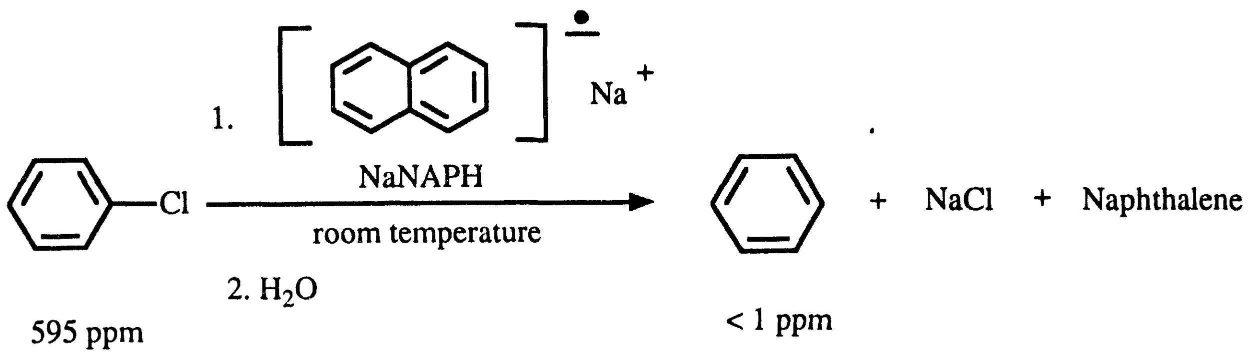


4. CHEMICAL DESTRUCTION OF CHLORINATED AROMATICS BY SODIUM 1-DIMETHYLAMINONAPHTHALIDE (NaDMAN)

The use of sodium metal in the presence of an appropriate electron carrier is potentially a good process for destruction of PCBs. We have selected this area to conduct our initial investigation because the process is simple and easy to carry out in the laboratory. It also provides an opportunity to establish an analytical procedure to determine the efficiency of the process for destruction of PCBs by sodium metal-based method and other processes in the subsequent studies.

We have first repeated the Goodyear process by using sodium metal in the presence of naphthalene as an electron carrier for PCB destruction. Chlorobenzene was used as a surrogate for PCBs and sodium naphthalide (NaNAPH) was prepared according to the published procedure.[6] Indeed the dechlorination process is very facile at room temperature. The reaction was followed by periodically withdrawing a small sample from the reaction mixture and quenching it with water. The extent of dechlorination was then analyzed by using GC/MS. It was found that the reaction was essentially complete within a few minutes with reduction of chlorobenzene concentration from 595 ppm by weight in tetrahydrofuran to less than 1 ppm (Figure 8).

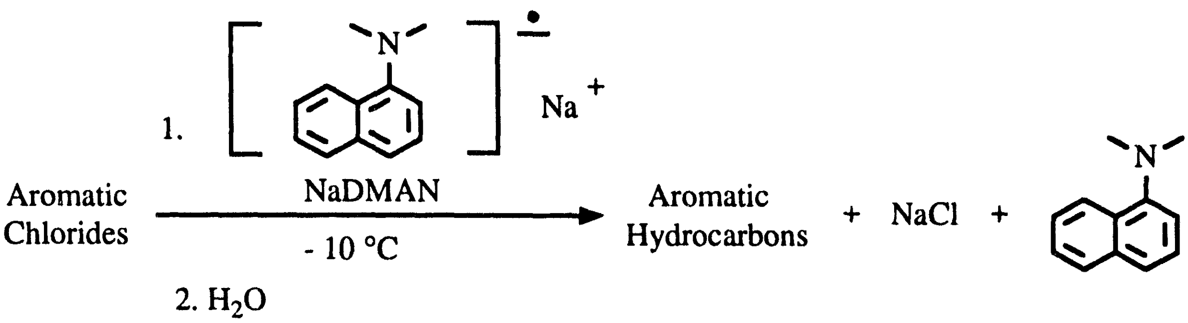
Figure 8. Dechlorination of Chlorobenzene by NaNAPH



With the establishment of the NaNAPH dechlorination condition as a baseline for comparison and a GC/MS method for following the reaction, we then turned our attention to finding an alternative electron carrier as a substitute for naphthalene. As indicated earlier, naphthalene has been classified as a priority pollutant by EPA, and its use is restricted. It is also difficult to separate naphthalene from other organic products after the dechlorination process is complete. A careful search of literature brought to our attention the use of 1-dimethylaminonaphthalene as a substitute for naphthalene.[24] Because of the presence of an amino functionality, 1-dimethylaminonaphthalene is very soluble in aqueous acidic solution and can be easily separated from other organic compounds. It can be regenerated by neutralizing the aqueous solution for easy recovery and reuse, minimizing pollution to the environment and reducing the cost of the dechlorination process.

Although the use of sodium 1-dimethylaminonaphthalide (NaDMAN) for dechlorination of aliphatic chlorides was reported,[24] extending the use of this reagent to aromatic chlorides had not been studied. It was gratifying to observe that sodium 1-dimethylaminonaphthalide was also very efficient in dechlorinating aromatic chlorides, such as chlorobenzene, 4-chlorobiphenyl, Aroclor 1242, and Aroclor 1254 (Figure 9). The efficiency of dechlorination is similar to that of NaNAPH. Recovery of 1-dimethylaminonaphthalene after the reaction was essentially quantitative.

Figure 9. Dechlorination of Aromatic Chlorides by NaDMAN



In comparison with naphthalene, the easy recovery of 1-dimethylaminonaphthalene from the reaction mixture offers a significant advantage. However, as a reagent NaDMAN in THF is less stable than NaNAPH. It was necessary to prepare NaDMAN at lower temperature (-10 °C) and immediately prior to use. Storing NaDMAN solution at room temperature resulted in gradual loss of its reactivity over several days.

5. EXPERIMENTAL SECTION

5.1 Establishment of an Analytical Procedure for Chlorinated Aromatics and PCBs

A GC/MS system comprised of an HP 5890A Gas Chromatograph and an HP 5970B Mass Selective Detector was employed as the analytical tool for identification of organic halides and quantitative determination of their concentrations. A flexible fused silica capillary column (HP-1, crosslinked methyl silicone gum, 25 m x 0.20 mm ID x 0.33 μm thickness) was installed in the GC oven. The GC conditions for analytical studies are summarized as follows:

Injection port temperature	250 °C
Detector temperature	280 °C
Initial and final oven temperatures	70 or 120 °C to 250 °C
Oven temperature programming rate	20 °C per minute

5.2 Determination of Detection Limits of Aromatic Halides

In order to determine the detection limits of the GC/MS system for various aromatic chlorides, a serious of standard solutions with varying concentrations were prepared. Four types of aromatic chlorides, such as chlorobenzene, 4-chlorobiphenyl, Aroclor 1242, and Aroclor 1254, were dissolved in freshly distilled dry tetrahydrofuran (THF) with concentrations ranging from 0.5 ppm to 10 ppm by weight. The detection limits of the GC/MS system for these chlorinated aromatics are summarized in Table 1.

Table 1. Detection Limits of Chlorinated Aromatics by the GC/MS System

chlorinated aromatics	detection limit ppm (w/w)[a]
chlorobenzene	< 1
4-chlorobiphenyl	< 1
Aroclor 1242	< 7
Aroclor 1254	< 8

[a] Part per million of chlorinated aromatics by weight in THF.

It is clear from Table 1 that for individual compounds, such as chlorobenzene and 4-chlorobiphenyl, a minimum concentration of 1 ppm can be detected by the GC/MS system using total ion current for monitoring. On the other hands, for mixtures, such as Aroclor 1242 and 1254 which contain many congeners, the detection limit of the instrument is reduced to 7-8 ppm due to the presence of lower concentrations of each individual congener in the mixture.

5.3 Preparation of Sodium Naphthalide (NaNAPH) Reagent.

The sodium naphthalide (NaNAPH) process patented by Goodyear was repeated in order to establish a baseline for comparison with new processes developed in our laboratory. The following experimental procedure is representative.

A 50-mL flask equipped with a nitrogen gas purge system and a magnetic stirring bar coated with glass was charged with 10 mL of freshly distilled dry THF and 0.23 g (10 mmol) of sodium metal cut into small pieces. To this sodium metal suspension in THF was added 0.64 g (5 mmol) of naphthalene with gentle stirring. The formation of a green radical anion solution started in a few minutes and was complete within two hours at room temperature. The concentration of the reagent is ca. 0.5 M. Sodium naphthalide prepared by this procedure is relatively stable and can be stored under a nitrogen atmosphere for future use. However, the freshly prepared reagent appears to exhibit higher reactivity for dechlorination of aromatic chlorides.

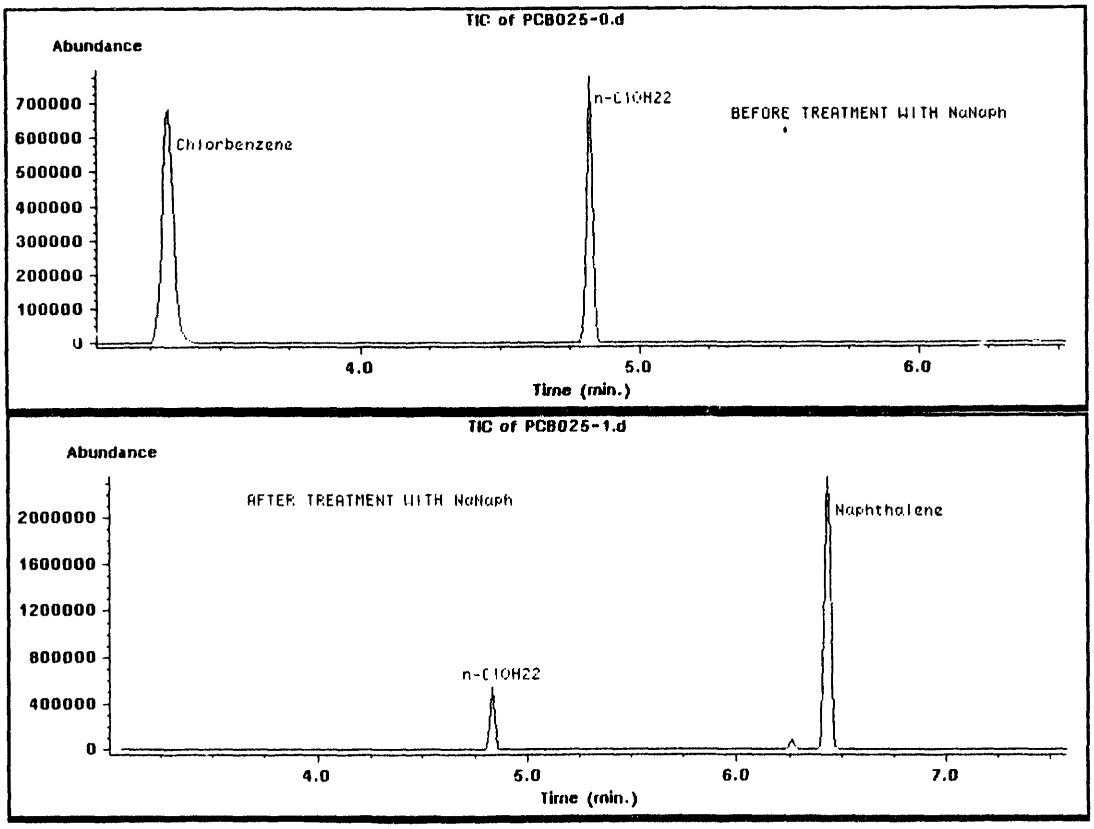
5.4 Preparation of Standard Solution of Chlorobenzene in Tetrahydrofuran

To a 100-mL volumetric flask were charged 51.5 mg of chlorobenzene and 53.0 mg of *n*-decane as an internal standard. The freshly distilled dry THF then was added to the flask until the total volume reached 100 mL. The concentration of the chlorobenzene solution is 515 ppm by volume or 595 ppm by weight. The concentration in terms of the weigh of the chlorinated aromatics relative to the total weight of the sample was utilized throughout this study.

5.5 Dechlorination of Chlorobenzene by NaNAPH Reagent

To a 100-mL flask fitted with a nitrogen gas purge system and a magnetic stirring bar coated with glass was added by a syringe 50 mL of the 595 ppm chlorobenzene solution containing 25.8 mg (0.23 mmol) of chlorobenzene. To this solution was added the freshly prepared NaNAPH solution (0.5 M) until the dark green color of the solution persisted. A total volume of 2.0 mL of the NaNAPH reagent was introduced. A small aliquot of the reaction mixture was immediately withdrawn by using a syringe and quenched with water. Analysis by the GC/MS system indicated the dechlorination process was already complete, and chlorobenzene could no longer be detected (< 1 ppm). The efficiency of the process is therefore greater than 99.8%. The NaNAPH to chlorobenzene molar ratio is 4 (a minimum ratio of 2 is required), far lower than those reported in the Goodyear patent. The GC/MS ion chromatograms before and after chlorobenzene was treated with the NaNAPH reagent are shown in Figure 10.

Figure 10. GC/MS Ion Chromatograms of Dechlorination of Chlorobenzene by NaNAPH



Dechlorination of chlorobenzene by using a NaNAPH solution stored under a nitrogen atmosphere at room temperature for 3 days was also studied. It was discovered that a molar ratio of 10 between the NaNAPH reagent and chlorobenzene became necessary. It appeared that decomposition of NaNAPH reagent occurred slowly at room temperature even under the protection of a nitrogen atmosphere.

5.6 Preparation of Sodium 1-Dimethylaminonaphthalide (NaDMAN)

Preparation of NaDMAN solution in THF is as straightforward as that of NaNAPH. A 50-mL flask equipped with a nitrogen gas purge system and a magnetic stirring bar coated with glass was charged with 10 mL of freshly distilled THF and 0.23 g (10 mmol) of sodium metal cut into small pieces. To this sodium metal suspension in THF was added via a syringe 0.86 g (5.0 mmol) of 1-dimethylaminonaphthalene at -10 °C with gentle stirring. The formation of a green radical anion solution occurred within minutes and the reaction was complete in about three hours at -10 °C. The concentration of the reagent was ca. 0.5 M. It was observed that this reagent is less stable than NaNAPH at ambient temperature even under the protection of a nitrogen atmosphere. After storing NaDMAN at room temperature for only two to three days, it essentially had lost all its reactivity for the dechlorination reaction.

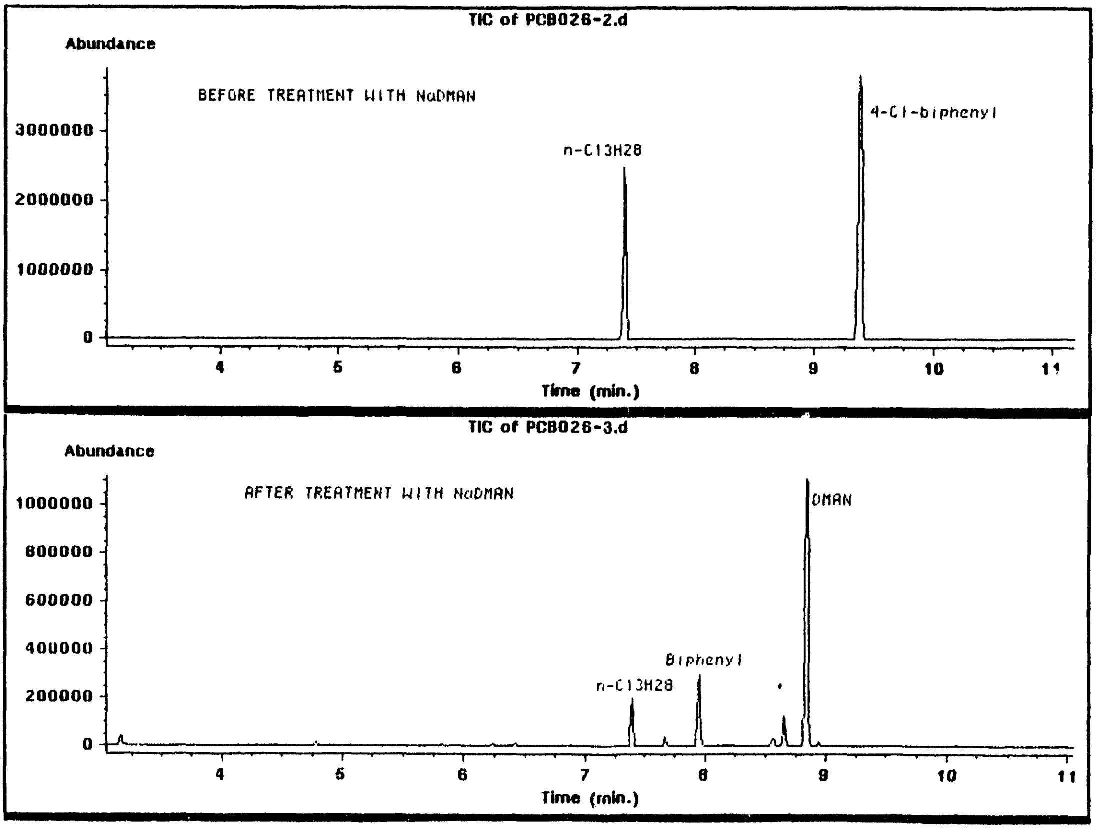
5.7 Dechlorination of Chlorobenzene by the NaDMAN Reagent

The following procedure is representative for dechlorination of chlorinated compounds by the NaDMAN reagent. A 100-mL flask fitted with a nitrogen gas purge system and a magnetic stirring bar coated with glass was charged with 30 mL of a 635 ppm chlorobenzene solution in THF containing 17 mg (0.15 mmol) of chlorobenzene. To this solution at room temperature was added a freshly prepared NaDMAN (0.5 M) until the dark green color of the solution persisted. The total volume of the reagent added was 1.5 mL (reagent to chlorobenzene molar ratio = 5 to 1). At this point, the dechlorination process was already complete and chlorobenzene could no longer be detected by the GC/MS system, indicating the concentration of chlorobenzene in the treated solution was less than 1 ppm and the efficiency of the process was better than 99.8%.

5.8 Dechlorination of 4-Chlorobiphenyl by the NaDMAN Reagent.

Dechlorination of 4-chlorobiphenyl by the NaDMAN reagent was investigated. Similar result was also obtained with 4-chlorobiphenyl being rapidly dechlorinated from an initial concentration of 585 ppm to less than 1 ppm, producing biphenyl as the reaction product. The GC/MS ion chromatograms before and after treatment are shown in Figure 11.

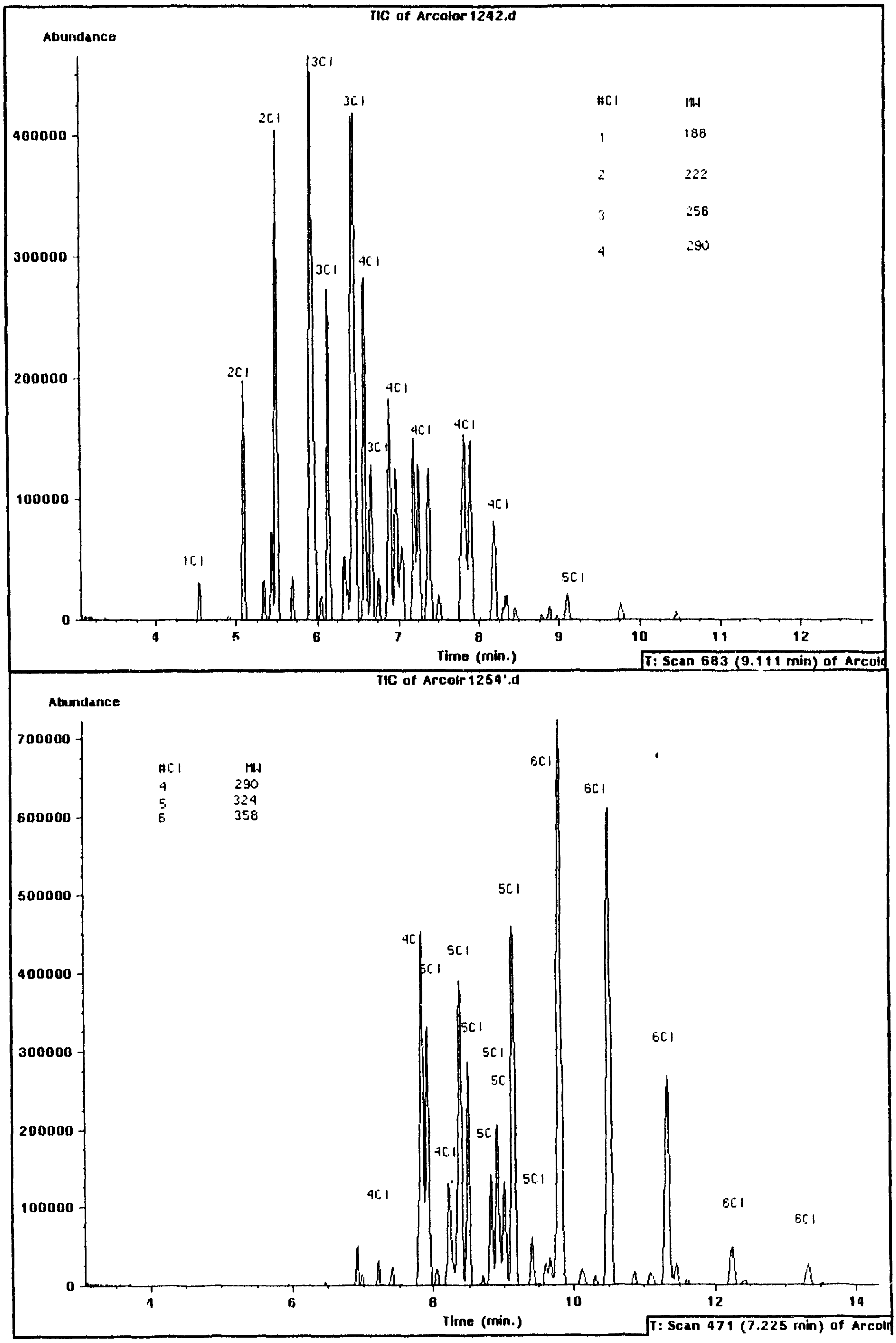
Figure 11. GC/MS Ion Chromatograms of Dechlorination of 4-Chlorobiphenyl by NaDMAN



5.9 Dechlorination of Aroclor 1242 and Aroclor 1254 by the NaDMAN reagent.

Aroclor 1242 and Aroclor 1254 were purchased from AccuStandard Co. of New Haven, CT. As indicated by the last two digits of the four-digit number, Aroclor 1242 contains approximately 42% chlorine by weight and Aroclor 1254 has 54% chlorine by weight. The GC/MS ion chromatograms of these two PCB mixtures are shown in Figure 12 in which the number of chlorine atoms in the congeners are indicated on the top of the peak. The tallest peak was selected to determine the limit of detection.

Figure 12. GC/MS Ion Chromatograms of Aroclors 1242 and 1254



The dechlorination procedure described for dechlorination of chlorobenzene by NaDMAN was also utilized. To 30 mL of a 614 ppm solution of Aroclor 1242 containing 16 mg of the PCB mixture having 0.19 mmol of chlorine was treated with a 0.5 M NaDMAN solution until the dark green color persisted. A total volume of 1.5 mL of NaDMAN was introduced, indicating a molar ratio of ca. 4 to 1 of reagent vs. chlorine content was needed to dechlorinate Aroclor 1242 to less than 8 ppm. Similar result was also obtained when 30 mL of a 583 ppm solution of Aroclor 1254 containing 15.5 mg of the PCB mixture having 0.24 mmol of chlorine was treated with 2 mL of a 0.5 M solution of NaDMAN (molar ratio between NaDMAN and chlorine content = ca. 4 to 1), reducing Aroclor 1254 to less than 7 ppm. The GC/MS ion chromatograms of these two experiments are shown in Figures 13 and 14.

Figure 13. GC/MS Ion Chromatograms of Dechlorination of Aroclor 1242 by NaDMAN

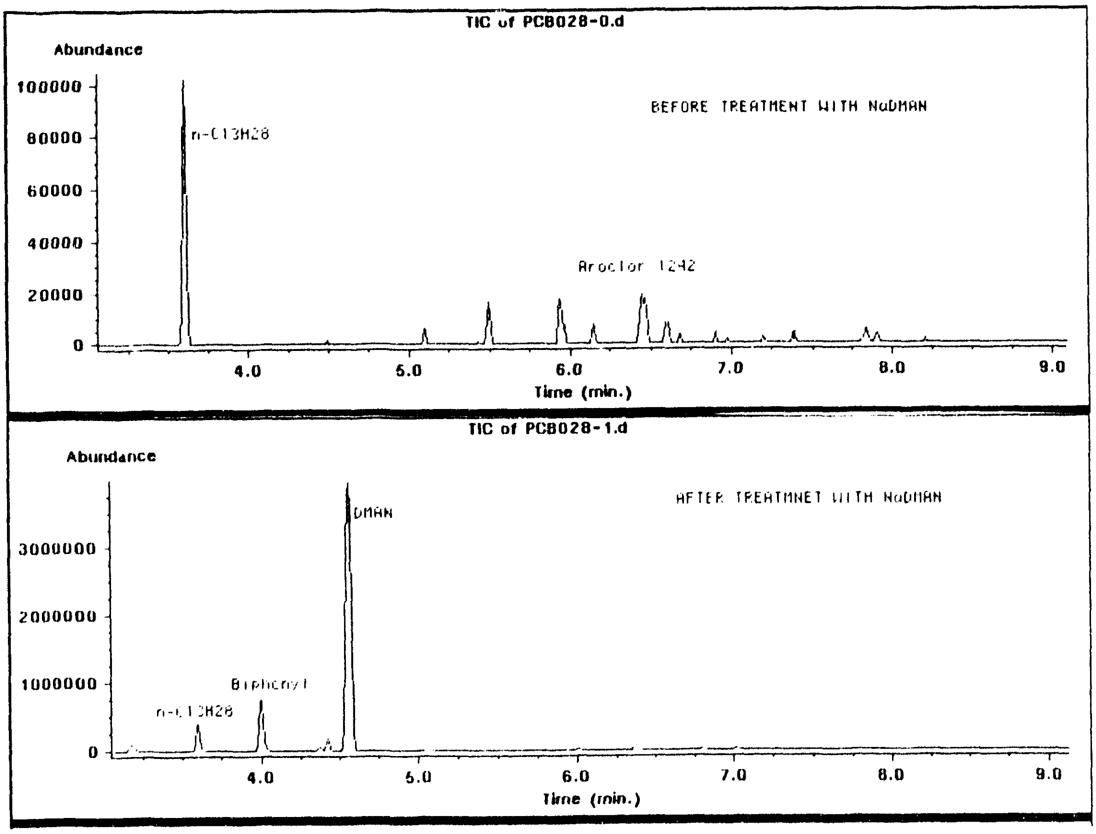
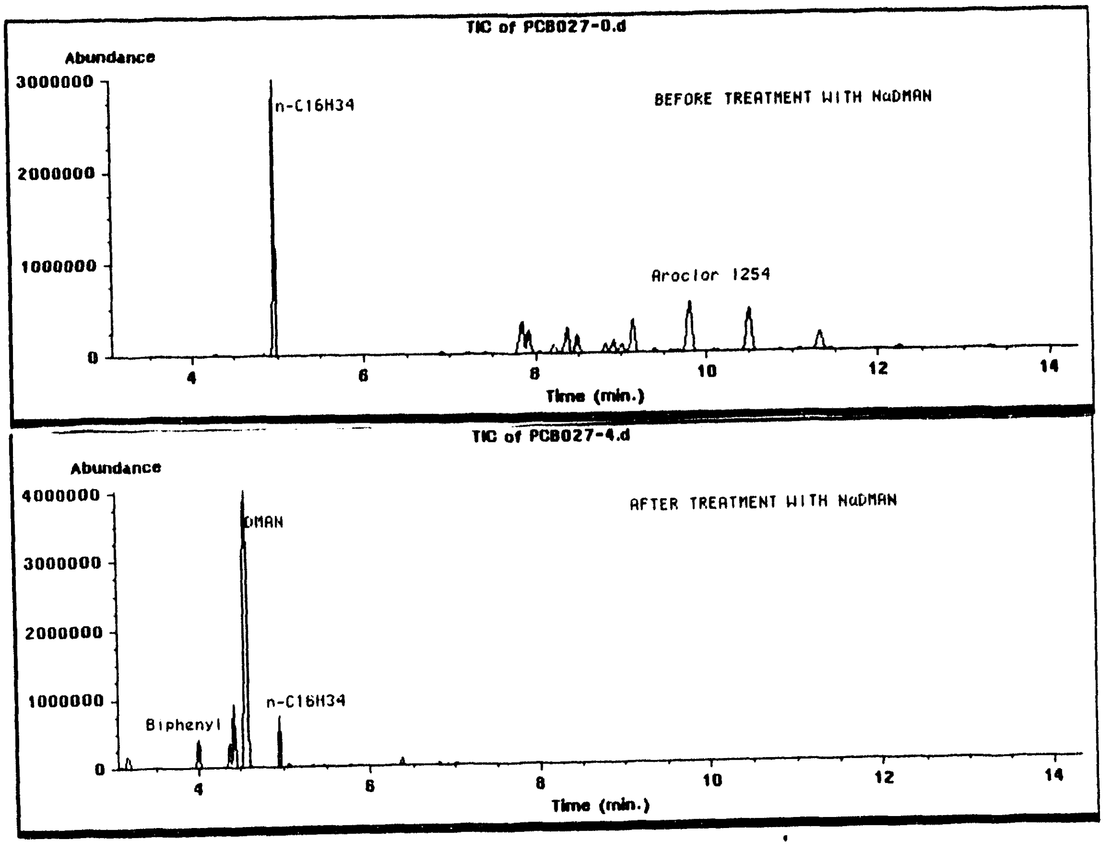


Figure 14. GC/MS Ion Chromatograms of Dechlorination of Aroclor 1254 by NaDMAN



5.10 Recovery of 1-Dimethylaminonaphthalene

Recovery of 1-dimethylaminonaphthalene from the reaction mixture was carried out by bubbling a stream of air through the solution until the dark green color disappeared. The mixture was then washed twice with 30 mL of a 10% HCl solution. The combined aqueous layers were treated with a 20% NaOH solution until the pH value became 14 followed by extraction three times with 50 mL of diethyl ether. The combined ether layers were dried over $MgSO_4$ and the ether solvent was evaporated under vacuum, providing essentially a quantitative recovery of 1-dimethylaminonaphthalene with a purity of 90%.

6. CONCLUSIONS

In this report, four general methods for chemical destruction of PCBs have been reviewed. These technologies have achieved limited success in some commercial-scale operations. The laboratory scale studies suggest that these remediation processes have good potential for effective dechlorination of PCBs. In our laboratory at West Virginia University, we have successfully utilized 1-dimethylaminonaphthalene as an electron carrier for sodium metal for dechlorination of aromatic halides. The easy recovery of 1-dimethylaminonaphthalene from the reaction mixture for recycle offers a significant advantage over other electron carriers, such as naphthalene. Continued research in the area of chemical remediation is still needed to adapt these chemical processes to an extremely complex problem of PCB pollution in the environment. The PCB pollutant in the environment may exist in the soil matrices, in aqueous solution and in transformer oil with varying concentrations, and may coexist with other pollutants. It is unlikely that one single chemical remedial procedure will be able to address all these problems. A variety of procedures need to be developed for effective removal of PCBs from the environment.

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Developement of Organic Sensors:
Monolayer and Multilayer Self-Assembled Films for Chemical Sensors

Quarterly Technical Progress Report
for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880, Collins Ferry Road
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By

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July 1993

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1.0 EXECUTIVE SUMMARY

Work accomplished in this quarter is subdivided into four areas.

Hiring of a technician:

Mark Phillippi was hired as the Research Assistant I. He started work on May 24. In addition, a M. S. graduate student, Xiaolei Hu, started working on the the project.

Acquisition of equipment:

The Surface Acoustic Wave Microbalance hardware, a computer, and hardware and software that permits computer control of the vapor phase generator and data acquisition were procured and checked for proper operation. A simple vapor generator was constructed in order to test the SAW microbalance sensitivity. The attached figure shows the quite large changes in beat frequency (with respect to an isolated SAW crystal) that occurs when a "naked" (no coating) SAW crystal was alternately exposed to dry argon or wet (nearly saturated with water vapor) argon.

The design of the vapor generator has been completed and the necessary parts ordered. The heart of the generator is a Kintek Modular Gas Standard Generator. This unit can hold 4 permeation or diffusion tubes in separate thermostatted ovens. With an air flow of 0.1 to 1 L/min, concentrations of organics in the 1 - 1000 ppm range can be produced. The vapor generator will also contain a purification unit for removing oil, particulates and water vapor from house compressed air, a humidifier system, and a circulating temperature bath capable of sub- and superambient temperatures. The SAW microbalance and the humidifier system will be housed in water-tight containers in the temperature bath. The main purpose of the temperature control is to determine the response of the SAW coatings over a range of temperatures anticipated in the field (0 - 40°C).

Literature search:

Over 50 papers on SAW sensors and the related quartz crystal microbalance have been read. These papers have helped with the design of the vapor generator.

Polyion deposition:

Polished silicon wafers have been used as prototypical substrates in order to explore the deposition of polyion layers. These wafers are ideal for measurement of thin organic films by ellipsometry. Their surface chemistry is anticipated to be identical to the surface chemistry of the SiO_x layer on the SAW crystals.

The first step in polyion deposition is the bonding of a silane layer with pendant amine groups and approximately 1 monolayer thickness. Three silanes have been tested:

$(MeO)_3Si(CH_2)_3NHCH_2CH_2NH_2$

$(CH_2CH_2NH(CH_2CH_2CH_2Si(OMe)_3))_n$ (an amine polymer with silane side chains)

$Cl_3SiCH_2CH_2py$ (py = pyridine)

Conditions for forming roughly 1 monolayer (0.5 to 2 nm thick layer) on the Si wafers have been determined. The third silane is very reactive towards moisture and tends to form clumps of polymers on the Si wafers.

When the silanized wafers are exposed to an acidic aqueous solution of poly(styrene sulfonic acid, sodium salt) (PSS), a layer of ca. 1-4 nm is adsorbed on to the surface. The adsorption of the anionic PSS is promoted by the positive charge of the protonated amine groups in the silane layer. Subsequent immersion of the substrate in a solution of cationic polymer (either poly(allylamine hydrochloride) (PAA) or poly(4-vinylamine hydrochloride) (PVP) yields an almost negligible increase in thickness (< 0.5 nm), yet another 1-4 nm layer of PSS can be adsorbed on top of the cationic layer. The incremental construction of the multilayer can be continued for at least 4 more immersions in polycation and then polyanion solutions.

These preliminary experiments have shown that polyion multilayers can be readily constructed with the chemicals in hand. There are two problems to be resolved before applying the polyion films to the SAW crystal surfaces: poor reproducibility of thickness and a discrepancy between the observed thicknesses and the literature reports (which indicate that a uniform 0.5 nm thick layer is deposited for both the polycation and the polyanion).

WINFIELD LOCK AND DAM REMEDIATION

Quarterly Technical Progress Report
for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880, Collins Ferry Road
Morgantown, West Virginia

By

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National Research Center for Coal and Energy
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July 1993

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ATTACHMENTS

EXECUTIVE SUMMARY

The United States Army Corps of Engineers (ACE) must remediate a contaminated industrial site, formerly owned by ACF Industries, Inc., in order to build a new lock on the Kanawha River at Winfield, WV. The original remediation plan, to incinerate the contaminated soil, generated much controversy in the surrounding communities, notably Eleanor, WV.

West Virginia University became involved in the project in August of 1992. Shortly after that time, a formal program to involve WVU in the solution to the remediation problem began. The WVU involvement has been two-pronged. WVU has interacted extensively with the citizens of Eleanor (and Putnam County) providing technical, logistical and financial assistance in their efforts to understand and evaluate the ACE plans for remediation. A primary objective for WVU is to inform the citizens of possible health and safety problems with proposed operations. In order to efficiently develop and communicate the necessary technical information, a resource group has been developed at WVU which is charged with developing enhanced technical (and other) capability to enhance the WVU effort. The members of this group have traveled, read and otherwise devoted some of their time to enhancing their knowledge of remediation. Some have provided insightful comments concerning published ACE plans and specifications (P&S). Other WVU faculty have developed site opinion surveys and studied social, political and economic issues associated with community involvement in hazardous waste site remediation.

A second portion of the WVU effort is directed towards actually supplying assistance in development of a remediation strategy for the site. The ACE does not have a particularly clear idea of what to do if incineration is not used and they have requested help from WVU and other parties in investigating their options. Such assistance involves an expanded effort by WVU to investigate the state of the art of remediation and begin development of some new technologies. These investigations are being conducted by the National Research Center for Coal and Energy (NRCCE) staff and WVU faculty.

INTRODUCTION

The site of the former ACF Industries, Inc. railroad tank car maintenance shop is contaminated by various organic and inorganic chemicals. The company abandoned the site in March 1986 and the U.S. Army Corps of Engineers acquired the site, which was needed for the approach to expansion of the Winfield Locks and Dam. The extent of contamination, and most explicitly, the presence of dioxin at the site, had been inadequately documented before the ACE took possession of the land. The ACE, when it became aware of the extent of contamination, undertook a study which culminated in the publication of an Engineering Evaluation and Cost Analysis (EE/CA) in May 1992 **(Attachment 1)**. The EE/CA was made public with a 30 day response period. The net conclusion of the EE/CA was that the ACE would incinerate the contaminated soil. The combination of citizen perception that they had not been appropriately informed of the problem and the proposal to incinerate the soil led to a concerted effort by the citizens to have the EE/CA reconsidered. The concerted effort, which included the involvement of the WV Congressional delegation, successfully led to reconsideration of the issue by the Army.

The subsequent reevaluation by the Army took nearly 7 months; the results, an Action Memorandum **(Attachment 2)** for the site, was released in December 1992. The Action Memorandum proposed that the soil be excavated, stored in temporary buildings, then remediated after further study.

As a result of the public involvement in the lock issue, Senator Robert C. Byrd of West Virginia and the Senate appropriations committee published some language which involved the Department of Energy and West Virginia University in the problem. The role of the DOE was to assist WVU financially in their efforts to safeguard the health and safety of the citizens and investigate the application of DOE technology in remediation of the site. The DOE-WVU effort is, thus, funded by this Cooperative Agreement and consists of establishment of a Resource Group and direct assistance to the area around the site as well as certain technological investigations directed towards the choice of the eventual remediation technology (or technologies).

WVU INVOLVEMENT AT WINFIELD

West Virginia University first became aware of Winfield and the problem existing there in August 1992. Representatives of WVU traveled to the site to discuss the problem with the ACE. The site was viewed from the outside and the history of the site and the nature of the lock expansion project were discussed.

In September 1992, the magnitude of concern for the remediation problem became more obvious. A representative of the NRCCE, Raymond J. Lovett, was chosen to become involved in the situation to provide technical and other assistance to the community. At the time, the concerned community consisted largely of an environmental group, P.R.O.T.E.C.T., and the town government of Eleanor. Eleanor contains three schools close to the site and Winfield has another three schools somewhat farther away, although Winfield is east of the site and more likely to be downwind.

On October 16, 1992, P.R.O.T.E.C.T. sponsored an appearance by Dr. Paul Connett, a chemist from Clarkson University in Potsdam, NY. Dr. Connett is an outspoken opponent of incineration, and organochlorine compounds, in any form. His talk was a, self proclaimed, polemic against incineration and the hazards of dioxin (which is actually used as a catchall descriptor of two classes of compounds, dioxins and furans, both of which are chlorinated). He in particular discussed the toxicity of 2,3,7,8 tetrachloro-p-dioxin, the most potent cogener. Following Dr. connett's talk, contact was made with both the ACE and ACF Industries, which promised as much assistance as needed to help the WVU efforts. Discussions with the area citizens, including P.R.O.T.E.C.T. members and public officials revealed that although P.R.O.T.E.C.T. members were adamantly opposed to incineration, other community members and officials were willing to accept incineration if it were shown to be the best option.

On November 4, 1992, a trip was made to Eleanor to visit with concerned citizens and, the next day, with some state Department of Environmental Protection, Congressman Bob Wise's staff and Paul Hill from the National Institute for Chemical Studies (NICS). The visit to Eleanor consisted of talks with Marlene Carr, a town of Eleanor councilwoman, the mayor of Eleanor, Lloyd Jividen, and the P.R.O.T.E.C.T group. The P.R.O.T.E.C.T. group gave me a copy of the complete record of the site, all 17 volumes. That evening I dined with Missy Woolverton of the WV Citizen's Action Group (WVCAG); we discussed the situation at Winfield.

The discussion on November 5, 1992 with the WVDEP included Dave White and Lucy Pontiveros of the Office of Air Quality, Lewis Baker of the Office of Solid Waste and Ken Ellison, an assistant director of OSW. The conversation generally concerned the roles of WVU and the state in the remediation. As with most of these early discussions, the WVU role was ill-defined and the agencies were attempting to determine exactly the course WVU would take. Following the DEP talks, a meeting with Susan Small of Congressman Bob Wise's staff and Paul Hill of NICS took place. In this meeting, aside from trying to develop the role of WVU, Susan revealed a plan to form an umbrella group from citizens in the area to coordinate the local effort.

Shortly after the visit to Charleston, the ACE called and asked me to come to Huntington to discuss the role of WVU. The ACE notes of that meeting on November 16 **(Attachment 3)** and a subsequent meeting in Morgantown on December 15 **(Attachment 4)** provide information on the remediation and the relationship between the Corps and WVU. The relationship is one of assistance and cooperation, but with the maintenance of distinctly separate identities.

The Umbrella Committee was formed in January 1993 and consisted of politicians and citizens whose job included overseeing and evaluating ACE operations. Since its formation, the Umbrella Group has held meetings every second and fourth Tuesday of the month. They are divided into a number of committees, including health and safety, technology and project watch. Each meeting consists of a committee report followed by new business; sometimes the ACE is invited to explain its latest plans. The health and safety committee has concerned itself with airborne problems and the safety of school children. They have requested a local health assessment from WVU, negotiations on which are in progress. The technology committee reviews ACE plans and specifications and risk assessments. The project watch committee oversees activity at the site.

WVU interaction with the ACE has largely been devoted to definition of role and technical review of their plans. Among the plans published are the air monitoring plans, the storage building P&S, and the demolition and decontamination P&S and risk assessment documents. When published, the plans are submitted to the Umbrella Group and WVU. The plans are distributed to members of the Resource Group at WVU for evaluation. Those evaluations are distilled by the NRCCE and submitted to the ACE.

Interaction with political units has largely been confined to Eleanor. The Corps of Engineers is going to buy the Eleanor water supply, due to potential contamination from the site. WVU assisted the town (largely financially) in obtaining an independent valuation of their supply so that they could appropriately consider the ACE offer.

WVU HAZARDOUS WASTE RESOURCE GROUP

The Hazardous Waste Resource Group was was established to provide technical and other asssistance to the Winfield effort. It consists of 20 faculty members form four colleges. The program encourages the acquisition of resources in order to aid the effort and it encourages travel to expand the faculty capability. To this time, most of the group effort has been directed towards understanding how it can help, reviewing various ACE documents and travel.

Dr. Gary Morris attended a teleconference on alternative thermal technologies (such as RF heating) in order to be able to contribute ides regarding these technologies. Dr. Jerry Fletcher attended a short course on new methods for putting large databases together to help with all of the information gathered. Dr. Susan Hunter attended the Incineration Conference in Knoxville, TN, where she brought back information regarding siting and public participation. Drs. Bill Trumbull and Andy Isserman attended a session sponsored by the American Bar Association on public participation in Washington, DC. Dr. Joe Donovan attended a conference on groundwater modelling for pollutant transport. Dr. Fred King attended a conference on field monitoring technologies. Dr. Bill Sack attended an EPA meeting concerning bioremediation. Dr. Raymond Lovett attended the EPA RREL Conference in Cincinnati, where all new EPA technologies are discussed.

Given the breadth of information which will continue to accrue, a newsletter has been started to provide timely information to the Resource Group **(Attachment 5)**. This newsletter will disseminate the information to the group to enable them to be aware of happenings at Winfield and other locales.

CURRENT STATUS

The Corps of Engineers has published P&S documents for the temporary storage buildings and demolition and decontamination. The risk assessment for the D/D was not well received and the Corps has decided to delay that aspect and combine it with excavation next spring. The major document due is the baseline risk assessment, which is underway. In addition ACF has just completed a sampling phase with which it hopes to better define the extent of the contamination, those data ought to be available soon.

The Umbrella Group is in the midst of deciding what sort of health assessment is viable in consultation with Dr. Alan Ducatman of the WVU Medical School. They also are concerned with some technical aspects, such as the need for a scrubber at the temporary storgae building. These questions were passed to WVU for study.

ATTACHMEMT 1

US Army Corps of Engineers
Nashville District

Engineering Evaluation/Cost Analysis (EE/CA)

For Removal & Treatment of Contaminated Soil

The Former ACF Industries, Inc. Site
Red House, West Virginia

Prepared By:
US Army Corps of Engineers
Nashville, Tennessee
May 5, 1992

ENGINEERING EVALUATION/COST ANALYSIS (EE/CA) FOR REMOVAL AND TREATMENT OF CONTAMINATED SOIL

AT

THE FORMER ACF INDUSTRIES, INCORPORATED SITE
RED HOUSE, WEST VIRGINIA

Prepared by:

U.S. Army Corps of Engineers

Nashville, Tennessee

April, 1992

CONTENTS

FIGURES

TABLES

TABLES

Number **Page**

LIST OF ACRONYMS

ACF	American Car and Foundry
ARAR	Applicable or Relevant and Appropriate Requirements
BNA	Base Neutral/Acid Extractable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COE	Corps of Engineers
EE/CA	Engineering Evaluation/Cost Analysis
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HAZMAT	Hazardous Material
HTRW	Hazardous, Toxic, and Radiological Waste
LDR	Land Disposal Restriction
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Act
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethylene
POTW	Publicly Owned Treatment Works
QA/QC	Quality Assurance Quality Control
RCRA	Resource Conservation and Recovery Act
SOP	Standard Operating Procedure
SOW	Scope of Work
SVOC	Semi-Volatile Organic Compounds
TCDD	Tetrachlorodibenzodioxin
TCE	Trichloroethylene
USACE	U.S. Army Corps of Engineers VOC Volatile Organic Compounds
WVAPCC	West Virginia Air Pollution Control Commission
WVDNR	West Virginia Division of Natural Resources
WVDOW	West Virginia Division of Water
WVCSR	West Virginia Code of State Regulations

1.0 SITE CHARACTERIZATION

1.1 Site Description

1.1.1 Site Location. This Engineering Evaluation/Cost Analysis (EE/CA) presents findings and recommendations on studies performed at the former American Car and Foundry Industries, Inc. (ACF) property located in Putnam County, West Virginia. The project site is approximately 20 miles northwest of Charleston, West Virginia near the communities of Red House and Eleanor. See Figure 1-1 for a vicinity location map. This 21.81 acre tract is adjacent to the right descending bank of the Kanawha River immediately upstream of the Winfield Locks and Dam. See Figure 1-2 for a general site layout.

1.1.2 Type of Facility and Operational Status. From 1952 until the facility closed in March 1986 ACF used the property to repair and service a fleet of tank and covered hopper railcars owned by ACF. ACF leased these railcars to various companies for hauling liquid and solid chemical commodities. During its prime, ACF maintained over 47,000 railcars through this facility. Industrial activity at the site is currently idle.

1.1.3 Current Site Ownership. On 8 December 1989 the U.S. Army Corps of Engineers (COE) filed a Declaration of Taking in U.S. District Court for the 21.81-acre tract of land then owned by ACF Industries. Acquisition of this property was necessary to construct the upstream approach for a new lock and gate bay at the Winfield Locks and Dam. Following a limited excavation and removal activity administered by ACF the COE took possession of the property on 1 May 1990. The COE has not used this site or its facilities since acquiring it.

1.1.4 Surrounding Land Use and Population Density. The land along the Kanawha River is used predominantly for agriculture and forest land with the exception of the urban development associated with the City of Charleston, West Virginia. Within the four West Virginia counties contiguous to the Kanawha River approximately 79 percent of the land is forested, 15 percent is agricultural, 4 percent is urban, and the remaining 2 percent is wetland. Most of the agricultural land is located downstream of the Winfield Locks and Dam. The primary urban areas are upstream of the site. There are three incorporated communities, Winfield, Eleanor, and Buffalo, within close proximity of the site; however, combined they represent only three percent of the land in Putnam County, West Virginia. The estimated

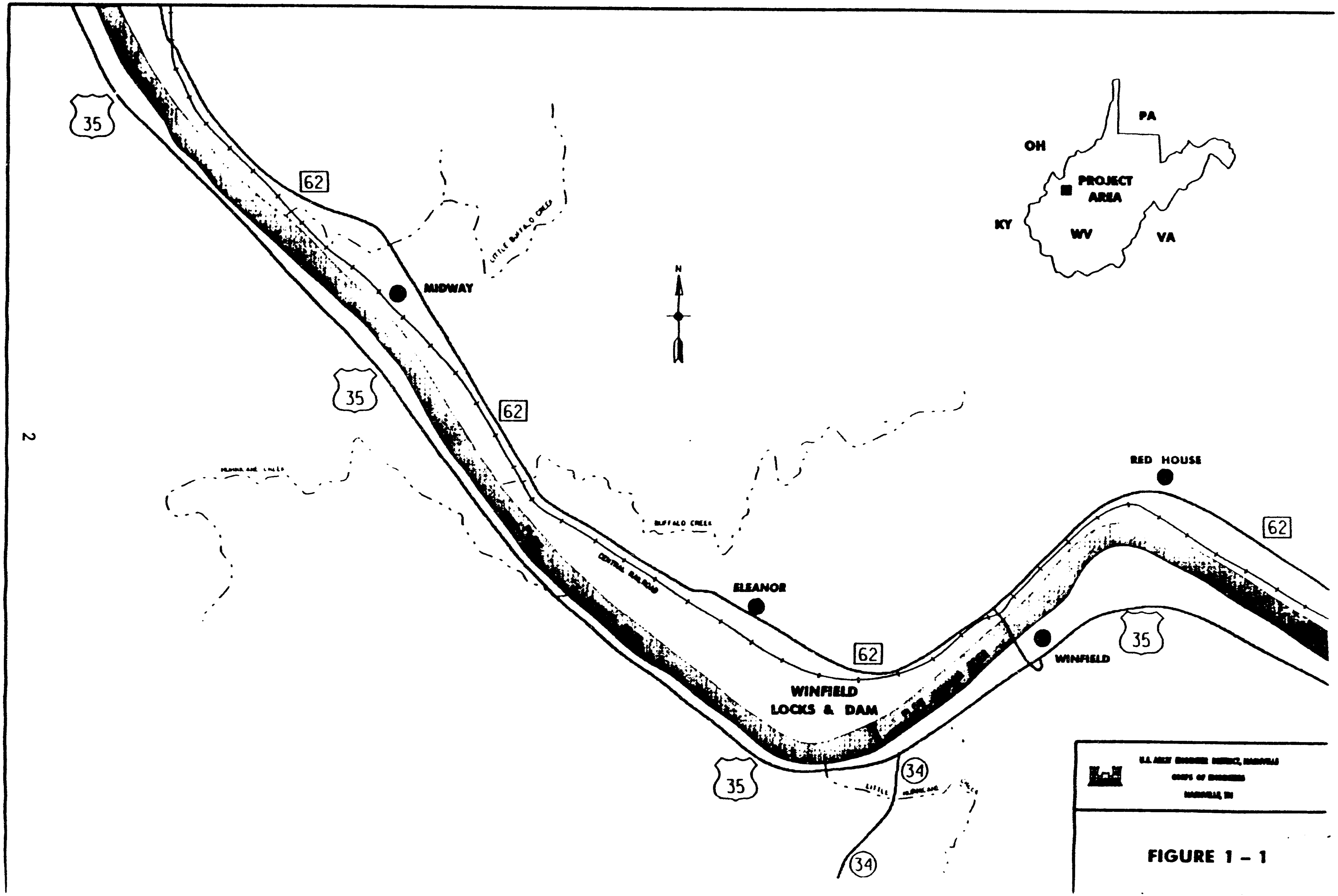

35
62
LITTLE BUFFALO CREEK
MIDWAY
N
35
62
BUFFALO CREEK
CENTRAL RAILROAD
ELEANOR
62
RED HOUSE
62
WINFIELD
35
WINFIELD
LOCKS & DAM
35
34
34
PA
OH
PROJECT
AREA
KY
WV
VA
U.S. ARMY [illegible]
CORPS OF ENGINEERS
[illegible]

FIGURE 1 – 1

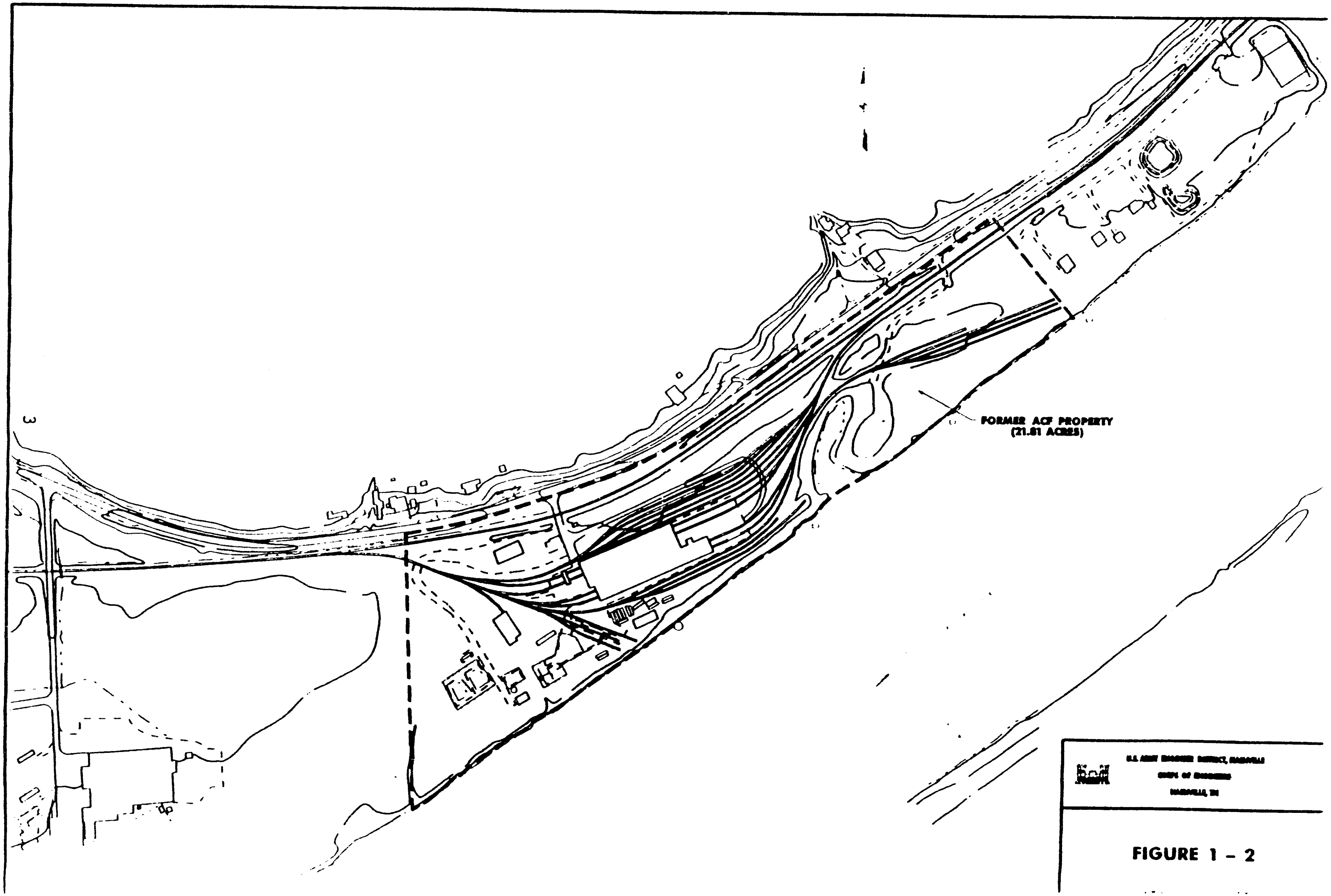

FORMER ACF PROPERTY
(21.81 ACRES)
U.S. ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TN

FIGURE 1 – 2

population in the area near the ACF site is 2,740, with most in the communities of Eleanor (1,550) and Winfield (790). There is a significant transient population associated with navigation activity at the adjacent Winfield Locks and Dam. In terms of lockages, the Winfield Locks are the busiest on the Inland Waterways Navigation System. In 1990 there were over 21,000 lockages.

1.1.5 Environmental Setting. The 21.81 acre ACF site is located adjacent to the Kanawha River immediately upstream of the Winfield Locks and Dam. It is bordered by the Kanawha River to the south and east and by Highway 62 to the north and west. The site is relatively flat, the elevation varies little from Elevation 580. Due to the former industrial use of the property there is a minimum of vegetation and habitat diversity. Vegetation is characterized by grasses and low scrub growth in the immediate area of former industrial activity and a narrow band of woody growth in drainage channels and along the riverbank.

1.1.6 Site Hydrology/Water Use. The ACF site lies within the Kanawha River flood plain. Surface water runoff flows through a simple drainage pattern directly to the Kanawha River. Piezometers within the project area indicate that there are two groundwater regimes at the site. There is a zone of perched water associated with the upper 30 feet of clay. The perched water is contained within sand interbeds characteristic of this clay layer. The water is perched at a higher elevation due to the low permeability of the clay which acts as an aquiclude (barrier) and restricts the downward flow of groundwater. The water level in the perched zone varies greatly depending on the amount of precipitation that has been falling on the area, as this is the main source of recharge for this zone. The 30 foot thick sand zone that underlies the perched zone, is a water table aquifer. The water level for the sand is about elevation 550-555. The recharge for this aquifer comes from the river, the higher groundwater in the hills to the north, and percolation from the overlying perched groundwater. Water use in the immediate area of the ACF site is limited to activities associated with the Kanawha River. The Town of Eleanor, about one mile downgradient, uses the water bearing aquifer as a potable water supply.

1.1.7 Site Topography - Geological and Geotechnical Information. The Winfield Locks and Dam and former ACF site lie within the Kanawha Section of the Appalachian Plateau Physiographic Province. The present topography was developed as the plateau was uplifted and then eroded by the downcutting of streams. At the project site the river is in a mature stage as evidenced by a well developed flood plain, numerous meanders, and a wide U-shaped valley. The ACF site is located in the alluvial flood plain of the Kanawha River. The river valley was originally filled with alluvium and glacial outwash deposits. The Kanawha River has meandered across these deposits leaving terraces along the margin of the present flood plain. Generally, the upper 30 feet (down to approximately elevation 550) of alluvium at the site consists of predominantly lean clay interbedded with sand. The occurrence of these sand interbeds appears to be rare and thin in the upper portion, but becomes more numerous and thicker in the lower portion. Underlying this clay, and resting on top of rock, is a poorly graded sand. In some areas, gravel, boulders, and cobbles are present in the bottom 2-3 feet. Top of rock in the area of the ACF site varies around elevation 520. The uppermost unit of rocks varies from shale to siltstone to claystone to indurated clay. Underlying the upper unit is a siltstone which represents a transition zone between the upper unit and an underlying sandstone. These rocks belong to the Conemaugh Group and are of Pennsylvanian Age.

1.1.8 Potential or Actual Release of Contaminants. In May 1990, COE representatives observed discolored water seeping from excavation pit walls in the area of the ACF removal activity. The soil in this area was also observed to be discolored and was characterized by a phenolic odor. This discovery was followed by sampling activity in an effort to define the limits and nature of the suspected contamination. Water samples were taken from surface water at the ACF facility, piezometer installations within the Winfield Locks and Dam area about a half-mile downstream of the ACF site, and from water supply wells belonging to the Town of Eleanor, West Virginia. The Town of Eleanor's primary source of water, which consists of four wells, is located approximately one mile downstream of the former ACF facility. Contamination was not detected in the water wells or the piezometers; however, samples collected from seeps exiting the excavation pit walls confirmed the presence of a wide range of contaminants including volatile organics and base neutral/acid extractables. Subsequent investigations have confirmed the presence of pesticides, polychlorinated biphenyls (PCBs), and dioxins in this area. These findings provided strong inferential evidence of residual soils contamination. In a separate 17 August 1990 incident, an equipment operator employed by the COE lock construction contractor encountered some unknown substances and experienced irritation of the skin and throat while removing pavement with a backhoe at the former ACF site. The unidentified substance, possessing a distinct odor, appeared to be originating from a buried vault remote from the excavation pit where ACF had conducted remediation. This event, which established a direct threat to human health, was instrumental in accelerating site characterization studies and regulatory action. Given the physical nature of the site and its proximity to the Kanawha River the probability is high that contamination has exited the site via the perched groundwater and surface drainage systems. No contamination of the underlying aquifer has been documented.

1.2 Site Background.

1.2.1 Prior Site Use. This site was utilized by ACF Industries as a railcar service and repair facility. During peak operation, ACF maintained over 47,000 railcars from this facility. These railcars were leased to a variety of interests for hauling solid and liquid chemical commodities. The property housed facilities to clean railcars. An on-site wastewater treatment system consisting of a series of lagoons was located adjacent to the Kanawha River. Shop facilities necessary for railcar repair and a paint shop were also located at this site.

1.2.2 Operational History. Aerial photographs taken in 1950 indicate that what became the ACF facility was at that time a prime agricultural area. It was a part of the Noffsinger farm until the 21.81 acre tract was acquired by ACF. Beginning with its construction in 1952 ACF operated the railcar service facility at this site until its closure in 1986. Industrial activity at the site has been idle since the shutdown of the ACF operation in 1986. The COE plans to excavate a large portion of the site in conjunction with the addition of a new lock and gate bay at the Winfield Locks and Dam. COE stopped construction activity at this site pending resolution of the documented soil and perched groundwater contamination.

1.2.3 Regulatory Involvement. Regulatory activity at the ACF site has involved both State and Federal agencies. State compliance and enforcement action has been the responsibility of the West Virginia Department of Natural Resources. The COE maintains a close coordination with all appropriate State and Federal regulatory groups. This coordination is necessary to ensure that proper response action is taken at this site in a timely and responsible manner.

1.2.3.1 Initial Corps of Engineers Evaluation. The COE has developed a Standard Operating Procedure (SOP) for the identification of the presence of hazardous and toxic materials at proposed project sites. On 30 November 1988, in accordance with this established SOP, the COE initiated environmental investigations to determine if hazardous and toxic wastes were present on the ACF property. On 1 December 1988, COE representatives met with ACF's Corporate Manager for Environment and Safety to discuss future environmental testing. The ACF representative expressed a desire to be present during any testing or reconnaissance and to be provided with two weeks notice prior to granting entry onto the property. On 14 December 1988, the COE with the assistance of their contractor conducted the initial site reconnaissance. The former ACF Plant Manager was in attendance. However, scheduled testing was not executed because ACF would not allow additional entry or sampling on the property.

1.2.3.2 West Virginia Division of Natural Resources Compliance Investigation. Responding to a public complaint, the West Virginia Division of Natural Resources (WVDNR) conducted a Complaint Investigation on 5 December 1988. On 14 February 1989, the WVDNR conducted a Compliance Evaluation Inspection with the primary focus of the inspection directed at the status and condition of various drums of waste materials on the site. However, during the course of the inspection, WVDNR personnel noted isolated areas of the property which were devoid of vegetation. ACF agreed to sample the drums and soils designated by WVDNR and provide WVDNR with split samples.

1.2.3.3 ACF Environmental Site Investigation. On 21 March 1989, Allstates Environmental Services, Inc., which was hired by ACF, initiated an environmental site investigation aimed at determining the extent of soil contamination within a localized portion of the plant area. On 27 April 1989, through a letter the Waste Management Division of the WVDNR informed the COE of their intent to compel assessment, and possibly remediation, at the ACF site. On 1 May 1989, the WVDNR ordered ACF to survey the contamination and submit a testing plan to determine the extent of contamination. ACF was given 30 days to comply. On 12 May 1989, Allstates Environmental Services, Inc. completed the environmental site investigation and defined the geographic boundaries of soil contamination. They also identified a number of chemical contaminants.

1.2.3.4 ACF Remediation Plan. On 9 June 1989, ACF advised the COE that they preferred to conduct the necessary cleanup at their expense. On 22 June 1989, the WVDNR approved ACF's environmental sampling survey and report. On 20 July 1989, ACF informed the WVDNR and the COE that they planned to utilize on-site bioremediation in place of the excavation and landfill disposal alternative selected through the earlier study. On 1 August 1989, the WVDNR stated that bioremediation was not feasible and expressed a clear preference for excavation and landfill disposal.

1.2.3.5 ACF Remediation. On 18 August 1989, the WVDNR issued Administrative Order Number HW-190-89 ordering ACF to perform a feasibility study for in-situ remediation. On 27

October 1989, the WVDNR issued Administrative Order Number HW-225-89 ordering ACF to clean up areas identified as contaminated. On 6 December 1989 the site work plan for the remediation was approved by the WVDNR. In the site work plan ACF agreed to excavate, transport, and dispose of the contaminated material at a suitable landfill as opposed to in-situ remediation. On 22 January 1990, ACF's contractor, Allstates Environmental Services, Inc., began environmental remediation at the ACF site. Through this removal action ACF excavated, removed, and disposed of 9151 cubic yards of contaminated soil. The hazardous waste soils (4466 tons) were disposed of at Envirosafe, Inc., in Toledo, Ohio in a secure chemical landfill. The nonhazardous soils (6641 tons) were disposed of at the Wetzel County, West Virginia special waste landfill. In addition, approximately 100 empty containers, most of them 55 gallon metal drums, (some with minor chemical residual) were unearthed, crushed, and shipped to Envirosafe for disposal in the chemical landfill. The environmental remediation was completed on 11 April 1990. On 7 May 1990, the WVDNR approved ACF's report stating that its actions satisfied the requirements of the site excavation plan agreed upon under West Virginia Waste Order Number HW-225-89. Later that month, following the discovery of contaminated water seeping from the pit walls of Allstates' excavation, ACF was informed that the COE believed that ACF was still responsible for contamination remaining at the site. On 16 July 1990, the COE presented ACF data indicating that contamination remained at the site and offered ACF the opportunity to formulate a plan to investigate the site. In a 14 August 1990 meeting with the WVDNR and the COE, an ACF representative read a prepared statement indicating that the cleanup of the ACF site had been completed and that ACF would not return to the site to conduct additional investigations and/or remediation.

1.2.3.6 U.S. Environmental Protection Agency. Region III of the U.S. Environmental Protection Agency (EPA III) was notified by a November 1990 COE letter of the situation at the former ACF property. During a meeting with EPA (III) on 6 December 1990, it was determined that the Department of Defense, rather than the EPA, has the responsibility for remedial actions on its lands which are not on the National Priorities List. EPA (III) provides consultation and technical assistance to the COE on this site. The Huntington and Nashville Districts of the COE meet regularly with EPA (III) to discuss testing results and response action strategies. EPA (III) also provides assistance in ensuring that all actions taken at the site are consistent with the National Contingency Plan.

1.2.3.7 West Virginia Air Pollution Control Commission. The West Virginia Air Pollution Control Commission (WVAPCC) was notified by letter on 23 January 1991 of the COE's intent to conduct a site investigation at the ACF site. Results of these investigations are regularly provided to the WVAPCC. The COE held meetings with the WVAPCC to discuss the investigations and the proposed removal action alternatives. The WVAPCC has expressed little concern regarding the site characterization activities; however, it is anticipated that it will be actively involved during the excavation and disposal phases. The COE intends to continue coordination efforts with the WVAPCC throughout the entire process.

1.2.3.8 West Virginia Division of Water. The COE has maintained a close coordination with the West Virginia Division of Water (WVDOW). The WVDOW's interest in this project stems from the former ACF site's proximity to the Kanawha River and the Town of Eleanor's water supply wells. The ACF site is situated on the right descending bank of the Kanawha River adjacent to the Winfield Locks and Dam. Eleanor's wells are located approximately one mile downstream of the ACF site. The WVDOW is kept informed of project activity through meetings with COE personnel and the submission of study reports and findings.

1.3 Analytical Data.

1.3.1 Analytical Data Sources. Water and soil samples have been collected by several different interests at the ACF site. Sampling associated with the initial environmental evaluation was performed by the Huntington District COE. This effort was followed by a Complaint Investigation administered by the WVDNR. Subsequently, ACF cooperated with the WVDNR in the performance of a Compliance Evaluation Inspection. As a result of the Compliance Evaluation Inspection, ACF hired Allstates Environmental Services, Inc. to complete an environmental site investigation. Additional sampling and analysis were performed in conjunction with ACF's remediation process. The Huntington District COE collected additional samples following the discovery of discolored water and soil along the ACF remediation excavation pit walls. In August 1990, the Nashville District COE (COE's Ohio River Division Field Operating Agent for HTRW) was contacted to initiate site characterization studies. The Nashville District COE has overseen several studies at the site. In addition, the Omaha District COE (COE's Center of Expertise for HTRW) has also administered studies at the site. The analytical results and study findings are discussed in Sections 1.3.2 through 1.3.5.5.3. Analytical results, when available, are included in the appropriate Appendix.

1.3.2 ACF Environmental Site Investigation. On 21 March 1989, Allstates Environmental Services, Inc., while under contract to ACF, began an environmental site investigation.

This study was part of an effort to determine the extent of soil contamination; however, the study was limited to a localized portion of the site. The environmental site investigation was completed on 12 May 1989. This study defined the geographic boundaries of soil contamination and identified the types of chemical contaminants present. Study findings indicated that the area of primary contamination was limited to a 21,600 square foot area with an estimated volume of contaminated soil of 3,200 cubic yards. Contamination was detected at soil depths ranging from 3 to 14 feet. The following organic contaminants were identified:

TABLE 1-1

ORGANIC COMPOUNDS DETECTED IN
SOILS DURING THE
ENVIRONMENTAL SITE INVESTIGATION

Tetrachloroethylene
Chloroform
Dichloroethane
Trichloroethane
Chlorobenzene
Methylene Chloride
Trichloroethylene
Benzene
Ethyl Benzene
Toluene

The report went on to recommend excavation and landfill disposal as the preferred remediation alternative.

1.3.3 ACF Remediation Activity. On 22 January 1990, ACF initiated environmental remediation at the site. This action was in response to West Virginia Hazardous Waste Order Number HW-225-89, dated 27 October 1989. ACF hired Allstates Remedial Services, Inc. to remediate the site. ACF remediation activity was scheduled to follow the remediation process developed in the environmental site investigation. However, site conditions encountered during the course of remediation dictated changes in the scope of Contaminated soils ranged in depth from 1-2 feet below the surface to approximately 20 feet. The total volume of soils excavated during the remediation was 9,151 cubic yards. The hazardous waste soils (4,466 tons) were disposed of at the Envirosafe, Inc. chemical landfill in Toledo, Ohio. The nonhazardous soils (6,641 tons) were disposed of at the

Wetzel County, West Virginia special waste landfill. In addition, approximately 100 empty containers, most of them 55 gallon metal drums, (some with minor chemical residual) were unearthed, crushed, and shipped to Envirosafe for disposal in the chemical landfill. Specific contaminants discovered during this phase of testing and excavation include various types of chlorinated hydrocarbons, aromatic petroleum hydrocarbons, and phenolic compounds. Several specific contaminants were found to be recurring in most of the progress samples. See Table 1-2 for a listing of identified compounds. The environmental response action of Allstates Remedial Services, Inc. was completed on 11 April 1990. On 7 May 1990, the WVDNR approved ACF's report stating that its actions satisfied the requirements of the site excavation plan agreed upon under West Virginia Waste Order Number HW-225-89.

TABLE 1-2

ORGANIC COMPOUNDS DETECTED IN
CONFIRMATORY ANALYSIS
ACF REMEDIATION ACTION

Methylene Chloride
1,1-Dichloroethene
1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
Trichloroethene
Chlorobenzene
1,1,2-Trichloroethane
1,1,2,2-Trichloroethane
Tetrachloroethene
Benzene
Toluene
Ethylbenzene

1.3.4 Preliminary Residual Contamination Survey. Following a 27-28 May 1990 rainstorm, COE representatives observed discolored water seeping from the excavation pit walls which had been left open following the remediation effort administered by ACF. Later that month, the COE collected samples of surface water at the former ACF facility, from piezometer installations within the Winfield Locks and Dam area about a half-mile downstream of the ACF property, and from water supply wells belonging to the Town of Eleanor, West Virginia. These wells, located about one mile downstream of the ACF site, are the primary source of drinking water for the Town of Eleanor. Contamination was not detected in any of the groundwater samples; however, seeps exiting the excavation pit walls contained high levels of contaminants, indicating contamination in the remaining adjacent soils. Table 1-3 presents a list of contaminants identified in samples collected in the area of the ACF remedial excavation. Information gained on contaminants from this survey was considered to be qualitative in nature. Neither the sample design nor the field and laboratory quality assurance/quality control (QA/QC) procedures were sufficient to define the extent and range of contamination. Therefore, this analytical data is not included in this EE/CA report.

TABLE 1-3

ORGANIC COMPOUNDS DETECTED IN
PRELIMINARY RESIDUAL CONTAMINATION SURVEY

Methylene Chloride
1,1-Dichloroethene
Chloroform
Trichloroethene
Chlorobenzene
1,1,2,2-Trichloroethane
Toluene
Ethylbenzene
1,2-Dichloropropane
1,2-Dichlorobenzene
1,2,4-Tetrachlorobenzene
Dibenzofuran
1,2-Dimethylbenzene
2,4-Dimethylphenol
2,4-Dichlorophenol
Acetone

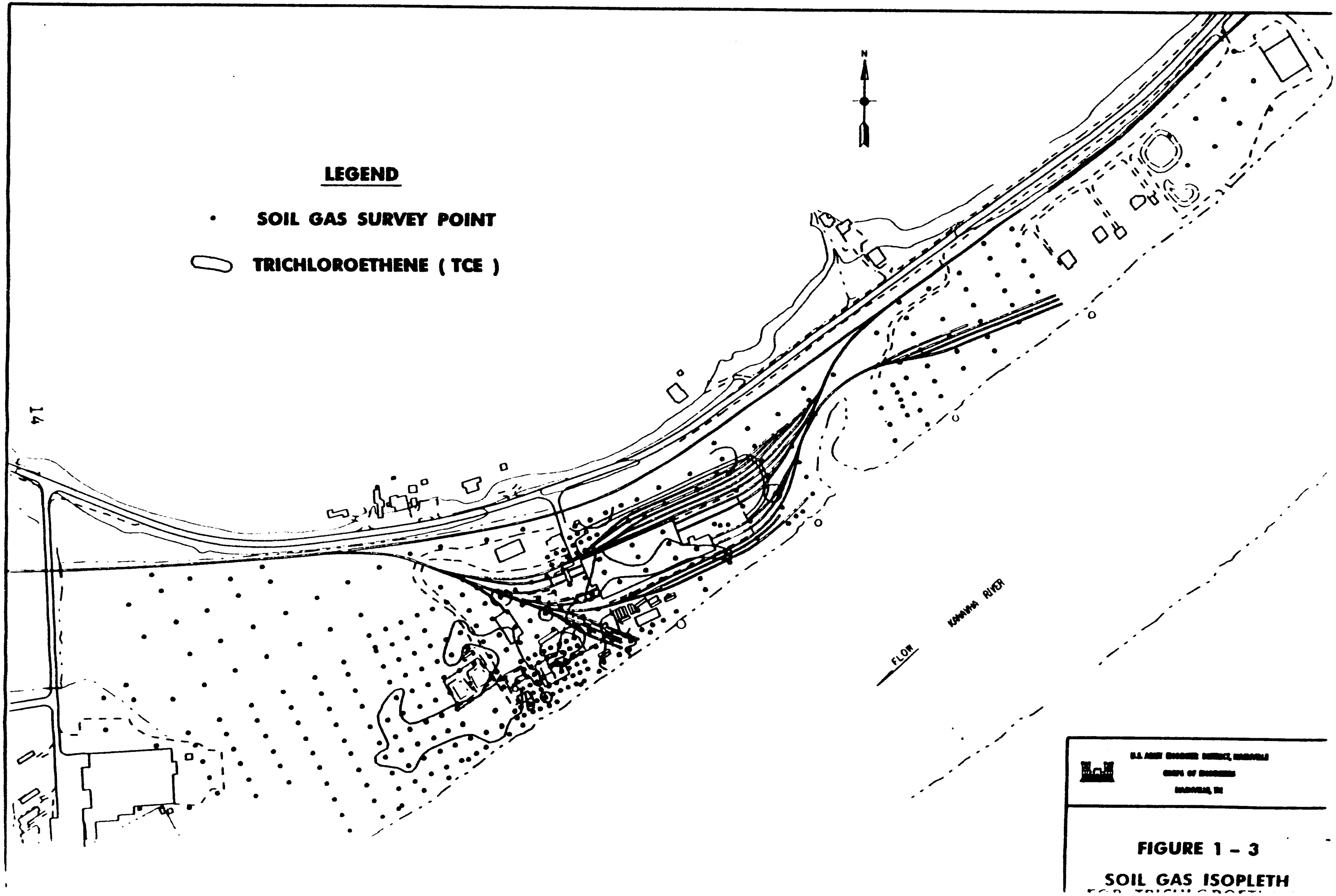
1.3.5 Confirmation of Contamination. On 17 August 1990, an equipment operator for the COE's construction contractor experienced irritation to the skin and throat while removing old pavement on the ACF site. Vapors from an unidentified chemical with a distinct odor seemed to be steaming up through the ground. The COE issued an order to stop all work in the area until the situation could be assessed. In September 1990, the COE planned an initial site investigation. This site investigation was designed to include soil gas surveys, soil sampling, and any necessary groundwater monitoring. Due to the nature of the contaminants identified the confirmation activities were expanded to include dioxin sampling and a total site characterization. Samples for all environmental site investigations administered by the COE were analyzed using appropriate EPA SW-846 methods and utilized a quality assurance/quality control (QA/QC) program in an effort to provide legally defensible data.

1.3.5.1 Soil Gas Survey. Prior to the initiation of soil sampling, a soil gas survey was conducted over the entire site. A passive soil gas method was selected and sampling points were established on a grid varying from 25 feet to 100 feet. The soil gas method used provided qualitative data for the identification of volatile organic (VOC) and semi-volatile organic (SVOC) contamination. This information was used to estimate the horizontal extent of VOC and SVOC plumes and as a tool for selecting soil sampling locations and the placement of groundwater monitoring wells. A typical soil gas isopleth developed from qualitative data generated during this survey is shown in Figure 1-3. The soil gas data indicated that VOC and SVOC contamination was present over a large portion of the site.

1.3.5.2 Soil Sampling. The objective of the soil sampling was to confirm the presence and identify the types and concentrations of contaminants present at the site. The soil sampling was accomplished by collecting and analyzing 27 soil samples consisting of soil borings and surficial samples from predetermined locations. The soil samples were analyzed for the following groups of parameters:

Volatile Organics
Semi-volatile Organics
Pesticides/PCBs
RCRA metals
Cyanide
Dioxin/Furans (3 samples)

The locations for the soil sampling were determined from the soil gas data and other available information. The soil



[illegible]
[illegible]
[illegible]

FIGURE 1 – 3

SOIL GAS ISOPLETH

sampling data were relatively consistent with the soil gas results; high concentrations of VOCs and SVOCs were detected in several areas of the site. In addition to these contaminants, pesticides, PCBs, and dioxins were detected. Sampling locations and analytical results are included in Appendix A. Given the number and concentrations of contaminants found in the soil matrices, it was evident that groundwater contamination was possible and must be investigated. Due to the environmental significance of dioxin and the fact that it was detected in two of the three samples analyzed, additional sampling was required to determine if dioxin contamination is localized or widespread.

1.3.5.3 Groundwater Monitoring. Initial groundwater monitoring at this site was accomplished by the installation of four groundwater monitoring wells, sampling each of these wells and three existing water supply wells in the area. Three of the monitoring wells were installed at the top of rock (approximate depth of 60 feet), and one was installed in shallow perched water (approximate depth of 15 feet). Each of the water samples were analyzed for the following groups of parameters:

- Volatile organics
- Semi-volatile organics (BNAs)
- Pesticides/PCBs
- RCRA metals

Low concentrations of volatile organic chemicals were detected in the shallow perched water, while no contaminants were detected in the deeper aquifer, which is the drinking water supply source. Well locations and the analytical data are included in Appendix B. Since no contamination was detected in the deeper aquifer, groundwater contamination does not appear to be a major concern.

1.3.5.4 Soil Sampling for Dioxin. Dioxin was detected in two of the three soil samples collected during the initial soil sampling. Due to the significance of dioxin, it was necessary to sample the soil matrix at additional locations to determine if dioxin contamination was widespread at the site or localized in the areas previously sampled. Thirteen additional soil sample locations were selected to be analyzed for dioxin. The collection and analysis of these samples was coordinated with the U.S. EPA Laboratory in Annapolis, Maryland. A draft EPA procedure (SOW 1290) was used for the analysis. This procedure is similar to SW 846 method 8280 but requires more strict laboratory quality control. The data was submitted to the U.S. EPA Laboratory for validation. The data was found to be valid and acceptable. The sample locations and data are contained in Appendix C. The Tetrachlorodibenzodioxin (TCDD) toxicity equivalence values were calculated for each sample. Over 50% of the samples were identified with dioxin contamination at a significant level. This confirmed that dioxin contamination was widespread and present in concentrations of sufficient level to be a major concern. Due to the disposal problems associated with dioxin contaminated soils, it was necessary to perform a total site characterization to determine the quantity of dioxin and non-dioxin contaminated soil.

1.3.5.5 Site Characterization. Total site characterization studies at the ACF site involved the collection and analysis of soil, groundwater, and river sediment samples. Sampling activity associated with these studies was performed during November and December 1991. The results of the total site characterization studies are discussed in Sections 1.3.5.5.1 through 1.3.5.5.3.

1.3.5.5.1 Soil Sampling. A soil sampling program was executed to better define contamination at the ACF site. This sampling program was designed to detail both the lateral and vertical extent of contamination. This information is necessary to establish the excavation limits for remediation. Soil samples were collected from 134 soil borings. Split spoon and coal mining equipment techniques were utilized during sample collection. These samples were screened for the presence of volatile, semi-volatile, and dioxin contamination. Based on screen results, certain samples were selected for a more complete analysis. These samples were analyzed for the presence of volatile organics, semi-volatile organics, pesticides/PCBs, metals (8 RCRA plus iron and manganese) and dioxins/furans. From the analyses, the extent of dioxin contamination has been determined to reside within the site boundaries except along the northern border. Specifically, dioxin contamination above action levels has been found between the railroad tracks and the exclusion zone fence north of the maintenance building. Other organic contamination above action levels is present, and generally their locations correspond with the dioxin contamination. However, some PAHs (polynuclear aromatic hydrocarbons) above action levels have been found sporadically across the site outside the dioxin plume. Lead, arsenic, and chromium concentrations that were detected above action levels are located in the dioxin plume. A figure detailing soil boring locations and the corresponding analytical data are included in Appendix D.

1.3.5.5.2 Groundwater Sampling. Groundwater samples were collected from selected wells screened in the shallow perched water and the deep aquifer. These samples were collected to document any movement of contaminants into the local groundwater system. A total of 14 wells were sampled. EPA sampling protocols were followed at all times.

These samples were analyzed for the presence of volatile organics, semi-volatile organics, pesticides/PCBs, metals, and dioxin/furans. The analyses indicate that halogenated organic solvents are present in the shallow, perched water. This contaminant group was not detected in the deeper aquifer. Concentrations of compounds in other contaminant groups were below current action limits in samples collected from both the perched water and the lower aquifer. Analytical results are included in Appendix E.

1.3.5.5.3 River Sediment Sampling. River sediment samples were collected from 16 locations in the Kanawha River in the vicinity of the ACF site. Sediment grab samples were collected using a ponar dredge. This sampling effort was designed to document the extent and nature of any off-site migration of contaminants from the site. River sediment samples were analyzed for the presence of volatile organics, semi-volatile organics, pesticides/PCBs, metals, and dioxin/furans. The river sediment sample analytical results indicate all analytes that were detected were below action levels. Analytical results are included in Appendix F.

1.4 Site Conditions that Justify a Removal Action.

1.4.1 Environmental Fate and Transport. The majority of contamination at the ACF site is limited to the soil matrices. Due to the high solubility and mobility of certain identified organic compounds there is a potential threat to the local groundwater system. A number of contaminants have been detected in perched groundwater; however, contamination of the deep, water supply aquifer has not been documented. The primary mechanisms for contaminant transport are vertical migration through the soil and horizontal migration due to leaching or surface runoff during periods of saturating rainfall. Other mechanisms include wind erosion and surface runoff from exposed areas.

1.4.2 Routes of Exposure. There are several potential routes of exposure for contaminants associated with the ACF site. These include: (1) Direct contact with waters, sediments, and soils on or adjacent to the site that have been contaminated by surface runoff and erosion processes. (2) Consumption of groundwater or surface water downgradient of the site. (3) Inhalation of contaminated dust that becomes airborne due to wind erosion or anthropogenic activities. (4) Direct contact of river water downstream of the site. The primary routes of concern are the potential dermal absorption and ingestion of contaminated surface water, groundwater, and soil. The populations at greatest risk to exposure are construction workers at the site, people residing in the vicinity, and transient individuals crossing the site from the river area. Populations that consume either groundwater or surface water may be at an increased risk of exposure to contaminants that may enter the water table and migrate off-site. These populations include individuals who reside downgradient of the site such as in the Town of Eleanor or other nearby residences.

1.4.3 Contamination of Drinking Water. Groundwater samples have been collected from several monitoring wells and piezometers on and adjacent to the ACF property and from regional water supply wells. As stated in section 1.3.5.5.2, analyses indicate the presence of halogenated VOAs (volatile organic analytes) in perched groundwater which does not serve as a drinking water supply. Similar analyses of the deep aquifer, which serves as a water supply for the Town of Eleanor, indicated detected constituents are below action levels. In addition, the City of Eleanor online wells 3 and 4 were tested in early December, 1991 for drinking water parameters and analytes that were detected were below applicable State of West Virginia and EPA MCLs (maximum contaminant levels).

1.4.4 Bulk Storage Containers. Environmental site evaluations have identified the contamination of soils at the ACF site. These studies have not confirmed the presence of bulk storage containers. There is a high probability that buried drums may be present at the site. Several local residents have alleged that drums and other storage containers have been buried at various locations on the former ACF property. A drill crew appeared to drill into a drum or other similar object while installing a monitoring well. During earlier remediation action ACF encountered approximately 100 buried drums while excavating contaminated soils. With the likelihood of bulk storage containers being unearthed during remedial soil excavation the potential exists for a release of contaminants.

1.4.5 Soil Contamination at or Near the Surface. Site evaluations have documented the presence of contaminants in soils at and near the surface. These contaminants have a direct route to the Kanawha River via the surface drainage system. In all probability, contaminants have left the site and entered the river following runoff producing storm events.

1.4.6 Critical Weather Conditions. The ACF site lies above the 100-year flood plain of the Kanawha River. Contaminants present in the soil at this site may migrate to the Kanawha River through either surface runoff or shallow groundwater flow following storm events. Erosion of the riverbank during periods of high flow offers another mechanism for contaminants to leave the site. In addition, high winds are capable of eroding the soil surface and transporting contaminants off the site.

1.4.7 Threat of Fire or Explosion. Site evaluations performed at the ACF site have not indicated the presence of reactive components that would result in the generation of fire or explosion. However, the possibility exists that such contaminants may be present in sufficient quantities to spontaneously react yielding fire or explosion. The most likely threat would appear to be from the uncovering of any buried drums during remedial excavation work that may contain such constituents.

1.4.8 Additional Federal or State Response Mechanisms. Federal, State, and local response mechanisms are in place should there be an accident or spill at the site during remediation. In addition to direct response from such groups as Federal and State HAZMAT teams and local civil defense forces the COE has a presence on the Kanawha River through the Winfield Locks and Dam. The COE would have the ability to minimize the impacts of releases to the Kanawha River through the operation of water resources projects in the Kanawha River Basin.

2.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

2.1 Statutory Limits on Removal Actions. The National Contingency Plan (NCP) states that Superfund financed removal actions shall be terminated after $2 million has been obligated for the action or 12 months have elapsed from the date that removal activities began on-site. The intent of this limitation is to ensure that Superfund monies are spent wisely, thereby enabling the entire action to be completed efficiently and cost-effectively. Although this project is not Superfund financed, Congress intends that federal agencies implement all removal activities consistent with the limitations proposed by the EPA Administrator.

2.1.1 Federal Lead Agency. In accordance with Executive Order 12580, the Department of Defense, along with other federal agencies, was given the authority to assume the responsibility as the Federal Lead Agency to conduct removal actions at facilities under their jurisdiction. EPA (III) has concurred with this position. All actions must be exercised consistent with Section 120 of CERCLA.

2.1.2 Exemptions. CERCLA allows the following exemptions to be invoked if the statutory limits are exceeded.

(1) The lead agency determines that: *
there is an immediate risk to public health or welfare or the environment,
* continued response actions are immediately required to prevent, limit or mitigate an emergency; and such assistance will not otherwise be provided on a timely basis, or

(2) The lead agency determines that: *
continued response action is otherwise appropriate and consistent with the remedial action to be taken.

This project is not subject to the above statutory limitations; however, in accordance with Congress' intent for federal agencies, it is the COE's position that a continued response action is otherwise appropriate and consistent with the removal action to be taken.

2.2 Removal Action Scope. The objective of this removal action is to remove, treat, and dispose of contaminated material at this site. This will involve removing all contaminated soil identified within the site and treating it in accordance with the Applicable or Relevant and Appropriate Requirements (ARARs). The COE acquired this property in December 1989 as part of a project to modernize the existing Winfield Locks and Dam. The removal action at the ACF site must be initiated prior to excavation for the additional lock and approach channel. In order to complete the excavation of contaminated soils within the construction schedule for the lock approach, a temporary storage building may have to be built on-site to contain all contaminated soil until treatment can be initiated. All contaminated material at the site must be addressed regardless of its location in relation to the COE construction activity. The decision for determining the vertical and horizontal extent of soil removal is dependent upon risk-based preliminary removal action goals.

2.3 Removal Action Schedule. Excavation activities are expected to be completed within eight months with a tentative starting date of April 1994; it is necessary to schedule these activities for the drier months. The entire removal action is projected to require approximately six years to complete with a tentative starting date of June 1992. The removal activities will involve developing and preparing the removal plans and specifications, awarding the removal contract, and executing the removal activities.

2.4 Applicable or Relevant and Appropriate Requirements (ARARs). The COE identified the following ARARs as applicable to the anticipated and potential response action:

Temporary Storage Building

- Resource Conservation and Recovery Act (RCRA) design requirements (Federal)
- Air Quality Standards (Federal and State)
- Nation Pollutant Discharge Elimination System (NPDES) requirements for treatment and disposition of groundwater during excavation (Federal)
- Clean Water Act (Federal)
- Safe Drinking Water Act (Federal)
- Fish and Wildlife Coordination Act (Federal)
- Clean Water Act - Section 404 (Federal)
- Executive Order 11988 (Federal)

Thermal Destruction

- RCRA requirements, excluding formal permitting procedures (Federal)
- RCRA requirements for incinerators (Federal)
- Air Pollution Control Standards (West Virginia Administrative Regulations, Air Pollution control commission, Chapters 16-20 and 20-5E, Series 25, 1988) (Federal and State)
- NPDES requirements (Federal)
- RCRA disposal restrictions for ash (Federal)
- Clean Water Act (Federal)
- Safe Drinking Water Act (Federal)

- Fish and Wildlife Coordination Act (Federal)
- Clean Water Act - Section 404 (Federal)
- Executive Order 11988 (Federal)

On-site Disposal

- RCRA design requirements (Federal)
- RCRA Land disposal Restrictions (LDR) (Federal)
- Air Quality Standards (Federal and State)
- NPDES requirements (Federal)
- Clean Water Act (Federal)
- Safe Drinking Water Act (Federal)
- Fish and Wildlife Coordination Act (Federal)
- Clean Water Act - Section 404 (Federal)
- Executive Order 11988 (Federal)
- Groundwater monitoring requirements (Federal and State)

Off-site Disposal

- RCRA Land Disposal Restrictions (LDR) (Federal)

These ARARs have been proposed to EPA (III) and to the WVDNR. Both agencies concurred with these proposed ARARs, and the State of West Virginia recommends including the following Federal and State regulations to the existing list:

- 29 CFR 1904 - Record keeping and reporting of occupational injuries and illness.
- 29 CFR 1910 - Occupational, Safety and Health Standards for employees engaged in handling hazardous material.
- 29 CFR 1926 - Safety and health regulation for construction.
- 40 CFR 263 - Federal standards for transporters of hazardous waste.
- West Virginia Code of State Regulation (WVCSR) 46 and 47 - Excavation on site must be protected from surface water run-on and run-off.
- WVCSR 45 - During excavation the West Virginia Air Pollution Control Regulations apply to particulate matter and volatiles.
- All applicable section of WVCSR 47 will apply to the anticipated activity.

2.4.1 RCRA Land Disposal Restrictions (LDR). In order to determine whether or not the contaminants detected on site would be classified as a listed RCRA hazardous waste, and be subjected to the LDRs, the COE reviewed the former property owner's (ACF) historical records and shipping manifests to determine if any of the contaminants were used in the facility's operations. The COE concluded that the contaminants detected on site were not RCRA hazardous wastes; in addition, the COE received correspondence from EPA (III) agreeing with this decision. Although the contaminants on site are not subject to the LDRs, the COE listed the LDRs as ARARs and intends to comply with them during the response action.

3.0 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

3.1 Identification of Treatment Technologies. Hazardous wastes can be treated and disposed of in a variety of ways, depending on the contaminants present. In accordance with guidance provided for alternatives to the land disposal of wastes the EE/CA report identifies appropriate technologies for the following waste categories: (1) recyclable and/or recoverable materials; (2) wastes restricted from land disposal; and (3) all CERCLA wastes not otherwise restricted, and all RCRA wastes not included in the first two categories. Category 1 materials found at the ACF site include railroad steel and a variety of building materials found in the numerous buildings on site. Where appropriate, these materials will be decontaminated and reused or recycled. Dioxin, a category 2 waste, has been found at this site and will be the determining factor for treatment options. Due to its toxicity and persistence, the options are severely limited. Category 2 wastes require pretreatment prior to land disposal, an alternative to land disposal, or disposal at a specific type of facility. Several other organic contaminants have been detected at this site. These contaminants are predominantly Category 2 wastes and include such compounds as TCE, PCE, chloroform, and toluene as well as several other volatile organics, semi-volatile organics, and pesticides. Currently the predominant method for treating contaminated soil similar to that found at this site is on-site incineration; however, new and innovative technologies are being developed. The following options are appropriate for addressing contaminated soils at this site:

1) Physical/Chemical Solidification
2) Disposal in Class I Landfill
3) On-site Treatment
4) Off-site Incineration
5) On-site Disposal

3.2 Physical/Chemical Solidification. Physical/Chemical solidification involves mixing the contaminated soil with a binding agent. This forms a solid which in turn can be disposed of in a landfill. Contaminants present in the soil are immobilized but they are not destroyed.

3.3 Off-site Disposal in a Class I Landfill. The excavation, removal, and off-site disposal of contaminated soil in a Class I landfill provides the simplest and quickest method of ultimate disposal; however, the presence of dioxin and other land ban wastes complicates matters. The land ban requires that certain contaminants be reduced below regulatory levels before they can be disposed of in a Class I landfill. Therefore, pretreatment of the waste may be required prior to land disposal.

3.4 On-site Treatment. Several technologies exist which treat organic containing wastes to levels below regulatory limits. Most of these technologies are mobile and could be utilized at this site. On-site technologies available include thermal treatment, soil washing followed by dechlorination, in-situ vacuum extraction followed by excavation and disposal, and bioremediation. These individual on-site treatment options are discussed below.

3.4.1 Thermal Treatment. The contaminated materials would be excavated and treated by thermal destruction with a mobile or transportable on-site incinerator. The ash residue would then be placed in an appropriate on-site landfill or hauled to an off-site landfill.

3.4.2 Soil Washing. The contaminated soil would be excavated and "washed" with a solvent. This solvent would extract the organics from the soil. The contaminated solvent would then be treated and either recycled or disposed of.

3.4.3 In-situ Vacuum Extraction. Prior to excavation of the soils, several dry wells would be installed in the contaminated areas. A vacuum would be drawn on each of the wells. The gas which is extracted from the wells would be treated prior to being released to the atmosphere.

3.4.4 Bioremediation. This technology can be applied both in-situ and after excavation. Nutrients and oxygen would be applied to the soil to enhance the microbes present in the soil. This would cause the microbes to multiply and degrade the contaminants. In some cases, bacteria may be added to the soil if appropriate microbes are not present.

3.5 Off-site Incineration. Off-site incineration is capable of treating dioxin and other organic contaminants at this site. To utilize this technology the contaminated soil would be excavated and then hauled to a commercial off-site incinerator for thermal destruction. The ash residue would then be disposed of in an appropriate landfill.

3.6 On-site Disposal. On-site disposal would involve excavating the contaminated materials and disposing of them in a waste pile. The waste pile would be constructed as a RCRA hazardous waste landfill including double liners, leachate collection and treatment, and a clay cap. Several constituents are present in the soil which are regulated under the land disposal restrictions. Pretreatment of the soil would be required prior to placement in the landfill.

4.0 INITIAL SCREENING OF REMOVAL ACTION ALTERNATIVES

4.1 Screening Criteria. Each of the removal action alternatives is subjected to an initial screening for fundamental characteristics that may eliminate it from further consideration. The purpose of this screening is to eliminate those technologies with obvious shortcomings. The initial screening factors are:

- The public health and environmental protection provided by the technology
- The ability of the technology to produce the desired results in the stipulated time frame
- The feasibility of the technology
- The acceptability of the technology in light of institutional considerations

If a removal action alternative fails any one of the screening factors it is not subject to the remaining factors and is removed from consideration. Table 4-1 presents a rating scheme for evaluation of technologies. Table 4-2 summarizes the ratings developed for each alternative based on the point system outlined in Table 4-1.

4.2 Rejected Alternatives. As stated earlier the purpose of this initial screening is to remove from consideration those alternatives with obvious shortcomings. Based on the rating scheme presented in Tables 4-1 and 4-2 the following treatment technologies were rejected.

- Physical/Chemical Solidification
- Off-site Disposal in Class I Landfill
- Soil Washing
- In-situ Vacuum Extraction
- Bioremediation
- Off-site Incineration
- On-site Disposal

A brief discussion of each of the rejected alternatives is presented in Sections 4.2.1 through 4.2.7.

4.2.1 Physical/Chemical Solidification. Physical/Chemical solidification is not considered appropriate for this site due to the large number of organic compounds present. Several organic compounds have been detected in relatively high concentrations. Evaluation of this technology has demonstrated that some organics cannot be effectively bound to the soil. As a result leaching may occur, allowing contaminants to leave the site or disposal facility. In addition, the physical/chemical solidification process increases the volume of material to be disposed of.

TABLE 4-1

SCREENING FACTOR RATING SCHEME

Criteria	Rating Points
1. Does the option protect public health and the environment?	
Option will provide ultimate long-term mitigation of threats to public health, welfare, and the environment.	4
Option will mitigate threats to public health, welfare, and the environment but long-term future threats may occur due to failure.	3
Option will mitigate threats to public health, welfare, and the environment but long-term future threats are likely due to failure.	2
Option does not mitigate threats to public health, welfare, and the environment.	1
2. Can the option be implemented within the time limits imposed by the situation?	
Yes	4
No	1
3. Is the option technically feasible in light of the situation?	
Option is proven technically feasible in large field-scale applications under similar site conditions, media, and contaminants.	4
Option is proven technically feasible in large field-scale applications under different site conditions.	3
Option is not proven technically feasible in large field-scale applications.	2
Option is not proven technically feasible, i.e., it has failed under similar site conditions, media, and contaminants or is an emerging technology.	1
4. What are the institutional considerations?	
Consistent with NEPA, extremely positive public perception, or minimal institutional requirement concerns.	4
Consistent with NEPA, acceptable public perception, or some institutional requirement concerns.	3
Consistent with NEPA, negative public perception, or major institutional requirement concerns.	2
Inconsistent with NEPA, negative public perception, or major institutional requirement concerns.	1

TABLE 4-2

INITIAL RATING OF ALTERNATIVES

	Public Health & Environment	Timeliness	Technical Feasibility	Institutional Considerations	Total
Physical/Chemical Solidification	2	4	1	3	10
Off-site Disposal in Class 1 Landfill	3	4	2	1	10
On-site Thermal Treatment	4	4	4	2	14
Soil Washing	4	4	1	3	12
In-situ Vacuum Extraction	4	1	1	3	9
Bioremediation	4	1	1	3	9
Off-site Incineration	4	4	3	1	12
On-site Disposal	2	1	4	1	8

4.2.2 Off-site Disposal in Class I Landfill. The off-site disposal in a Class I Landfill of contaminated soil from this site would provide the quickest method of ultimate disposal; however, the soil is contaminated with several Land Disposal Restricted (LDR) wastes. The land ban requires that certain contaminants be reduced below regulatory levels before they can be disposed of in a Class I Landfill. No commercial Class I Landfills exist that will accept wastes containing high levels of dioxin. Concentrations of dioxin in excess of 2 ppb are considered high. The levels of dioxin found on this site exceed this concentration by a significant amount. Also, public opposition to the transportation of wastes containing dioxin precludes any transportation of soil off-site prior to subjecting that soil to some form of on-site treatment.

4.2.3 Soil Washing. This technology has been shown to be effective on soils contaminated with several of the organics at this site. It has also been shown to work on soils contaminated with PCBs which are similar to dioxin; however, this process has not been proven on a large scale with dioxin contaminated soils. This technology is still fairly new and emerging. Dioxin contaminated solvent wastes generated from this process would have to be treated on-site.

4.2.4 In-situ Vacuum Extraction. This technology has been proven on a large scale at sites contaminated with volatile organic compounds. This technology would not address the dioxin and non-volatile contaminants found at this site. This technology would require an extended period of time to treat the soil.

4.2.5 Bioremediation. This technology has been proven to work for several organics present at this site, however, it has only been shown to work for dioxin in small-scale applications. The technology has not been proven for conditions encountered at this site.

4.2.6 Off-site Incineration. This technology is capable of treating dioxin and the other organic contaminants at this site. No commercial incinerators exist at this time which are permitted to accept soils with dioxin concentrations above 2 ppb. The levels of dioxin at this site are significantly higher than this limit. Also, it is estimated that approximately 61,000 cubic yards of in-situ soil will have to be treated. This quantity exceeds the capacity of commercial incinerators. As in the case of off-site landfill disposal, public opposition to the transportation of wastes containing dioxin constrains the feasibility of this option.

4.2.7 On-site Disposal. The placement of contaminated materials in an on-site landfill would provide a relatively quick and simple means of disposal. RCRA designed landfills are fairly effective at containing hazardous wastes. This technology does not destroy the contaminants present; thus, long-term liability must be considered. On-site disposal is not acceptable to the State of West Virginia. Public concerns associated with locating a hazardous waste landfill adjacent to a major surface water body must also be considered. The soils to be excavated at the ACF site are contaminated with several LDR wastes. In order for this technology to comply with the Land Disposal Restrictions, the soil would have to be pretreated, most likely by on-site incineration, to reduce the concentration of several land ban constituents before it could be placed in a landfill.

4.3 Alternatives Recommended for Additional Evaluation. During the initial screening of alternatives, for an alternative to receive additional consideration it must not have received a score of 1 for any of the rating criteria presented in Table 4-2. On-site thermal treatment is the only technology to survive this initial screening. On-site thermal treatment will be subjected to a more complete evaluation in Section 5.0.

5.0 ANALYSIS OF REMAINING REMOVAL ACTION ALTERNATIVES

5.1 Evaluation Criteria. On-site thermal treatment, the only technology that passed the initial screening summarized in Section 4.0, is subject to a more complete analysis. Ordinarily this process would be used to evaluate two or more alternatives that passed the initial screening. However, with only one alternative, this process will be utilized to better determine the applicability of on-site thermal treatment to remediate contaminated soils at the ACF site. The evaluation process begins with the identification of action specific ARARs, followed by the application of the following evaluation criteria:

- Technical Feasibility
- Reasonable Cost
- Institutional Considerations
- Environmental Impacts

A rating system developed for these four technology evaluation criteria is presented in Table 5-1. Ratings for on-site thermal treatment are presented in Table 5-5.

5.1.1 Technical Feasibility. The technical feasibility of an alternative is evaluated based on that technology's ability to satisfy a number of issues. These issues include:

- Effectiveness
- Useful Life
- Annual Operating Requirements
- Demonstrated Performance
- Constructability

5.1.2 Reasonable Cost. A cost analysis is required for each alternative. This analysis includes the development of cost figures for direct capital costs, indirect capital costs, and annual operating costs. Following the identification and development of capital and operation and maintenance costs a present worth calculation is performed. This allows the direct comparison of different technologies with expenditures extending over different time periods.

5.1.3 Institutional Considerations. A review of relevant institutional considerations begins with an analysis of how the alternative will meet the objectives outlined in Section 2.0. These objectives include statutory limits on removal actions, the removal scope, the removal schedule, and compliance with ARARs. This analysis also includes the identification of Federal, State, and local concerns about the technology and any permitting requirements. Safety concerns, both during implementation and operation, are also

TABLE 5-1

REMOVAL ACTION TECHNOLOGY SELECTION CRITERIA

1. Technical Feasibility

A. Effectiveness

Destroys hazardous substances.	4
Prevents release of hazardous substances; contaminants are isolated but not eliminated.	3
Minimizes the release of hazardous materials; adequately protects public health and environment.	2
Allows or Promotes release of hazardous substances; ineffective.	1

B. Demonstrated Performance

Proven reliable in the field under similar conditions on the same waste material; widely demonstrated to be effective.	4
Proven reliable in the field under similar conditions on similar waste materials.	3
Proven reliable, but under different conditions and materials; limited experience and reliability.	2

C. Useful Life

Permanent; irreversible.	4
Long-term, potentially reversible; effectiveness decreases with time with a low probability of release.	3
Long-term, potentially reversible with a high probability for release.	2
Short-term solution; difficult to repair or replace upon failure; temporarily mitigates hazards; long-term abilities questionable.	1

D. Environmental Effects Upon Operations

Performs well under all environmental conditions.	4
Performs well under most environmental conditions.	3
Performs adequately under most conditions.	2
Susceptible to adverse weather conditions.	1

TABLE 5-1

(CONTINUED)

2. Institutional Considerations

A. Permitting and Other Factors Affecting Start-Up

No permitting or significant lead time required.	4
Minimal lead time required (3 months)	3
Moderate lead time required (6 months)	2
Significant lead time required (1 year)	1

B. Time to Complete

Can be completed within the 12 month statutory limit.	4
Site is expected to qualify for an exemption to the 12 month limit, and alternative can be completed within a reasonable time thereafter.	3
Site is expected to qualify for an exemption, but requires significant time beyond the 12 month limit to complete.	2
Cannot be completed within the 12 month statutory limit, and the site is not expected to qualify for an exemption.	1

C. Safety

1) During Installation/Operation

Very safe; requires no more than normal safety procedures required for workers at hazardous waste sites; no threat to surroundings at any time.	4
Safe; requires few safety procedures other than those normally required at a hazardous waste site; minor threat to adjoining residential areas may occur.	3
Hazardous; requires stringent safety procedures to ensure worker safety; may require evacuation of homes near the site.	2
Very hazardous; requires remote operation and and evacuation of area homes.	1

2) Effects of Failure

Very safe; redundant controls prevent hazardous substance release.	4
Failure results in hazard that is less than that presented by the site prior to removal action.	3
Failure results in hazard that is approximately equal to that presented by the site prior to the removal action.	2
Failure results in hazard greater than that presented by the site prior to the removal action.	1

TABLE 5-1

(CONTINUED)

3 Environmental Impacts

Positive environmental impact.	4
No detrimental environmental impact.	3
Minimal adverse environmental impact.	2
Extreme adverse environmental impact.	1

addressed. The possible transportation of hazardous materials is identified. Any detrimental impacts to adjoining property use or value is discussed.

5.1.4 Environmental Impacts. The analysis of environmental impacts within the EE/CA report fulfills the equivalency requirements for an environmental impact analysis as mandated under the National Environmental Policy Act (NEPA). This analysis begins with an identification of the environmental media which will receive either adverse or beneficial impacts from implementation of the particular technology. A distinction is made on which significant adverse effects are irreversible. Consideration includes the following resources and their associated standards:

- Surface Water
- Groundwater
- Drinking Water
- Air

In addition to the protection of general environmental resources, the environmental analysis also considers other specific environmental and cultural resources including:

- Sole Source Aquifers
- Archaeological and Historic Resources
- Wild and Scenic Rivers
- Wetlands
- Flood Plains
- Critical Habitats of Threatened and Endangered Species
- Prime and Unique Farmlands
- Federal Parklands and Wilderness Areas
- National Forests and National Grasslands

5.2 On-site Thermal Treatment.

5.2.1 Action Specific ARARs. The following ARARs are applicable to on-site incineration:

- RCRA Incinerator Requirements, excluding formal permitting procedures
- Air Pollution Control Standards, West Virginia Administrative Regulations, Air Pollution Control Commission, Chapters 16-20 and 20-5E, Series 25, 1988
- NPDES Requirements
- RCRA Requirements for disposal of ash
- OSHA Safety and Health Standards (29 CFR Parts 1904, 1910, and 1926)
- WVCSR 45, 46, and 47

5.2.2 Technical Feasibility. Incineration has been proven to be effective at destroying organic contaminants in soil. Operating parameters can be adjusted so that the incinerator complies with ARARs. Likewise, any associated equipment such as pollution control devices can enable the incinerator to comply with appropriate ARARs. Several commercial mobile or transportable incinerators are available which have successfully treated wastes similar to those found at the ACF site. On-site incineration provides ultimate destruction of contaminants. The useful life of the incinerator is irrelevant since it will be in operation on a temporary basis only. Operation and maintenance are straightforward and typically performed by the incineration vendor. This technology is relatively unaffected by environmental conditions. No-site specific characteristics exist which will delay or prohibit construction. The incinerator, either a transportable or mobile incinerator, will be on-site approximately 19 months after approval of this document. The actual incineration of soils will take approximately five years. There is little uncertainty associated with this technology. On-site incineration is a proven and accepted technology for ultimate destruction of organic contaminants in soil.

5.2.3 Reasonable Cost. An estimate of direct and indirect capital costs and operation and maintenance costs has been developed for the use of on-site incineration. These costs are shown in Table 5-2. Assuming the removal action will last five years, the total expenditure in October 1991 dollars is $98.7 million.

5.2.4 Institutional Considerations. On-site incineration is acceptable to both the State of West Virginia and EPA (III). This alternative will be coordinated with the WVDNR, both the Air Pollution Control and Water Pollution Control Sections, and with EPA (III). A NPDES permit will be required for any scrubber or quench water discharged from the process. Other permits will not be required; however, the substantive requirements of these permits will be met. Safety features of the incinerators will be evaluated during the bidding process and this will be a criteria for selection. This alternative would preclude the off-site transportation of any hazardous materials. Operation of the incinerator will be temporary; therefore, adjoining property use and values will not be adversely impacted. In fact, the ultimate destruction of contaminants at the site should benefit adjacent property use and value.

TABLE 5-2

WORKSHEET 1: CAPITAL COST
ON-SITE THERMAL TREATMENT
(OCTOBER 1991 DOLLARS) (1)

	Cost Component	Year Incurred	Cost Estimate	Contingency	Total
1.	Mobilization (2)	0	172,000	34,000	206,000
2.	Decontamination Facilities	0	216,000	43,000	259,000
3.	Decontaminate Existing Structures	0	436,000	175,000	611,000
4.	Site Demolition	0	1,798,000	719,000	2,517,000
5.	Materials Storage Building (3)	1	10,244,000	2,093,000	12,337,000
6.	Excavate and Haul	1 - 2	3,134,000	1,097,000	4,231,000
7.	Incineration (4)	2 & 5	4,593,000	918,000	5,511,000
8.	Incineration (5)	2 - 5	29,534,000	10,337,000	39,871,000
9.	Ash Disposal	2 - 5	9,198,000	2,759,000	11,957,000
10.	Water Treatment (3)	0 - 5	5,782,000	1,735,000	7,517,000
11.	Demobilization (2)	1 & 3	875,000	175,000	1,050,000
	Subtotal:		**65,982,000**	**20,085,000**	**86,067,000**
12.	E & D		7,000,000	1,400,000	8,400,000
13.	S & A		3,500,000	700,000	4,200,000
	Total:		**76,482,000**	**22,185,000**	**98,667,000**

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(1) Costs are for remediation activity only, costs associated with the identification and quantification of contaminants is not included.

(2) This cost does not include costs for incinerator mob/demob.

(3) This cost includes annual operating costs.

(4) This cost represents incinerator mob/demob and trial burns.

(5) This cost represents incinerator operation costs.

5.2.5 Environmental Impacts.

5.2.5.1 Impacted Media. Surface water and air could be adversely impacted due to failure of air or water pollution control devices. This alternative will benefit surface water, groundwater and drinking water by removing a potential source of contamination.

5.2.5.2 Resource Evaluations. Resources in the area will be affected by this alternative as described below:

Surface Water - Any wastewater which is discharged to the Kanawha River from this site will be treated to appropriate water quality criteria or technology-based standards prior to discharge. Likewise, any discharges to a publicly owned treatment works (POTW) will be pre-treated to appropriate standards as required by 40 CFR 403 and local POTWs.

Groundwater - Measures will be taken during the excavation of contaminated soils to prevent the additional contamination of groundwater. Contaminated groundwater encountered during excavation will be treated to the appropriated standards identified above and discharged to the Kanawha River or a POTW.

Drinking Water - Measures will be taken during the excavation to protect drinking water supplies in the area.

Air - Emissions during excavation will be monitored and excavation will be stopped if levels exceed those established in conjunction with the West Virginia Air Pollution Control office. Emissions from the incinerator will be controlled using appropriate pollution control devices. Noise pollution will be present during excavation and incineration. A Noise Abatement Program will be established.

Sole Source Aquifers - Environmental site investigations performed at the ACF site have not detected any contamination of the local water supply aquifer. Measures will be taken throughout the remediation process to protect sole source aquifers in the area, notably the water supply for the Town of Eleanor.

Archaeological and Historic Resources - In the Environmental Impact Statement (EIS) for the Kanawha River Study, the COE identified four archaeological sites that would be impacted by construction of the additional lock at the Winfield Locks and Dam. Remediation of the ACF site will not threaten any archaeological sites in addition to those noted in the COE study.

Wild and Scenic Rivers - None present in the affected area.

6.0 RECOMMENDED REMOVAL ACTION ALTERNATIVE

6.1 Recommendation. Based on the COE's environmental characterization studies and the evaluation procedure documented in this EE/CA report, on-site thermal treatment is recommended for the removal of contaminated soils at the ACF site. On-site thermal treatment will be combined with temporary storage of contaminated material to facilitate the COE's construction of an additional lock at the Winfield Locks and Dam. In addition, buildings and other structures associated with the ACF site will be evaluated and decontaminated as necessary prior to demolition and disposition.

REFERENCES

EPA, "Draft Engineering Evaluation/Cost Analysis Guidance for Non-Time-Critical Removal Actions" June 1987.

USACE, "Site History, Hazardous and Toxic Wastes on Property Formerly Owned by ACF Industries, Incorporated" November 1990.

USACE, "Remediation of Hazardous, Toxic, and Radioactive Wastes at the Former ACF Industries Facility, Red House, WV" January 1992.

USACE, "Kanawha River Navigation Study Winfield Lock Replacement Interim Feasibility Report, Main Report and Environmental Impact Statement" September 1986.

USACE, "Draft Endangerment Assessment, Winfield Locks and Dam, Kanawha River, Former ACF Industries Facility, Red House, WV" August 1991.

TCT-St. Louis, "Engineering Report, Phase I, Contamination Evaluation at the Former American Car & Foundry Site, Winfield Lock and Dam Project, Red House, WV" July 1991.

TCT-St. Louis, "Engineering Report, Phase II, Contamination Evaluation at the Former American Car & Foundry Site, Winfield Lock and Dam Project, Red House, WV" July 1991.

TCT-St. Louis, "Engineering Report, Phase III, Contamination Evaluation at the Former American Car & Foundry Site, Winfield Lock and Dam Project, Red House, WV" July 1991.

TCT-St. Louis, "Engineering Report, Phase IV, Groundwater Investigation of the Phase IV Contamination Evaluation at the Former American Car & Foundry Site, Winfield Lock and Dam Project, Red House, WV" July 1991.

EPA, Alternative Treatment Technology Information Center. Office of Environmental Engineering and Technology Demonstration.

EPA, Computerized On-Line Information System. Risk Reduction Engineering Laboratory, Edison, NJ.

EPA, "Guide for Conducting Treatability Studies Under CERCLA" December 1989.

EPA, "Superfund Treatment Technologies: A Vendor Inventory" September 1986.

"Code of Federal Regulations", Volume 40, Part 264.

Calgon Carbon Corporation, "Adsorption Handbook"

EPA, "Compendium of Costs of Remedial Technologies at Hazardous Waste Sites" October 1987.

EPA, Training Course Notebook - "Hazardous Material Treatment Technologies"

Government Industries, Inc., "Treatment Technologies", 2nd Edition, August 1991.

Executive Order 12580, "Superfund Implementation" January, 1987.

LAW Environmental, "Final Quality Control Summary Report for Winfield Locks and Dam, Red House, West Virginia" April, 1992.

LAW Environmental, "Draft Quality Control Summary Report for the River Sediment Investigation of Winfield Locks and Dam, Red House, West Virginia" March, 1992.

Wetlands - None present in the affected area.

Flood Plains - This alternative will take place above the 100 year flood plain of the Kanawha River.

Critical Habitats of Threatened and Endangered Species - The COE EIS did not identify any critical habitat for threatened or endangered species in the affected area.

Prime and Unique Farmlands - Prior to construction of the ACF facility in 1952 this site was categorized as prime and unique farmland. However, presently there are no prime and unique farmlands in the affected area.

Federal Parklands and Wilderness Areas - None present in the affected area.

National Forests and National Grasslands - None present in the affected area.

5.3 **Summary**. A Summary of evaluation criteria ratings, based on the rating system presented in Table 5-1, for on-site thermal treatment is presented in Table 5-5. This alternative can be instituted within a reasonable time frame to avoid delays in the lock construction schedule. As in any expenditure of public funds, reasonable cost is of paramount importance in the evaluation and selection of the desired alternative. However, for addressing contaminants at the ACF site institutional considerations have a major impact on the selection process. Technical feasibility and the minimizing of environmental impacts must also be considered in the evaluation of alternatives.

TABLE 5-3

ON-SITE THERMAL TREATMENT
RATING OF SELECTION CRITERIA

Criteria	Rating Points
Technical Feasibility	
Effectiveness	4
Demonstrated Performance	4
Useful Life	4
Environmental Effects Upon Operations	4
Institutional Considerations	
Permitting and Other Factors Affecting Start-up	3
Time to Complete	3
Safety	
During Installation/Operation	3
Effects of Failure	3
Environmental Impacts	4

ATTACHMENT 2

ACTION MEMORANDUM

Removal Action for the Former ACF Industries, Incorporated
Red House, West Virginia

under the

Comprehensive Environmental Response,
Compliance and Liability Act

Prepared By:

Nashville and Huntington Districts
U.S. Army Corps of Engineers

Removal Action for the Former ACF Industries, Inc. Site, Red House, West Virginia

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Responsiveness Summary

I. PURPOSE

The purpose of this Action Memorandum is to document approval of the U.S. Army Corps of Engineers removal action under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9605 (CERCLA) for the former ACF Industries, Inc. property and adjoining Corps-owned property near Red House, West Virginia. The site required for the removal action consists of the 22-acre former ACF property as well as contiguous land acquired by the U.S. Army Corps of Engineers in order to construct a new lock and gate bay at the Winfield Locks and Dam. Environmental investigations revealed contamination of the former ACF Industries property, as described herein. This report, and the actions proposed herein, are pursuant to the National Contingency Plan, 40 C.F.R. 300 et seq. (NCP).

II. SITE CONDITIONS AND BACKGROUND

A. Site Description

1. Removal Site Evaluation

The Corps of Engineers initiated acquisition of the ACF property through the filing of an imminent domain action in U.S. District Court in December 1989. The ACF property is adjacent to land the Corps owns in conjunction with the Winfield Locks and Dam on the Kanawha River. At the time of acquisition of the ACF property, ACF was responding to a Resources Conservation and Recovery Act (RCRA) Administrative Order of the West Virginia Department of Natural Resources (WVDNR) which required ACF to clean up the site. On May 7, 1990, WVDNR issued an Administrative Order stating that ACF's Environmental Remediation Final Report "satisfies the requirements of the site excavation plan agreed upon under West Virginia Hazardous Waste Order #HW-225-89".

On 17 August 1990, an equipment operator employed by the Corps of Engineers' lock construction contractor encountered an unknown substance while removing pavement at the site with a backhoe. This incident occurred at an area remote from the excavation pit where ACF had conducted its cleanup effort under the WVDNR's Administrative Order. The operator experienced skin and throat irritation, and reported a distinct odor. Because this incident indicated that the area posed a threat to contractor personnel, the Corps issued a stop-work order.

Key problem areas characteristic of the ACF facility include the presence of contaminated soils and perched water, unoccupied buildings, inactive waste treatment facilities, drains and excavated areas. Perched water is located in lenses of relatively permeable soils underlain by clays and silts. Perched water was encountered intermittently from near the ground surface down to the top of the aquifer that supplies the Town of Eleanor with its drinking water. Also present are spoil piles from ACF's previous cleanup efforts, and debris on the bank of the Kanawha River, which forms the southern boundary of the site.

These problems represent past releases and substantial threats of releases of hazardous substances into the environment which may present an imminent and substantial danger to the public health or welfare. Accordingly, the Corps took initial removal action steps to restrict entry onto the former ACF facility by installing fencing and signage around the perimeter at the site in June 1991. Afterwards, the Corps prepared an Engineering Evaluation/Cost Analysis (EE/CA) which called for further removal action steps including excavation of contaminated soils with placement in on-site temporary storage buildings. The excavation and storage of contaminated soils represents only an initial step toward ultimate disposition of the hazardous substances on the site. Prior to excavation and storage, the Corps intends to conduct a baseline risk assessment that will determine potential health risks in the event no removal action is taken, and to refine site-specific action levels. Concurrent with the removal action design, the Corps will conduct a supplemental risk analysis to determine any required engineering controls indicated to mitigate the potential release of chemicals to the environment associated with the removal action. Once the removal action is completed, the Corps will perform a Feasibility Study (FS) and remedial action risk assessment which will present a detailed analysis of alternatives available to ultimately treat/dispose of the hazardous substances. Following the preparation of the FS, the Corps will select and execute the treatment technology which most safely and effectively treats/disposes of the contamination.

2. Physical Location

The site is located in Putnam County, West Virginia, approximately 20 miles northwest of

Charleston, West Virginia. The former ACF property is bounded on the south by the Kanawha River; on the north by Conrail Main Line and Highway 62, and is immediately upstream of the Winfield Locks and Dam. See Figure 1 for a vicinity map. There are six schools and three communities (Winfield, Eleanor and Red House) within a five mile radius of the site. The Town of Eleanor's water supply wells lie approximately one mile downstream of the site. The estimated population near the ACF site is 2,740, with the majority of the population in the communities of Eleanor and Winfield. See Figure 2 for a site layout. The ACF property was acquired subsequent to Corps acquisition of a tract located west of the ACF property. Both parcels were acquired in conjunction with the Winfield Lock modification project. The extent of contamination on the former ACF property and the geographical limitations of the Corps property made it necessary for the Crops to propose construction of temporary storage buildings approximately 1500 feet onto the tract west of the former ACF property.

3. Site Characteristics

According to information obtained from ACF and the West Virginia Department of Natural Resources, the former facility was utilized by ACF Industries as a railcar service and repair facility from 1956 until 1986, at which time industrial operations ceased. During its period of operation, ACF maintained and cleaned over 47,000 railcars there. These railcars were used by a variety of interests for hauling solid and liquid chemical commodities. A steam rack and wastewater treatment system consisting of a series of ponds was located on the property adjacent to the Kanawha River. Facilities necessary for railcar repair and painting were also located at this site. The railcars were purged, cleaned, repaired and painted; structural facilities necessary for supporting these activities are still present. Prior to the use by ACF, the land use was agricultural. The site is currently owned by the U.S. Army Corps of Engineers. The removal action recommended in this Action Memorandum is the first Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) removal action at the site.

4. Release or Threatened Release into the Environment of a Hazardous Substance, or Pollutant or Contaminant

Hazardous substances, defined by Section 101(14) of CERCLA, known to be on site consist of at least ten forms of dioxins and furans, metals and approximately 130 organic compounds.

The Corps has conducted a sampling and testing program, which culminated in a total site characterization study during November and December 1991. Data from this program resulted in an estimate of 61,000 cubic yards of in-situ contaminated soil. This total consists of 46,000 cubic yards of soil contaminated with both dioxins and organic compounds and 15,000 cubic yards of soil contaminated with non-dioxin organic wastes. This estimate of dioxin-contaminated soil was based on 1 part per billion dioxin as the action level. The action level for dioxins was proposed at 1 part per billion (ppb) as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalents, after consulting with representatives from federal and state agencies and private corporations, and after reviewing available literature. The Corps received a memorandum from the Environmental Compliance Program, USEPA, dated June 20, 1990, regarding disposal of dioxin-contaminated wastes. This memorandum recommended using the 1 ppb level for cleanup at CERCLA sites. The action level used for this site may change depending upon the findings of a baseline risk assessment to be conducted, and thus the final estimate of contaminated soil may also change.

The potential exists for the contamination of groundwater above MCLs as long as the contaminated soils remain in place. Perched water at the site has been found to contain contaminants above MCLs. Additional sampling and analysis of both perched water and the aquifer that supplies drinking water to the Town of Eleanor will be performed, as part of the baseline risk assessment, to determine the potential for contaminant migration and risk to drinking water supply wells and receptors.

Soil samples tested revealed concentrations as high as 19,000 parts per billion (ppb) as 2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD) toxicity equivalents. The procedure for calculating the

2,3,7,8-TCDD toxicity equivalents is found in "Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and -Dibenzofurans (CDDs and CDFs) and 1989 Update", dated March 1989, published by the U.S. Environmental Protection Agency.

Potential dioxin exposures via direct contact (dermal absorption or ingestion) with contaminated soils may endanger human health. Nearby residents, towboat crews and Corps construction workers and operations personnel on the site may be exposed to contaminants via inhalation of dust emissions from activities at the site or from wind erosion. However, the former ACF property was fenced and access was restricted to only authorized personnel in June 1991. Warning signs are clearly posted. Restriction of the area prevents any inadvertent or improper access, providing a higher degree of protection to nearby residents and workers. Direct surface erosion from the site may impact the ecosystems of the Kanawha River. Routes of exposure will be further addressed in the baseline risk assessment.

5. National Priorities List Status

The former ACF site is currently on the Federal Facilities Docket, and as such will be considered for inclusion on the National Priorities List (NPL), in accordance with the National Contingency Plan. It was listed on the Federal Agency Hazardous Waste Compliance Docket on 17 July 1992, and is expected to receive a Hazard Ranking System rating.

6. Maps, Pictures and Other Graphic Representations

Attached is a plan showing the areal extent of dioxin and organic contaminated soil, along with a profile of the underlying soils that are contaminated with organics only. (See Figures 3 and 4.) Also included is a groundwater profile, showing the site's relationship to the Town of Eleanor's wells (Figure 5).

B. Other Actions to Date

1. Previous Actions

On 27 October 1989, the West Virginia Division of Natural Resources (WVDNR) issued an Administrative Order requiring ACF to clean up areas identified during a prior ACF investigation. On 22 January 1990, ACF's contractor, Allstates Environmental

Services, Inc., began excavation, removal and disposal of the contaminated soil. A total of 9,151 cubic yards of contaminated soil and an undetermined amount of contaminated water were disposed of, as referenced in Allstates Environmental Services' report "ACF/Redhouse, Phase II Environmental Remediation - Final Report", dated 26 April 1990. Approximately 100 empty containers, most of them 55 gallon drums, were also unearthed, crushed and disposed. The action was completed on 11 April 1990. ACF has advised the Corps that the cost of that action was approximately $2 million. Based on the results of the Corps' subsequent sampling and testing program, the WVDNR-ordered cleanup performed by ACF has been determined to have been incomplete and ineffective. Figure 6 depicts the areas excavated by ACF.

On 1 May 1990, the Corps of Engineers took possession of the property. Later that month, surface contamination was noticed by Corps employees and additional studies were initiated. These studies included sampling and testing of soil, surface water, groundwater and river sediments, and were conducted in phases from May 1990 until December 1991. Total costs of the sampling and testing events were approximately $2 million.

2. Current Actions

Due to the concern about public health and welfare, the Corps has been conducting tests on groundwater from the wells that supply the Town of Eleanor with drinking water and, during the testing period, has been paying the incremental cost difference for supplying Eleanor with drinking water from an alternative source (West Virginia-American Water Company). Because of the high cost of both continued monitoring and providing water by contract to Eleanor, the Corps will negotiate a settlement with the Town to enable it to acquire a safe and satisfactory alternative water supply source.

C. State and Local Authorities' Roles

1. State and Local Actions to Date

Following a Complaint Investigation conducted on 5 December 1988, prior to Government acquisition of the property, the West Virginia Department of Natural Resources (WVDNR) closely monitored the activities at the ACF property. From the initial public complaint until the Corps of Engineers took possession of the land in May 1990, the WVDNR acted as the lead agency for compelling ACF to conduct a site investigation and subsequent cleanup under RCRA. Following ACF's effort, the WVDNR approved Allstates Environmental Services' report on 7 May 1990, stating that the ACF efforts satisfied the requirements of the excavation plan agreed upon under West Virginia Waste Order Number HW-225-89. When additional contamination was discovered, the Corps under Presidential Executive Order 12580 became the lead agency for addressing the contamination as owner of a contaminated Federal facility.

The Corps has continued to maintain coordination and communication with the WVDNR. The Corps has also consulted with EPA Region III throughout this removal action. In an effort to ensure that guidelines are followed, the Corps has consulted with and informed EPA Region III of all steps taken and decisions made.

2. Potential for Continued State/Local Response

The EPA Region III and the newly reorganized West Virginia Division of Environmental Protection (WVDEP) have reviewed and provided comments on the Engineering Evaluation/Cost Analysis (EE/CA), a document prepared by the Corps of Engineers. Functions previously performed by the WVDNR are now conducted by the WVDEP. The Corps will continue to involve these agencies throughout the CERCLA process. The data from the risk assessment, monitoring of the Town of Eleanor's wells, and other activities described in this Action Memorandum, will be available to the Environmental Protection Agency, State of West Virginia, and the Town of Eleanor.

III. THREATS TO PUBLIC HEALTH OR WELFARE OR THE ENVIRONMENT, AND STATUTORY AND REGULATORY AUTHORITIES

According to the Corps of Engineers' Endangerment Assessment, dated 20 April 1992, conditions at the former ACF facility pose a threat to human health and welfare. Section 300.415 of the National Contingency Plan lists the factors to be considered in determining the appropriateness of a removal action. Paragraphs (b) (2) (i), (ii), (iii), (iv), (v) and (vi), of Section 300.415 all directly apply to the existing situation at the former ACF site and are discussed here in order of importance.

A. Sec. 300.415 (b) (2) (i):

> "Actual or potential exposure to nearby human populations, animals or the food chain from hazardous substances or pollutants or contaminants"

Soils found at several locations are contaminated with organic compounds, dioxins and furans. The most widely spread contaminants detected were dioxins and furans followed by volatile organic chemicals. Dioxin exposures via direct contact (dermal absorption or ingestion) with contaminated soils may endanger human health. Nearby residents, towboat crews, Conrail employees, persons traveling State Route 62 and local construction workers and operations personnel may be exposed to contaminants via inhalation of dust emissions from activities at the site or from wind erosion. Surficial erosion and runoff from the site may impact the ecosystems of the Kanawha River. Additionally, the potential exists for contamination of the aquifer that supplies the Town of Eleanor with drinking water.

B. Sec. 300.415 (b) (2) (ii):

> "Actual or potential contamination of drinking water supplies or sensitive ecosystems."

The volatile organic chemicals pose a risk to public health due to their mobility in the soil and solubility in water. The Town of Eleanor draws its drinking water from two wells installed in the aquifer atop bedrock. These wells are approximately one mile downgradient from the site. Given the solubility and mobility of identified compounds, the possibility exists for contamination of the groundwater levels. Due to concern for the public health and welfare, the Corps of Engineers is temporarily paying the incremental cost difference of supplying Eleanor with an alternative source of drinking water.

C. Sec. 300.415 (b) (2) (iv):

> "High levels of hazardous substances or pollutants or contaminants in soils largely at or near the surface, that may migrate."

Site investigations and evaluations have confirmed the presence of dioxin and furan contaminants in soils at and near the surface and within spoil resulting from ACF's remediation effort. At one location near the Kanawha River, sampling encountered soils with a total dioxin equivalent concentration of 19,000 parts per billion. These contaminants have the potential for a direct route to the Kanawha River via open excavations, sewers, outfalls and surface drainage systems.

D. Sec. 300.415 (b) (2) (v):

> "Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released."

The existing flood protection system on the Kanawha drainage basin and the site topography combine to keep the site from experiencing substantial flooding. However, contaminants present in the soil at the site have the potential to migrate to the Kanawha River by surface runoff or shallow seeps following storm events. Bank failure and soil erosion during periods of increased flow in the Kanawha River are another means for contaminants to leave the site. Strong winds may also cause contaminated soil particles to become airborne.

E. Sec. 300.415 (b) (2) (iii):

> "Hazardous substances or pollutants or contaminants in drums, barrels, tanks, or other bulk storage containers, that may pose a threat of release."

It is probable that buried drums are present at the former ACF facility. Several local residents who once worked at the site have stated that drums and other storage containers were buried at various locations on the former ACF property. Additionally, a Corps' contractor drilled into a drum or similar object while conducting subsurface explorations in November 1991. Furthermore, during the ACF cleanup, Allstates Environmental Services encountered approximately 100 buried drums while excavating contaminated soils.

F. Sec. 300.415 (b) (2) (vi):

> "Threat of fire or explosion."

Site evaluations performed at the ACF facility did not indicate the presence of reactive components that would result in the generation of fire or explosion. However, this does not preclude the possibility that such contaminants may be present if buried drums remain. The most likely threat of fire or explosion would be from the uncovering of buried drums containing these components during cleanup excavation work. These conditions will be addressed in the removal specifications and in the site safety and health plan.

IV. ENDANGERMENT DETERMINATION

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Action Memorandum, may present an imminent and substantial endangerment to public health, or welfare, or the environment.

V. PROPOSED ACTIONS AND ESTIMATED COSTS

A. Proposed Action

1. Proposed Action Description

This Action Memorandum proposes, as the removal action required at the site, the excavation of contaminated soil and temporary storage at the site until a remedial action is selected. The Corps intends to conduct a baseline risk assessment that will analyze the existing conditions and set site-specific action levels. A supplemental removal action risk analysis will also be conducted, and will provide input for control features required to mitigate any potential releases associated with the removal action. During the removal, all contaminated water generated will be treated at an on-site water treatment plant before discharge. While the actual design of the water treatment process has not been developed, it is believed at this time it will consist of existing available technology. This may consist of biological degradation and conventional, physicochemical processes such as: sedimentation/equilization, granular filtration, carbon adsorption, and air stripping. These and other methods will be evaluated. Any contaminated sludge or filters will be treated as necessary based on the type and concentration of contaminants. Additionally, the existing structures on the site will be demolished, decontaminated and removed, or stored on-site as appropriate. After the soils are placed in storage, and the threat to public health and the environment is minimized, the Corps will conduct another risk assessment and a Feasibility Study (FS) to determine the best method for ultimate disposal of the soils.

2. Contribution to Remedial Performance

The Corps of Engineers is proposing a removal action consisting of excavation and storage of the contaminated soil in temporary buildings. This action contributes to long-term remedial action by serving as the first step. The Corps will conduct a baseline risk assessment to analyze existing conditions and set site-specific action levels to be used in determining quantities which require removal. A supplemental risk analysis will then be conducted which will define controls to be implemented during removal in order to ~~minimize or~~ eliminate releases of contaminants. The excavation and storage action will limit the continued probability for release of contaminants to the environment. After the soil is in storage, supplemental studies and a remediation action risk assessment will be conducted. These studies will be used to produce a Feasibility Study (FS). This document will examine different available technologies for the ultimate disposal of the contaminated soil. The transition to a remedial action, while authorized in the National Contingency Plan, deviates from the recommendation in the EE/CA, which called for incineration. The proposed removal action is recommended in response to comments received during public review of the EE/CA which expressed concern over on-site incineration. The Feasibility Study will allow a more detailed analysis of alternatives and emerging technologies.

Excavation and storage of the soil is the logical first step for the remediation which will finally treat the soils. In-situ technologies, discussed briefly below, would be the only alternatives that would not require excavation as the first step. These alternatives have been determined to be inappropriate for treating all of the contaminants found at this site.

3. Description of Alternative Technologies for the Removal Action

Alternatives to excavation include in-situ vacuum extraction and in-situ bioremediation.

In-situ vacuum extraction involves the installation of several dry wells in the contaminated area. In this alternative, a vacuum is drawn on each of the wells, and gas extracted from the wells is treated prior to being released to the atmosphere.

The bioremediation alternative is generally applied to both in-situ and excavated soils. In this alternative, nutrients are applied to the soil to enhance the microbes present in the soil. This causes the microbes to multiply and degrade the contaminants. In some cases, bacteria and/or fungus may be added to the soil if appropriate microbes are not present.

The in-situ technologies mentioned here have not been demonstrated to effectively and efficiently destroy all of the contaminants present at this site. Chlorinated compounds, including furans and dioxins, would be difficult, if not impossible, to destroy using bioremediation. In-situ vacuum extraction has been shown to be effective only on volatiles. Additionally, in-situ technologies would not be as timely as removal in limiting the continued potential for release of contaminants to the environment. A more in-depth discussion of alternative technologies, and the reason for the selection of the proposed action, can be found in the Engineering Evaluation/Cost Analysis.

4. Engineering Evaluation/Cost Analysis (EE/CA)

The Corps of Engineers prepared an EE/CA, dated 5 May 1992, recommending a removal action. The EE/CA was then submitted for public review. The EE/CA called for excavation and storage of contaminated soils with subsequent on-site incineration. After reviewing public comments, the Corps recommends as its removal action only excavation and temporary storage of the contaminated soils. Further studies, conducted as part of the National Contingency Plan requirement for a Feasibility Study, will thoroughly examine all available remedial technologies.

5. Applicable or Relevant and Appropriate Requirements (ARARs)

This effort will comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the National Contingency Plan.

The following have been identified as ARARs for the excavation and on-site storage of contaminated soils:

- National Pollutant Discharge Elimination System (NPDES) requirements for treatment and disposition of groundwater during excavation (Federal)

- Resource Conservation and Recovery Act (RCRA) design requirements, Subtitle C (Federal)
- RCRA Title 40, Parts 264 and 265
- Air Quality Standards (Federal and State)
- Clean Water Act (Federal)
- National Environmental Policy Act (Federal)
- Safe Drinking Water Act (Federal)
- Fish and Wildlife Coordination Act (Federal)
- Clean Water Act - Section 404 (Federal)
- Executive Order 11988 (Federal)
- Executive Order 12580 (Federal)
- 29 Code of Federal Regulations (CFR) 1904 - Record keeping and reporting of occupational injuries and illness
- 129 CFR 1910 - Occupational, Safety and Health Standards for employees engaged in handling hazardous material
- 29 CFR 1926 - Safety and Health regulation for construction
- West Virginia Code of State Regulations (WVCSR 46 and 47) Excavation of site must be protected from surface water run-on and run-off
- WVCSR 45 - During excavation, the West Virginia Air Pollution Control Regulations apply to particulate matter and volatiles

6. Project Schedule

The following tentative schedule pertains to the excavation and storage of contaminated soils at the site and is predicated on the approval of this Action Memorandum by November 1992, completion of construction of the temporary storage buildings by April 1994, and completion of demolition of the existing structures found on the site by August 1994.

Preparation of Plans and Specifications:
Aug 92-Aug 93

Review and Revise Plans and Specifications:
Sep 93-Jan 94

Advertise/Award Contract:
May 94-Aug 94

Execute Excavation and Storage:
Aug 94-Jun 95

It is very important that the removal action be executed within this schedule so as to alleviate threats to the environment and public health, as previously discussed herein.

B. Estimated Costs

The costs to complete the excavation and storage of the estimated quantity of 61,000 cubic yards of contaminated soils, along with the treatment of contaminated water, is estimated at $32.3 million. This cost includes treating contaminated water generated during the removal process. Additionally, this estimate includes the operating and maintenance costs associated with the storage building for 10 years. See Table 1 for a breakdown of this cost.

VI. EXPECTED CHANGE IN THE SITUATION SHOULD ACTION BE DELAYED OR NOT TAKEN

The probability exists for contamination exceeding maximum contaminant levels to reach the groundwater aquifer that supplies the Town of Eleanor with drinking water. This would create a subsequent threat to human health. With the possibility of the deterioration of the remaining buried containers, there is a potential for a change in the nature of contamination. Further delay to the removal action could result in serious adverse environmental and public health impacts and result in a more extensive and costly cleanup.

VII. OUTSTANDING POLICY ISSUES

The presence of dioxins and furans at the former ACF facility complicates the removal action process. Dioxins and furans, with their reported toxicological characteristics, are contaminants of national concern. Consequently, removal action alternatives are limited by the presence of these toxic substances. Currently no off-site chemical landfills are permitted to accept dioxin-contaminated soils in concentrations and quantities found at the ACF site. One off-site incinerator in Coffeyville, Kansas, has been granted a permit to treat dioxins; however, a disposal area for the ash has not been identified and the facility is not accepting dioxin-contaminated wastes at this time.

VIII. ENFORCEMENT

Enforcement-sensitive. Enforcement strategy is not a part of the Action Memorandum for purposes of consistency with the National Contingency Plan.

IX. RECOMMENDATION

This decision document represents the selected removal action for the former ACF Industries site at Red House, West

Virginia, developed in accordance with CERCLA as amended, and not inconsistent with the NCP. This decision is based on the administrative record for the site. This Action Memorandum recommends that a removal action be conducted to excavate the contaminated soil and temporarily store it on site in above-ground storage buildings. Contaminated water recovered during excavation will be treated at an on-site wastewater treatment plant. Prior to the removal action, the Corps intends to conduct a baseline risk assessment in order to determine potential health risks in the event no action is taken, and to refine site-specific action levels. Concurrent with the removal action design, the Corps will conduct a supplemental risk analysis which will define the risks associated with potential releases that may occur during the excavation of the contaminated soils. In order to address the continuing concerns over public health and welfare related to the Town of Eleanor's current water supply, the Corps will negotiate a settlement with the Town to enable it to acquire a safe and satisfactory alternative water supply source. After the soil is in storage, supplemental studies and a remediation action risk assessment will be conducted. These studies will be used to produce a Feasibility Study (FS). This document will examine different available technologies for the ultimate disposal of the contaminated soil. Please refer to the Responsiveness Summary (attached) for the Corps of Engineers' responses to public comments.

Recommended By:

Earle C. Richardson
Colonel, Corps of Engineers
Huntington District Engineer

Date SEP 21 1992

Approved By:

Albert J. Genetti, Jr.
Brigadier General, Corps of Engineers
Ohio River Division Engineer

Date 9 December 1992

ATTACHMENT 3

CEORH-ED-AE (200-1c) 16 November 1992

MEMORANDUM FOR RECORD

SUBJECT: Winfield Additional Lock and Gate Bay, Meeting With West Virginia University to Discuss Corps/WVU Coordination During Cleanup of Former ACF Property

1. On 13 November 1992, Messrs. Ken Waddell, Jerry Phelps, Dave Meadows, Tim Kearney and Mark Kessinger of the Huntington District met with Mr. Ray Lovett of West Virginia University's National Research Center for Coal and Energy to discuss coordination efforts between the two agencies during the cleanup of hazardous substances on the former ACF property at Red House, West Virginia.

2. Opening Remarks. Mr. Ken Waddell opened the meeting by welcoming Mr. Lovett to the Huntington District. Most of the District representatives had met Mr. Lovett at the Public Meeting in Eleanor when Dr. Paul Connett spoke, but this was Mr. Lovett's first visit to the District.

3. WVU's Role. Mr. Lovett stated that WVU's role was to insure that the citizens of Putnam County are acquainted with the specifics of the cleanup. He said WVU would act in an advisory role and would not make decisions, would help the citizens be informed by utilizing its technical staff. He added the Senator Byrd had three major goals and these are, in no particular order: 1) that the new Winfield Lock be constructed, 2) that the contaminated site be remediated, and, 3) that the citizens participate in the process. Mr. Lovett stated these goals appeared to be consistent with the Corps' goals. He also mentioned that Congressman Wise's Office is working to establish an "Umbrella Group" of local representatives which could be streamlined into our main contact group to improve communication.

4. Public Perception. Mr. Lovett said that the public has a low opinion of the Corps and he believes the negative impression of the Corps is due to the intrinsic way the Corps does business. He stated that the citizens are concerned because of the "incubation" of Corps' policy and the abrupt 30-day review period for the EE/CA. Mr. Lovett noted that one of WVU's roles would be to diffuse much of this negative impression. By becoming involved earlier in the process, he believes that WVU can evaluate the advantages and disadvantages of situations and explain them to the public.

5. WVU to Investigate Remedial Technologies. Mr. Waddell asked Mr. Lovett if WVU would be conducting an independent study of alternative treatment technologies for remediating the contaminated soils and Mr. Lovett replied that it would be. Mr. Lovett explained that WVU had about 25 persons with various areas of expertise that could become involved if necessary. Mr. Waddell asked if the Corps could request information on a specific technology, or request WVU to investigate an innovative technology, and Mr. Lovett responded that it could. Mr. Waddell suggested that representatives from the Huntington and Nashville Districts meet with WVU personnel in Morgantown in December to discuss our working relationship in more detail.

6. Corps' Feasibility Study. Mr. Waddell stated the Corps' primary objective of its feasibility study is to do a thorough and complete study which is not driven by a schedule. He said the feasibility study should produce a recommended plan for treating the contaminated soils which will withstand technical challenges from the USEPA, the WVDEP and the public. He noted that the feasibility study would be conducted by the Nashville District and is tentatively scheduled to start in August 1993.

7. Public's Current Concerns. Mr. Lovett said that the local citizens had concerns about the mechanism with which the Corps excavates the contaminated soils. He stated that one concern is with fugitive dusts that may result from the excavation activities. He added that WVU plans to look into this matter very closely. He also said that the citizens are strongly in favor of segregating the contaminated soils. Mr. Lovett stated that there is not a homogeneous problem now and the public believes that mixing the organic-contaminated soils with the dioxin-contaminated soils would constrain the treatment to one method. He said that the public prefers that the Corps separate the contaminated soils inside the buildings. He also said that there was some concern about the fabric structures that are proposed to store the contaminated soils. He stated that the public would feel more secure if the Corps used firm structures. Mr. Waddell replied that the fabric structures are being used for the same purpose at some of the EPA's hazardous waste sites and the structures have been proven safe and effective for containing hazardous materials. Mr. Lovett said that WVU was considering taking citizens to Ashtabula, Ohio to see the fabric building being used there to store contamination.

8. Lock Construction and Well Testing. Mr. David Meadows presented an overview of the Corps' plan to construct the new Winfield lock and also the Corps' plan for testing the Town of Eleanor's water wells and other wells on, or near, the ACF site.

9. Health-Related Issues. Mr. Lovett said that WVU was very interested in health-related issues and was in the process of establishing timetables for addressing these issues. He added that WVU was considering conducting an epidermology study with the Agency for Toxic Substances and Disease Registry.

9. Closing Remarks. Mr. Lovett said that he hopes that WVU can work to eliminate the "darkness" that is perceived by the public about the Corps. Mr. Waddell stated that the Corps welcomes the opportunity to utilize WVU's resources during the its feasibility study and that the Huntington District would contact the Nashville District regarding the upcoming meeting in December.

Mark D. Kessinger
MARK D. KESSINGER
Civil Engineer
Engineering Management Branch

CF:
WVU-NRCCE (Mr. Lovett)
CEORD-OC
CEORD-PE
CEORN-ER-M (Mr. Forte)
CEORH-DE
CEORH-DL
CEORH-ED
CEORH-ED-D (Mr. L. McCoy)
CEORH-ED-G
CEORH-OC
CEORH-PA
CEORH-SO

ATTACHMENT 4

CEORH-ED-AE (200-1c) 15 December 1992

MEMORANDUM FOR RECORD

SUBJECT: Winfield Additional Lock and Gate Bay, Meeting With West Virginia University to Discuss Corps/WVU Coordination During Cleanup of Former ACF Property

1. On 14 December 1992, representatives of the Huntington and Nashville Districts met with West Virginia University (WVU) personnel to discuss coordination efforts between the two agencies during the cleanup of hazardous substances on the former ACF site at Red House, West Virginia. The meeting's agenda is at Enclosure 1 and a list of attendees is at Enclosure 2.

2. Opening Remarks. Mr. Ken Waddell opened the meeting by stating that the Corps looks forward to the opportunity to cooperatively work with the University to minimize the overlap of effort for the cleanup. He announced that the Action Memorandum had proceeded through the Corps' chain of command, was approved by the Assistant Secretary of the Army for Civil Works, and was signed by the Ohio River Division Commander on 9 December 1992. The Action Memorandum recommends that the cleanup process be separated into 2 phases: a removal/storage phase, and a remedial phase. The second phase will consist of a feasibility study to evaluate treatment alternatives. The Huntington District has developed a tentative schedule and recommends advertising the Phase II-A construction contract on 11 March 1993 and awarding the contract the end of May 1993. The tentative schedule, which has not been approved, also calls for the construction of the temporary storage buildings to begin in the late summer or early fall of 1993, the decontamination and demolition of existing structures in the fall of 1993, and the excavation and storage of the contaminated soil in the fall of 1994.

3. WVU's Mandate. Mr. Ray Lovett of WVU's National Research Center for Coal and Energy made reference to the Federal Register (Enclosure 3) and Senator Byrd's news release of September 1992 (Enclosure 4) in presenting WVU's mandate for the project. He said that he believes WVU's mandate is to help apply technological developments, through U.S. Department of Energy (DOE) Programs, to the Winfield site and to help explain the process to the local citizenry.

4. Construction of New Lock and Discovery of Contamination. Mr. Mark Kessinger presented an overview of the need for the new lock at Winfield and the discovery of hazardous substances on the former ACF Industries site. He said the Winfield project, constructed in the 1930's, is the first of three locks and dams on the Kanawha River and is the busiest locks in the U.S. in

terms of the number of lockages each year. He noted that significant delays of up to 24 hours are occurring at the locks causing an average loss to the towing industry of about $17 million annually. He explained that the Corps' solution to the delays was to construct a new 110' by 800' lock chamber landward of the two existing 56' by 360' locks. He said construction of the new lock is to proceed in two phases. Mr. Kessinger stated that Phase I, initiated in April 1990 and completed in October 1991, consisted of the construction of 26 coffer cells, relocation of Dry Branch Creek through four wetland ponds, and construction of dikes to contain excavated soils during the second phase of construction. He said that Phase II, which was scheduled to begin in December 1991, has been delayed due to the discovery of hazardous substances on the former ACF site. He noted that the 22-acre ACF facility lies in the area of the upstream approach to the new lock and from 1956 to 1986 was used to clean and repair railcars that ACF leased to various companies for hauling solid and liquid chemical commodities. Mr. Kessinger said that prior to the Corps taking possession of the ACF property, the West Virginia Division of Natural Resources (WVDNR) issued ACF an administrative order to fully remove contamination present at the site. He said that ACF hired Allstates Environmental Services to clean the site and from January 1990 to April 1990, Allstates excavated 9,151 cubic yards of soil and approximately 100 drums and shipped the materials to off-site landfills in Ohio and Wetzel County, West Virginia. Following this effort, he stated that the WVDNR issued a letter to ACF stating that it had fulfilled the requirements of the administrative order. He explained that the Corps took possession of the property on 1 May 1990 and later that month, observed discolored water seeping from the excavation pit walls. He said that the Corps immediately began a testing program, which with the assistance of the Nashville and Omaha Districts, evolved into an extensive sampling and testing program of over 200 soil and sediment samples and 14 groundwater monitoring wells. Mr. Kessinger stated that the Corps estimates as a result of the sampling and testing program that there are 61,000 cubic yards of contaminated soils on the ACF site. He noted that 46,000 cubic yards are contaminated with dioxins and organics and the remaining 15,000 cubic yards is contaminated with organics only.

5. <u>Working Relationship Between Huntington and Nashville</u>. Mr. Waddell explained the working relationship between the Huntington District and Nashville District, and addressed each district's future involvement with WVU. He stated that the Nashville District is the center of expertise for Hazardous,

Toxic and Radioactive Waste (HTRW) within the Ohio River Division of the Corps. He continued that Nashville was the agent for executing the remaining cleanup activities for the ACF site. He suggested that for technology issues, WVU work directly with Nashville because it will be responsible for assessing cleanup alternatives. He added that Huntington will maintain management responsibilities for the overall Winfield project.

6. <u>WVU's Role</u>. Mr. Lovett emphasized that the University was in a three-cornered program involving the DOE and Senator Byrd. He said that the DOE is concerned that WVU acquire technologies as efficiently as possible and that it is extremely important to Senator Byrd that WVU maintain its ability to evaluate technologies in an non-advocating role. He said the University is to be in a position to evaluate what is proposed and recognize the good points and bad points of each proposal and relay this to the citizenry so that it can make sound judgments. He added that WVU has the programs in place to move technology from the DOE laboratories to application at the ACF site and can also assist in the public relations side of the process. Mr. Waddell stated that although WVU and the Corps will be exchanging information, it must be made clear that WVU in not a tool of the Corps. He added that he views the working relationship as a mechanism to compare data and a means for each agency to come up with the best technical solution to the contamination problem, recognizing that the agencies may come up with different conclusions.

7. <u>Action Memorandum</u>. Mr. Kessinger stated that the Action Memorandum had been signed on 9 December 1992 by the Ohio River Division Commander and divides the cleanup into a two-stage process. He said that the first stage is a removal action which includes the decontamination and demolition of the existing structures on the site, construction of two temporary storage buildings, and the excavation of the contaminated soil and its placement in the storage buildings. He explained that after the soil is in storage, a feasibility study will be conducted evaluating different available technologies for the ultimate treatment and disposal of the contaminated soil. He said that the second stage of the cleanup is the remedial action which will be the process of actually treating and disposing of the soil.

8. <u>Nashville's Work Efforts</u>. Mr. Mike Zoccola stated that Presidential Executive Order 12580 designates the Corps as the lead agency for the cleanup. He said that the cleanup has been characterized as a non-time critical removal action under the

Comprehensive Environmental Response, Compensation, and Liabili Act (CERCLA). He explained that in May 1992, the Corps issued the Engineering Evaluation/Cost Analysis (EE/CA), which was prepared in consultation with the State of West Virginia and th U.S. Environmental Protection Agency (EPA), and recommended on-site incineration as the method for destructing the contaminant is the soil on the ACF site. Mr. Zoccola said that through discussions with the EPA and the State, it was agreed upon that dioxin is the contaminant that controls the selection of the treatment method and, at this time, incineration is the only wa to destruct dioxins on a large-scale basis. He added that the action level for dioxin was set at 1 part per billion (ppb) afte consultation with the EPA. He said that the public is concerned about incineration and has requested that the Corps look for other treatment alternatives, but the citizenry agrees that the Corps should continue with removal and storage of the contaminated soil. He explained that the Corps will proceed wit the removal action and, under the CERCLA process, will follow this effort with a feasibility study to evaluate alternative treatments. He noted that treatability studies will be a part o the feasibility study and that these studies most likely will be performed in laboratories and possibly, some will be done on-site. (More details on the feasibility study can be found at Enclosure 5.) Mr. Zoccola stated that during the excavation of the contaminated soil, the Corps will conduct confirmatory testing as the excavation is extended in order to determine that clean zones have been reached.

9. Huntington's Work Efforts. Mr. Larry McCoy gave an overview of the Huntington District's work efforts associated with the project. He explained that in order for the Huntington District to incorporate various innovative design features, Phase II had been split into two segments, Phase II-A and II-B. Phase II-A will consist of excavation of soil inside the cofferdam, construction of a slurry wall around the lock construction work area, installation of a dewatering system and filling two of the wetland ponds for placement of the temporary storage buildings and locating the treatment area. He said that the temporary storage buildings would most likely be fabric-walled structures which can be placed under a negative pressure to trap emissions. He added that these structures have been approved by the EPA for storing hazardous materials and are being used at Superfund sites around the country. He distributed a preliminary project schedule (Enclosure 6) which identifies milestones for each of the five contracts.

10. Monitoring of Eleanor's Wells. Mr. David Meadows presented the latest information on testing results for the Town of Eleanor's wells, as well as other wells on and adjacent to the ACF site. He stated that one issue involving the Town's wells deals with the Corps' construction of relocated Dry Branch. After Dry Branch was relocated and an outlet ditch from the wetland ponds to the Kanawha River was constructed, Mr. Meadows said that the West Virginia Department of Public Health became concerned that, during high water stages on the Kanawha River when the River backs up the ditch, surface water from the Kanawha could infiltrate into the aquifer that supplies water to the Town's Well #3 and Well #4 (Enclosure 7). He said another concern of the citizenry is that contamination from the ACF site could be migrating into the aquifer that supplies the wells. Mr. Meadows stated that the Corps has sampled and tested 14 wells in the vicinity of the ACF site (Enclosure 8). He also distributed a plan of the State's April 1992 delineation of the five-year wellhead protection area for Eleanor's wells (Enclosure 9), and summary results of the Corps' August 1992 well sampling (Enclosure 10) and September 1992 well sampling (Enclosure 11). Mr. Meadows explained that vinyl chloride had been detected in Monitoring Well #2 on the ACF site in concentrations ranging from 5.6 to 11.0 ppb. He said the maximum contaminant level is 2.0 ppb for drinking water standards. He emphasized that contamination in one well does not mean that the groundwater is contaminated and that the EPA recommends conducting a sampling cycle over a one-year period to determine whether or not groundwater is contaminated. Mr. Meadows stated that Huntington and Nashville are considering the installation of additional wells below the ACF site downstream of Monitoring Well #2 to determine if vinyl chloride is moving down gradient into the Phase II excavation area. He said that Eleanor's wells currently are not being used and the Corps is paying the additional cost for Eleanor to buy water from the public water supply. He added that the Corps plans to continue to monitor the groundwater, perhaps less frequently, until the contaminated soils are placed in storage.

11. West Virginia University Interaction. Mr. Lovett stated that WVU was running two separate, but interrelated, programs. The University is working with the DOE and Senator Byrd to try to develop a mode of operation to achieve efficient remediation and to develop some mechanism to evaluate technologies and integrate new technologies. He added that a State University working with a combination of two Federal agencies (the DOE and the Corps) and Congressional interests is unusual. He said WVU also is to

assist the public in interpreting policy and law, to respond to questions from the public, and to determine the pros and cons of the Corps' technical proposals. He explained that the National Research Center for Coal and Energy is the coordinating agency and that research to evaluate various technologies would be conducted independently by WVU. He emphasized that WVU would not propose technologies, but would evaluate the pros and cons for technologies proposed by the Corps. He said that the University may make the Corps aware of certain technologies and provide its assessment of that technology's chance for success at the ACF site. He confirmed that the law says that the Corps has authority to make the final decision regarding treatment and that the Corps is qualified to do so. He added that this Corps/WVU interaction may allow for the mechanism to take laboratory technologies and apply them in the field. Mr. Lovett stated that the University was going to conduct a survey of the local citizenry and review the Corps' documents in order to present to the public possible scenarios of what can be expected.

12. Closing Remarks. Mr. Waddell said that the Corps was planning to conduct a workshop in Huntington in February with all groups involved in the Winfield project. He said the workshop's purpose will be to present the process for constructing the new lock while remediating the ACF site and receive input from all others involved. Mr. Kessinger stated that ACF has requested an opportunity to get back on the site to conduct its own sampling plan. He said the request is under consideration. Mr. Lovett noted that anything that he knows about the project he can disclose to ACF and Mr. Waddell replied that the Corps will not disclose any information to Mr. Lovett that it feels is confidential. Mr. Waddell also stated that the funding for the citizen's technical assistance had be approved, but had not been appropriated, and that legislation was written such that the Corps is to administer the funds. Mr. Zoccola said that the Nashville District will proceed with the feasibility study as envisioned and from the discussions of the meeting WVU is another resource for information during the study. Mr. Waddell emphasized that the Corps will share information with the University and that plans and specifications would be provided to WVU for review and comment. Mr. Lovett stated that WVU would review the Corps' risk assessments but that it did not want to be in a position to conduct a risk assessment of its own. As far as air monitoring, Mr. Lovett said if the West Virginia Division of

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Environmental Protection can not assure the public that the Corps' program is adequate, WVU may have to do an independent air monitoring study.

Mark D. Kessinger

11 Encl
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MARK D. KESSINGER
Civil Engineer
Engineering Management Branch

CF:
WVU-NRCCE (Mr. Lovett)
CEORD-OC
CEORD-PE
CEORN-ER
CEORN-ER-H (Mr. Zoccola)
CEORN-ER-M (Mr. Forte)
CEORH-DE
CEORH-DL
CEORH-DL-M (Mr. Smith)
CEORH-ED
CEORH-ED-D
CEORH-ED-G
CEORH-OC
CEORH-PA
CEORH-SO

INFORMATION MEETING

West Virginia University
National Research Center for Coal and Energy
and
U.S. Army Corps of Engineers
Huntington and Nashville District

Cleanup of Hazardous Substances
at Former ACF Industries Site
Red House, West Virginia

14 December 1992
1:00 p.m.
617 North Spruce Street
Morgantown, West Virginia

AGENDA

1.	Opening Remarks	Mr. Ray Lovett/Mr. Ken Waddell
2.	Construction of New Lock at Winfield	Mr. Mark Kessinger
3.	Working Relationship Between Huntington and Nashville Districts	Mr. Waddell
4.	Action Memorandum	Mr. Kessinger
5.	Nashville District Work Efforts a. Baseline Risk Assessment b. Feasibility Study c. Treatability Study d. Decon/Demolition of Existing Structures e. Removal Action Risk Analysis f. Remediation Action Risk Assessment	Mr. Mike Zoccola
6.	Huntington District Work Efforts a. Construction of Temporary Storage Buildings b. Lock Construction	Mr. Larry McCoy
7.	Monitoring of Town of Eleanor's Wells	Mr. David Meadows
8.	West Virginia University Interaction a. Inform/Advise Citizens b. Conduct Research	Mr. Lovett
9.	Open Discussion	All

Enclosure 1

NAME	JOB TITLE/DESCRIPTION	OFFICE	PHON
MARK KESSINGER	ENGINEERING MANAGER	CORPS-HUNTINGTON	529-
MICHAEL ZOCCOLA	Chief, HTRW Design Branch	Corps-Nashville	615-736-
RAYMOND LOVETT	Program Mgr., NRCCE	WVU-Morgantown.	293-
PAUL ZIEMKIEWICZ	NRCCE/WVU	Morgantown	293-
DAVID MEADOWS	CHIEF, SOILS SECTION	COE-HUNTINGTON	529-
KEN WADDELL	CH, ENGINEERING DIVN	〃	529-
JOE DONOVAN	ASST. PROFESSOR of HYDROGEOLOGY	WVU	293-5
Larry McCoy	Chief, Civil Design Section	COE-Huntington	529-5
Alan Sexstone	ASSOC. PROFESSOR Environmental Microbiology	WVU	293-3
BRIAN REED	Asst Professor/Civil Engineering	WVU	293-
Kung Wang	Assoc. Professor/Chemistry	WVU	293-

Enclosure

design, and construct as part of such modifications historical wetlands at an alternative site located contiguous to the Yolo Bypass, immediately east of the Davis Water Pollution Control Plant, and along the north side of the Willow Slough Bypass.

(b) REPORT DEADLINE.—The Secretary shall complete a separate project modification report to carry out subsection (a)(3) for planning, design, and construction requirements on or before September 30, 1993.

Louisiana.

SEC. 345. BANK STABILIZATION AND MARSH CREATION.

(a) STUDY.—The Secretary shall conduct a study on bank stabilization and marsh creation by construction of a system of retaining dikes and by beneficial use of dredged material along the Calcasieu River Ship Canal, Louisiana, at critical locations.

(b) REPORT.—Not later than 1 year after the date of the enactment of this Act, the Secretary shall transmit to the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works of the Senate a report on the results of the study conducted under subsection (a), including recommendations for specific measures to be undertaken under section 205 of this Act (relating to beneficial uses of dredged material) as a result of such study.

SEC. 346. CONNECTICUT COASTAL SALTMARSH RESTORATION AUTHORIZATION.

Subject to the cost sharing provisions of the Water Resources Development Act of 1986, the Secretary shall, as part of the long term goal of Corps of Engineers water resources development program of increasing the quality and quantity of the Nation's wetlands, investigate and carry out saltmarsh restoration projects along the coastline of the State of Connecticut.

SEC. 347. WINFIELD, BUFFALO, AND ELEANOR, WEST VIRGINIA.

(a) TECHNICAL ASSISTANCE.—The Secretary shall provide technical assistance to the towns of Winfield, Buffalo, and Eleanor, West Virginia, for the purpose of assisting the residents of such towns in analyzing and understanding the remedial options available for dealing with substances posing a risk to the environment at the Corps of Engineers lock and dam construction site in the vicinity of Winfield, West Virginia.

(b) AUTHORIZATION OF APPROPRIATIONS.—There is authorized to be appropriated to carry out this section $100,000 for fiscal years beginning after September 30, 1992. Such sums shall remain available until expended.

SEC. 348. LAND CONVEYANCE, CITY OF FORT SMITH, ARKANSAS.

The Secretary may convey to the city of Fort Smith, Arkansas, all right, title, and interest of the United States (excluding all oil, gas, and other minerals and subject to existing encumbrances) in and to a tract of real property (including improvements thereon) of approximately 400 acres located adjacent to the city and under the jurisdiction of the Secretary. Such conveyance shall be subject to terms and conditions agreed to between the Secretary and the city and to such other terms and conditions as the Secretary considers appropriate to protect the interests of the United States.

SEP

File DSIR

News From U.S. Senator
Robert C. B
West Vi
Phone (202) 2

FOR IMMEDIATE RELEASE:
Monday, September 28, 1992

CONTACT: Ann Adler
(202) 224-3904

WASHINGTON, D.C.....U.S. Senator Robert C. Byrd, D-W.Va., announced Tuesday that the U.S. Department of Energy's (DOE) Morgantown Energy Technology Center is entering into a 5-year, $5 million cooperative agreement with West Virginia University (WVU) to conduct research into safer, more effective environmental clean-up methods that could be used to remove contaminants from soil surrounding the Winfield Lock and Dam on the Kanawha River.

Byrd, Chairman of the Senate Appropriations Committee, in July, added an amendment to a report accompanying an appropriation bill directing DOE and the Morgantown Energy Technology Center to work with WVU in developing a solution to the soil contamination problem at Winfield.

"This research agreement will apply WVU's nationally recognized expertise in environmental remediation and mine land reclamation to develop better, faster, cheaper, and safer disposal methods and uses for hazardous waste from DOE and private sector industrial sites," Byrd said.

"This agreement is intended to help identify an environmentally sound method of cleaning the dioxin-contaminated soil at Winfield that also addresses the health concerns of the residents of the Eleanor area," Byrd said.

(more)

Enclosure

"The information generated from this study will have applications for projects across the nation as well as at the Winfield site and other locations in West Virginia," Byrd said.

The Army Corps of Engineers is currently evaluating methods t clean up the Winfield Lock and Dam site.

"The common method of soil incineration, which has been considered a prime alternative for remediation of the Winfield sit could release some hazardous substances into the air," Byrd said.

"Concerns about health and safety associated with hazardous waste incineration, which I share with the people of the community of Eleanor, led me to add the directive to the appropriation bill that has prompted this agreement," Byrd said.

The appropriation bill with Byrd's directive has won final congressional approval and has been sent to the President to be signed into law.

Under the cooperative agreement WVU will conduct research in eight areas: systematic assessment of the state of Hazardous waste clean-up technologies; site remediation technologies; hazardous waste minimization in advanced combustion systems; excavation systems for hazardous waste sites; contaminant recovery from aquifers; chemical destruction of polychlorinated biphenyls (PCBs) development of organic chemical sensors, and portable spectrograph systems.

Officials of DOE and WVU are expected to sign the cooperative agreement Tuesday.

###

Environmental and regulatory.—The Committee recommends a decrease of $1,665,000 in environmental research in regulatory impact analysis, consisting of $1,000,000 in the new initiative programs, and $665,000 for regulatory analysis.

Policy and management.—The Committee recommends an increase of $1,060,000 for headquarters program direction of which $560,000 is to restore employment floors and $500,000 is for contractual services.

For the Energy Technology Center [ETC] program direction, the Committee recommends an increase of $17,334,000, consisting of $4,410,000 for restoring employment floors, and $12,924,000 for nonpersonnel overhead expenses. Within program direction totals, amounts are $28,162,000 for PETC, $26,830,000 for METC, and $3,898,000 for Metairie and the Bartlesville project office.

The Committee is in agreement with bill language added by the House to reduce PETC and METC personnel floors and to increase the Bartlesville project office floor, in order to support an expanded oil program at Bartlesville. Funding for these positions should be accommodated as an adjustment to program direction figures outlined above.

The Committee recommends an increase of $2,520,000 to restore employment floors for the Energy Technology Centers' technical program.

The Committee recommends a decrease of $1,270,000 to provide for absorption of 50 percent of the pay raise included in the budget.

Cooperative research.—The Committee recommends an increase of $5,000,000 for cooperative research. The recommended increase includes $1,000,000 for the agreement with the State of Illinois, $2,000,000 for the Western Research Institute [WRI], and $2,000,000 for the University of North Dakota Energy and Environmental Research Center [UNDEERC].

Facilities.—The Committee recommends an increase of $2,700,000 for facilities consisting of $2,000,000 for equipment purchases at the National Research Center for Coal and Energy's Fuel Utilization Laboratory and $700,000 to initiate the refurbishment of METC's pilot plant building [B–4] to accommodate health and safety concerns in that facility.

Use of prior year funds.—The Committee accepts the administration's proposal to offset $17,000,000 of new budget authority with uncosted and unobligated funds from prior years. The Committee directs, however, that the Department submit a detailed breakdown of the sources of these offset funds to the Committee.

General.—The Committee supports the continued involvement of the Ames National Laboratory in the fossil energy research and development program. A minimum of $1,500,000 should be provided to Ames from funds already provided for programs managed by METC and PETC to cover work in syngas/natural gas to liquids, catalyst development, gas stream clean up, waste management, instrumentation (including instruments and protocol evaluation for air toxics), and low-quality natural gas upgrading.

waste management programs. An immediate commercial application of the technology development is available in the remediation of contaminated soils discovered by the Corps of Engineers at the Winfield lock and dam project in West Virginia. The Office of Technology Development will apply the technical expertise of the Morgantown Energy Technology Center at the Winfield lock and dam site. In the evaluation of waste remediation options, the expertise of West Virginia University in site remediation will also be applied as an independent evaluator of technical options pertaining to the site, and the Committee expects that the university will work with the town of Eleanor, WV, and the surrounding county of Putnam to advise affected communities of the technical options available for hazardous waste remediation at the Winfield lock and dam site. The Committee notes that opportunities such as this have the potential not only to further accelerate the commercialization of technology options developed within the fossil energy research and environmental management programs, but also to extend the benefit of such developments to non-DOE site remediation and help serve local communities.

ALTERNATIVE FUELS PRODUCTION

(INCLUDING TRANSFER OF FUNDS)

Appropriations, 1992	−$8,361,000
Budget estimate, 1993	−7,500,000
House allowance	−7,500,000
Committee recommendation	−7,500,000

The Committee concurs with the House proposal to transfer, as recommended by the President, $7,500,000 from this account to the general funds of the Treasury. The funds to be transferred represent investment income earned as of October 1, 1992, on principal amounts that are in a trust fund established as part of the sale of the Great Plains Gasification Plant in Beulah, ND.

NAVAL PETROLEUM AND OIL SHALE RESERVES

Appropriations, 1992	$232,336,000
Budget estimate, 1993	238,094,000
House allowance	238,094,000
Committee recommendation	238,094,000

The Committee recommends an appropriation of $238,094,000, the same as the budget estimate and the same as the House allowance. A comparison of the Committee recommendation and the budget estimate is shown in the following table:

	Budget estimate	Committee recommendation	Change
Oil reserves:			
Naval Petroleum Reserves Nos. 1 and 2	$209,494,000	$209,494,000	....
Naval Petroleum Reserve No. 3	20,600,000	20,600,000	....
Program direction (headquarters)	7,400,000	7,400,000	....
Subtotal, oil reserves	237,494,000	237,494,000	....

A. BASELINE RISK ASSESSMENT

0 Will be Performed to Evaluate Exposure Risks to Human and Environmental Receptors due to Site Wastes in the Absence of Remediation (i.e. No Action Alternative) for both Current and Future Land Uses.

0 Preliminary Remediation Goals will be Reviewed and Modified as Necessary.

0 Will be Conducted in Accordance with EPA Guidelines.

Enclosure 5

B. FEASIBILITY STUDY

0 Will be Performed to Identify, Screen, and Evaluate Alternative Remedial Technologies for the Ultimate Disposition of the Contaminated Soil.

0 Will be conducted generally in 3 Phases although, in practice, these phases are not always distinct:

1. Development of alternative technologies: During this phase, treatment alternatives will be identified that appear feasible for achieving the remediation goals established in the baseline risk assessment.

2. Screening alternative technologies: Selected technologies, or combination of technologies, will be screened to ensure only those applicable to the contaminants present and other site specific characteristics will be considered further. This screening will be based upon a technology's ability to remediate the contaminants in the given matrix, the risks associated with the technology, its implementability, and cost. Treatability studies will be conducted during this phase, as necessary, to evaluate promising technologies.

3. Detailed analysis of alternative technologies: Each surviving technology will be evaluated against the following evaluation criteria

Overall protection of human health and the environment
Compliance with ARARs
Long-term effectiveness and permanence
Reduction of toxicity, mobility, or volume
Short term effectiveness
Implementability
Cost
State acceptance
Community acceptance

C. TREATABILITY STUDY

0 As stated above, will be conducted during the feasibility study. They are conducted to achieve the following:

Provide data to allow treatment alternatives to be fully developed and evaluated and to support the remedial design of a selected alternative.

Reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected.

D. DECON/DEMOLITION OF EXISTING STRUCTURES

0 95% complete with a set of plans and specifications which will tear down, decontaminate, and dispose of all existing structures at the site, at or above ground level. Includes among other things:

Metal and block buildings with associated facilities
Concrete and asphalt slabs
Railroad ties and rails

0 Materials identified which cannot be decontaminated will be stored on site and treated along with the contaminated soil during the remedial phase.

0 All work will be done in accordance with the new debris rule published in the 18 August, 1992 Federal Register.

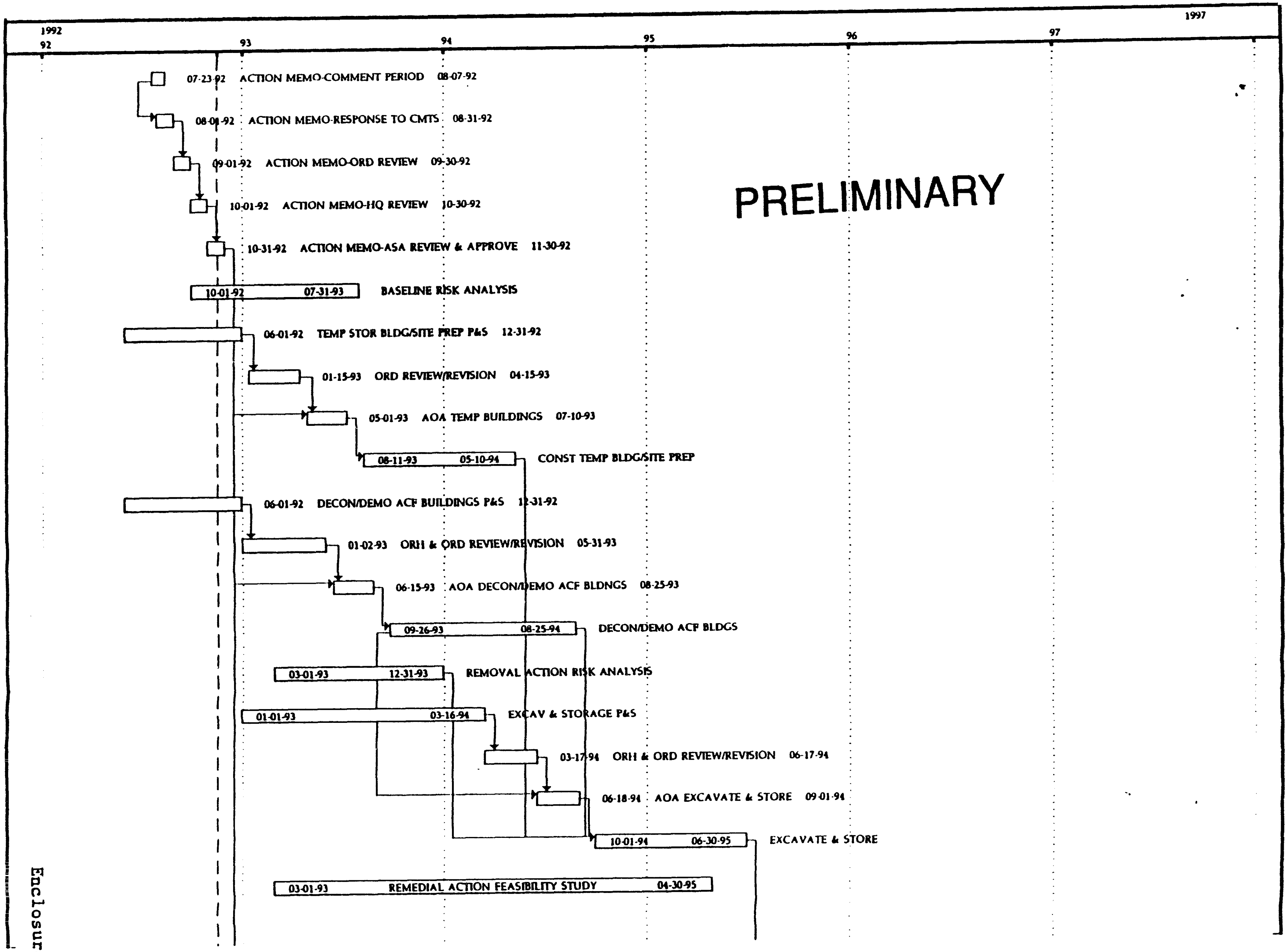
E. REMOVAL ACTION RISK ANALYSIS

0 Will be performed in order to evaluate exposure risks to human and environmental receptors due to the removal action. It will be used to develop requirements for controls to mitigate risks associated with the excavation and storage of the contaminated soils. These controls will be specified in the removal action plans and specifications.

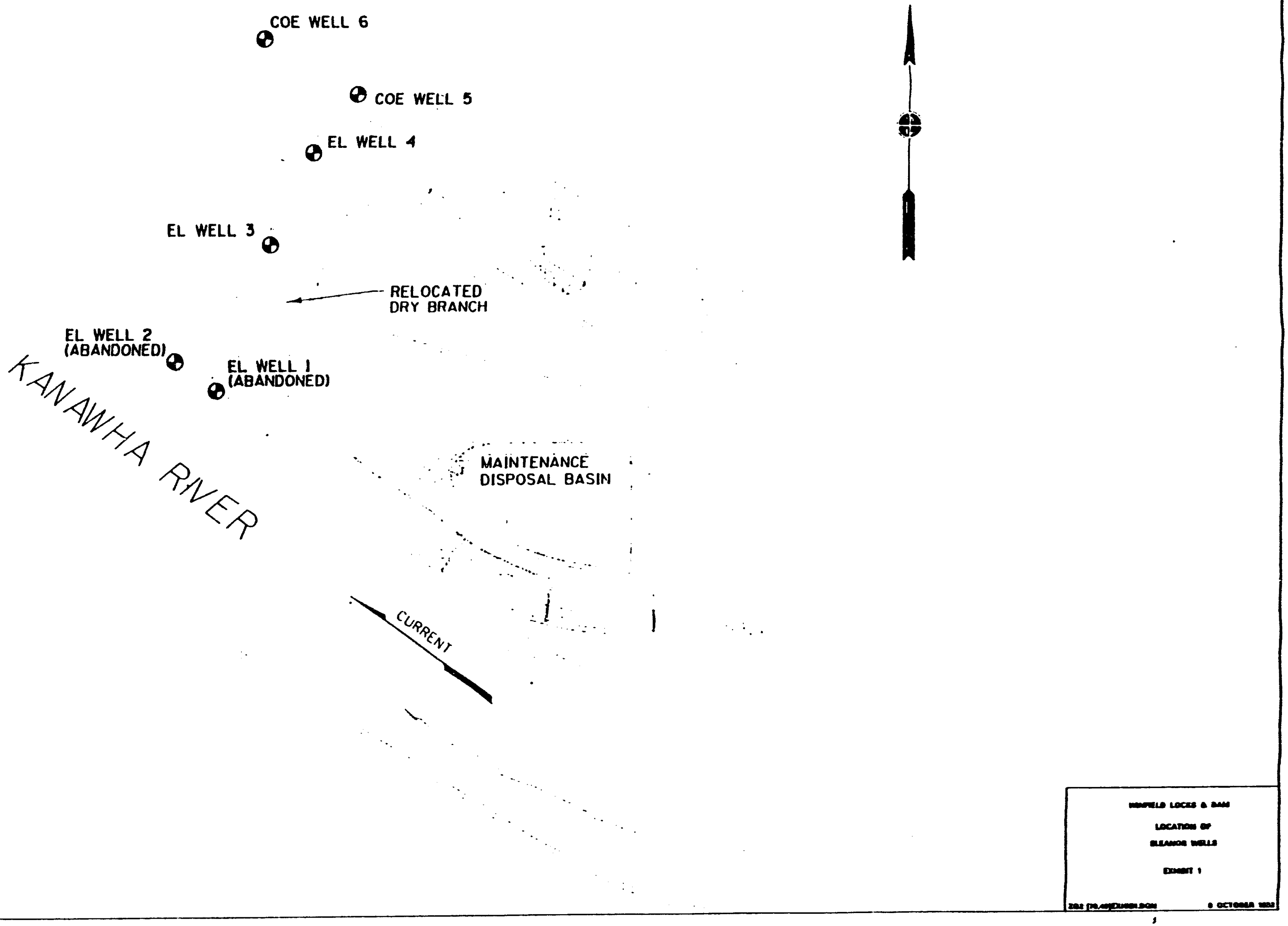
F. REMEDIATION ACTION RISK ASSESSMENT

0 As stated above, risk is one of the factors by which alternatives will be evaluated in the feasibility study. If warranted, a more detailed evaluation of the risks associated with the selected alternative may be necessary.

PRELIMINARY

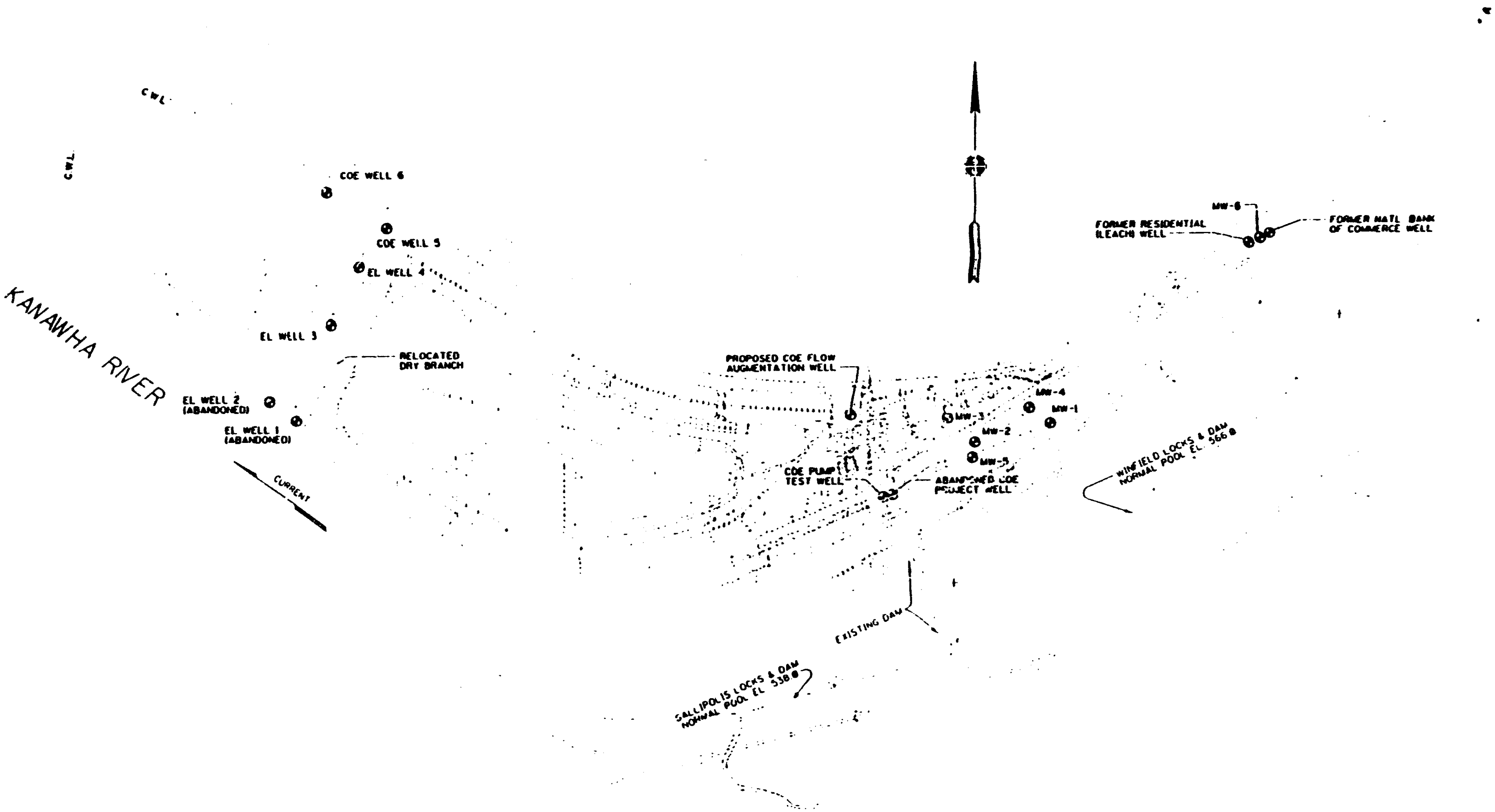


Enclosure 6


COE WELL 6
COE WELL 5
EL WELL 4
EL WELL 3
RELOCATED DRY BRANCH
EL WELL 2 (ABANDONED)
EL WELL 1 (ABANDONED)
KANAWHA RIVER
MAINTENANCE DISPOSAL BASIN
CURRENT
WINFIELD LOCKS & DAM
LOCATION OF
ELEANOR WELLS
EXHIBIT 1
[illegible]
[illegible] OCTOBER [illegible]

Enclosure

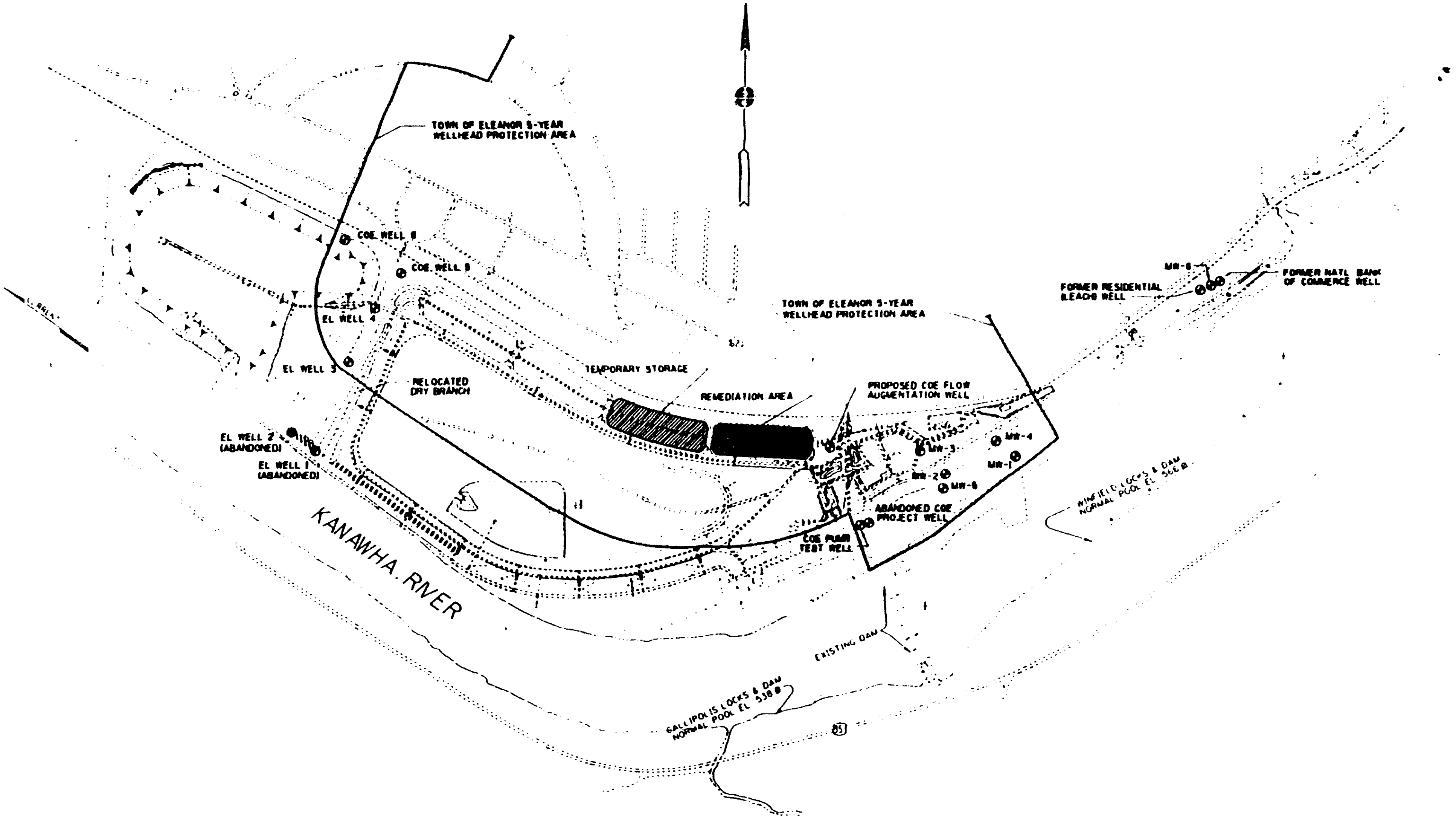
Enclosure 8



WINFIELD LOCKS & DAM
LOCATION OF
ELEANOR WELLS

EXHIBIT 8

[illegible] [illegible]



WINFIELD LOCKS & DAM
ELEANOR WELLHEAD
PROTECTION AREA
(5 YEAR)

EXHIBIT B

[illegible] [illegible] OCTOBER [illegible]

Enclosure 9

WINFIELD LOCKS AND DAM
GROUNDWATER MONITORING
AND
ELEANOR WATER SUPPLY WELLS
RESULTS OF AUGUST 17-18, 1992 SAMPLING

26 October 1992

Contaminated soils at the former ACF Industries site have the potential to contaminate the groundwater aquifer for the Town of Eleanor's water wells. In August 1992, the Corps continued sampling and testing to determine the present quality of this aquifer. Eleanor Wells 3 and 4, Corps Well 5 and monitoring wells 2, 3, 5 and 6, as shown on the attached exhibit, were sampled and tested. The sampling was performed on August 17 and 18, 1992 by Huntington District and Ohio River Division Laboratory (ORDL) personnel. Tests were conducted by ORDL to determine the levels of 182 compounds including dioxin, volatiles, semivolatiles, PCB's/pesticides, herbicides, fluoride, nitrate, nitrite and metals.

The August 1992 test results indicate that vinyl chloride was present at monitoring well 2 at a concentration of 2.2 ppb. This is slightly above the maximum contaminant level (MCL) of 2 ppb. Vinyl chloride has been detected on the former ACF Industries site, however, since the presence of vinyl chloride in this case has been found in only one location, it may be attributed to the fact that polyvinyl chloride (PVC) pipe was used a liner for the monitoring wells. When PVC is used as a liner for a well, the detection of vinyl chloride is most likely when the pipe is new, however with time, that potential diminishes. Monitoring well 2 was installed in April 1991.

Beryllium was detected in Eleanor Well 4 at a concentration of 11.3 ppb which is above the proposed MCL of 4 ppb. Beryllium is a naturally occuring metal in the soil. The concentration of this metal is typically reduced to an acceptable drinking water standard by water treatment methods used by the Town of Eleanor.

The practical quantitation limits (PQL) for the following semivolatiles: benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene (not for all tests), indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, hexachlorobenzene (not for all tests), pentachlorophenol (not for all tests), and the metal, antimony, were greater than the proposed MCL for each compound. The lab notes that although the PQL is above the MCL, the actual detection limit for those compounds is much lower than the PQL given in the report, but has not been quantified. The lab further states that if these compounds had been present in the samples above the detection limit, but below the PQL, the actual values would have been reported with a "J" qualifier. None of these compounds were qualified with the "J" qualifier. The PQL for these compounds will be below the proposed MCL in all future testing.

Aluminum, manganese and iron were detected at concentrations above the secondary MCLs as illustrated in the table below. Typically secondary MCLs are not enforced; however, that decision is up to State regulatory agencies. The West Virginia Department of Health and Human Resources (WVDHHR) has elected to enforce secondary MCLs. Secondary MCLs do not pertain to the health effects of the drinking water but to the aesthetic qualities of the drinking water such as taste, odor, and appearance. These metals occur naturally in the soil and are typically reduced to an acceptable drinking water standard by water treatment methods used by the Town of Eleanor.

TABLE I

Parameter	MCL	MW-2	MW-3	MW-5	MW-6	EL 3	EL 4	COE 5
				(ug/l)(ppb)				
Aluminum	200**	1659	12670	4379	17570	-	-	-
Iron	300**	49000	2330	17800	43600	4321	7710	1766
Manganese	50**	4065	700.8	904.4	2169	293.2	257.1	68.6

** Secondary MCL

Evaluation of this data has indicated that additional sampling and testing should be performed. Interim guidance from the United States Environmental Protection Agency (USEPA) for groundwater monitoring recommends performing at least seven cycles of testing prior to making a determination as to whether or not a MCL has been exceeded. Usually, these sampling and testing cycles extend over a period of one year to allow for seasonal sampling. To evaluate the groundwater, the Huntington District will conduct sampling and testing, at a minimum, over a one-year period. Since continuation of sampling and testing was initiated in August 1992 and the Town of Eleanor went to an alternative water supply for a ninety-day period, the sampling and testing will continue for an additional nine months. A period of three months will be required after the last sampling cycle to allow for the completion of the testing and evaluation of the results. During the additional sampling, testing and evaluation, the Town of Eleanor will remain on an alternative water supply. The Huntington District will continue to provide funding for the additional expenses incurred by the Town of Eleanor during this period and will be evaluating the disposition of wells as a water supply for the Town of Eleanor.

Additional sampling and testing was performed on September 17, 1992 and October 14 and 15, 1992. The results of these tests will be provided when they have been completed. If you have any comments or questions concerning the sampling and testing, please contact Mr. David F. Meadows at (304) 529-5243.

WINFIELD LOCKS AND DAM
GROUNDWATER MONITORING
AND
ELEANOR WATER SUPPLY WELLS
RESULTS OF SEPTEMBER 18, 1992 SAMPLING

7 December 1992

The September 1992 test results indicate that vinyl chloride was present at monitoring well 2 at a concentration ranging from 5.6 to 11.0 ppb. This is above the maximum contaminant level (MCL) of 2 ppb. Results for this compound were obtained from two different labs. Each indicated the presence of vinyl chloride.

Beryllium was not detected in Eleanor Well 4 during this sampling period.

Aluminum, manganese and iron continued to be detected at concentrations above the secondary MCLs as illustrated in Table I on the folowing page. Typically, secondary MCLs are not enforced; however, that decision is up to State regulatory agencies. The West Virginia Department of Health and Human Resources (WVDHHR) has elected to enforce secondary MCLs. Secondary MCLs do not pertain to the health effects of the drinking water but to the aesthetic qualities of the drinking water such as taste, odor, and appearance. These metals occur naturally in the soil and are typically reduced to an acceptable drinking water standard by water treatment methods used by the Town of Eleanor.

Nitrite was present at Eleanor Well No. 3 at a concentration 1070 ppb. This is above the MCL of 1000 ppb. This is the first observation of this compound during any of the test results to date. The test used to detect nitrite has a reputation of sometimes producing "false" results. A different procedure will be utilized in future testing. This compound cannot be treated by Eleanor's water treatment system.

To evaluate the groundwater, the Huntington District will conduct sampling and testing, at a minimum, over a one-year period. The next sampling and testing will be performed on 16-17 December 1992. Additional sampling and testing cycles will be scheduled.

ATTACHMENT 5

◆WVU Hazardous Waste Newsletter◆

Winfield Lock & Dam

A Publication of the Environmental Technology Division of The National Research Center for Coal and Energy
Volume 1 Issue 1 July 1993

◆ Winfield Report

WELCOME

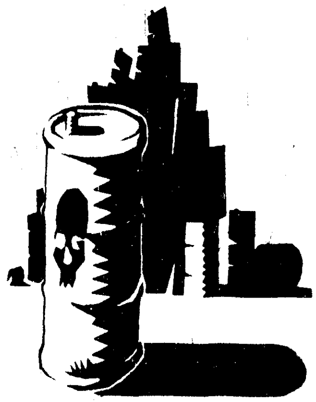
This is the first edition of a newsletter which will inform all of you associated with the Winfield Lock and Dam hazardous waste clean-up of the latest details. In addition, other information regarding the Environmental Technology Division will be provided, with some mention of important external events.

We will minimally provide you with lists of interesting conferences, new technical acquisitions of the Division, details on the latest occurrences at Winfield Lock and Dam and elsewhere and information concerning WVU faculty, their travels and noteworthy accomplishments. These first few additions must necessarily catch up on the news, but as time goes on we will use space to initiate new features.

The newsletter will be composed and produced by Nancy Reese; please call Nancy if you have suggestions for improvement.

I have prepared a short report for the Department of Energy concerning the Winfield situation. If you would like a copy (and this is not great literature, more of a temporal travelogue) please contact Nancy and she will send you one. Additionally, please notice the list of Corps of Engineers proposed documents. I will need people to review these documents as they arrive; if you feel capable of assisting with these reviews please let us know, otherwise I will have to beat the bushes for reviewers. Your reviews are converted into a general document which I submit to the Corps of Engineers. The Corps subsequently considers our comments in developing the final plans and specifications or environmental impact statement.

I hope this newsletter can be of use to all of you. Feel free to contribute your thoughts and information of interest to us. I do not intend to have a restricted circulation list; if your colleagues would like to receive the newsletter, please have them notify Nancy for a complimentary subscription.



- Raymond J. Lovett

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CORPS Document List

Decon/Demo Plans & Specs

Decon/Demo Risk Analysis

Temporary Buildings Plans & Specs Out

Baseline Risk Analysis

Phase II B Plans & Specs

Excavation/Storage Risk Analysis

Excavation & Storage Plans & Specs

Remedial Action Feasability Study Risk

◆ Resource Group Report

Trip Reports:

What's the travel really about?

In February, Dr. Gary Morris from the Department of Mechanical and Aerospace Engineering attended the first of two satellite seminars entitled "Innovative Thermal Treatment Technologies: Uses and Applications for Site Remediation" in Pittsburgh, PA. This seminar was subtitled "Thermal I: Thermally Enhanced Volatilization" and it covered the technologies of low temperature thermal desorption (two methods), steam injection, and radio frequency heating.

Dr. Morris states in his general notes section of his travel report, "Apparently I was the only professor to attend. Most attendees were from consulting companies or industries that were in need of some soil remediation . . . the experience was well worth the time and money invested." From that statement, I can venture to say that his trip was a good one!

If you'd like to know more about this particular seminar, Dr. Morris can be reached at 293-4111 ext. 342.

◆◆◆

In May, Dr. Susan Hunter from the Political Science Department attended the Incineration Conference held in Knoxville, TN. She attended a session on innovative technologies, in which she found that "almost no information was available about alternatives to incineration, although many presenters called their equipment something else." There were also various presentations to be seen. Various ones dealt with risk management, with no great deal of

see REPORTS

Reports

discussion centered around Dioxin. Another one dealt with waste management in Hong Kong and the one presented by Mike Poulson dealt with selling a hazardous waste facility in the state of Washington, to a community willing to accept the facility. "The **Key Thing** that was stressed at this conference," Dr. Hunter states, "was not to go in with your own ideas about what the community should do. Public relations did not mean selling, but instead meant listening to people's concerns and values." Excellent words of wisdom for those dealing with the public in high tension situations.

If you'd like to know more about the presentations or sessions, Dr. Hunter can be reached at 293-3811.

◆◆◆

Also, in May, Dr. William Sack from the Department of Civil Engineering attended a Bioremediation Conference in Dallas, TX. He reports that there were seven papers/poster sessions on the topic of Halogenated solvents, which he feels were "quite helpful for our work on the Cooperative Agreement." He also reports that there was quite a bit of work on wood preserving wastes, creosote, PCP, petroleum associated wastes, and bioremediation of PCB's and Dioxins.

"I made some good contacts," Dr. Sack says, "and plan to try to visit either the Athens EPA Lab or the EPA Lab in Cincinnati to see their setup and improve our learning curve in the bioremediation area." Sounds like a worth while venture.

If you'd like more information about this conference, Contact Dr. Sack at 293-3031 ext.618. ■

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PUBLICATIONS

We at the Environmental Technology Division acquire various Publications in our office. Here's a list of what we have presently coming in:

Air & Waste
Journal of the Air & Waste Management Association
(Monthly Publication)

The Bioremediation Report
Covering the Technology and Business of Bioremediation
(Monthly Publication)

CENTERPOINT
A Publication of the Hazardous Substance Research Centers Program
(Semi-Annual Publication)

Environmental Business Journal
Strategic Information for a Changing Industry
(Bimonthly Publication)

The Hazardous Waste Consultant
(Bimonthly Publication)

Hazardous Waste News
(formerly Hazardous Waste Report)
(Weekly Publication)

Land and Water
The Magazine of Natural Resource Management and Restoration
(Bimonthly Publication)

ETD Loan Policy

We at the Environmental Technology Division acquire resources, we need to make it available to as wide an audience as possible, but we also must avoid having things lost in the system. We have five types of resource and specific ways in which we intend to handle them:

1) Books - We will lend them for 2 weeks at a time. They must be picked up and dropped off at the NRCCE building, although we can deliver if we are in the neighborhood.

2) Reports - Most of these reports are government documents, which we can copy for your personal use. Any reports which, due to copyright laws, cannot be copied will be handled like a book. Most of our NTIS reports will be on microfiche, which cannot be loaned out.

3) Newsletters - These will be distilled into information in our newsletters. They will be available for reading at the NRCCE, but **will not** be loaned out.

4) CA Selects - These are computer searches which come out every 2 weeks. We receive five separate searches; Chemical Instrumentation, Recovery and Recycling of Wastes, Liquid Waste Treatment, Pollution Monitoring and Solid and Radioactive Waste Treatment. I have conducted some tests and any circulation list for these will lose them in a pile on someone's desk forever. In order to make the information available to you, you may read them at the NRCCE or develop a subset search which we may be able to extract and send you. I solicit all better ideas.

5) Software - We will be acquiring environmental software which must be run on NRCCE computers. This software will be available in two manners; either you can come to the NRCCE and run copyrighted software or we will perform the calculations for you. You can have copies of Shareware. This enterprise is in its rudimentary stages, we have little software and have not yet hired our operator, but we have the resources to develop this capability and will do so. Keep in mind the possibility that funds from your grants may be necessary to support this service.

We solicit your requests for additions to these various categories and hope that you will feel free to propose better ways of making

- Raymond J. Lovett

WVU Hazardous Waste Newsletter

◆ Up Coming Conferences/Events ◆

July 7-10
Practical Approach to Hazardous Substances Accidents Conference to be held in St. John, New Brunswick *(Cost of $575.00)*
Phone: (613) 232-4435 for more information.

July 12-16
Ninth Annual Waste Testing and Quality Assurance Symposium to be held in Arlington, VA *(Call for Cost)*
Phone: U.S. EPA,
Gail Hansen (202) 260-4761 **OR** David Friedman (202) 260-3535 for more information.

July 12-16
The Princeton Course Groundwater Pollution and Hydrology to be held in San Francisco, CA *(Cost of $1,095)*
Phone: (813) 855-6898 for more information.

July 13
Seminar on Characterization and Remediation Dense Nonaqueous Phase Liquids at Hazardous Sites to be held in Philadelphia, PA *(FREE)*
Phone: Eastern Research Group at (614) 674-7374 for more information.

July 14
Same Seminar as above to be held in Atlanta, GA *(FREE)*

July 14-16
Contaminated Soils: Hydrocarbon and Heavy Metals Conference to be held in Ann Arbor, MI *(Call for Cost)*
Phone: (413) 549-5170 for more information.

July 20-21
Technologies for Remediating Sites Contaminated with Explosive and Radioactive Wastes to be held in Sacramento, CA *(FREE)*
Phone: Heike Mihench at (617) 674-7374 for more information.

July 22-23
Bioventing: Principles Applications and Case Studies Short Course to be held in Seattle, WA *(Cost of $590.00)*
Phone: International Network for Environmental Training at (301) 299-1150 for more information.

July 27
Same Seminar as July 13th to be held in New York, NY *(FREE)*
Phone: Eastern Research Group at (617) 674-7374 for more information.

July 27-29
Bioremediation of Organic Constituents in Soil and Ground Water Short Course to be held in Boston, MA *(Cost of $720.00)*
Phone: Nat. Ground Water Assoc. at (800) 551-7379 **OR** (614) 761-1711 for more information.

July 28
Same Seminar as July 13th to be held in Boston, MA *(FREE)*
Phone: Eastern Research Group at (617) 674-7374 for more information.

August 2-6
Same Seminar as July 12-16th to be held in Orlando, FL *(Cost of $1,095)*
Phone: (813) 855-6898 for more information.

August 9-13
Hazards Evaluation - Qualitative Methods Hazards Identification and Assessment Course 1 to be held in Seattle, WA *(Cost of $1,695)*
Phone (212) 705-7526 for more information.

August 9-13
Safety Analysis & Risk Assessment for Chemical Process Industry Practitioners to be held in Seattle, WA *(Cost of $1,695)*
Phone: (202) 705-7526 for more information.

August 9-13
AIChE: Hazards Evaluation - Qualitative Methods Hazards Identification and Assessment Course 1 to be held in Seattle, WA *(Cost of $1,695)*
Phone: AIChE Continuing Ed. at (212) 705-7526 for more information.

Letter from the Editor

To those faculty who are planning to travel to a conference or seminar, remember to submit a trip report, once you return.

Your reports help to keep us informed of what's going on out there.

To those faculty who haven't written one and you've travelled, please do so ASAP.

Thank you for your support and don't forget to take some good notes while you're there!

- M. Reese

National Research Center for Coal & Energy
Environmental Technology Division

Executive Editor/Designer: M. Reese

Assessments of Technologies for Hazardous Waste Site Remediation: Non-Treatment Technologies and Pilot Scale Test Facility Implementation

Quarterly Technical Progress Report
for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880, Collins Ferry Road
Morgantown, West Virginia

By

Raymond J. Lovett
National Research Center for Coal and Energy
Environmental Technology Division
West Virginia University
Morgantown, West Virginia 26506

July 1993

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1.0 EXECUTIVE SUMMARY

This project will provide fundamental information which will enable WVU Hazardous Waste Site Remediation Resource Group members to intelligently address questions which arise during the course of the remediation project at the Winfield Lock and Dam. The technology assessments will also allow the expansion of efforts already outlined in project MC-1. Additionally, the project will develop the capacity to perform pilot scale evaluations in B-17, a building located at the Morgantown Energy Technology Center facility of the Department of Energy.

Once these new technology assessments are integrated into MC-1 and a continuing information acquisition program is developed via the Resource Group, these additional technologies will be used to ascertain optimal site operations. Significant research and development opportunities are expected to become evident as a result of the combination of MC-1, MC-9 and MC-10.

Remediation of Hazardous Sites with Stream Reforming
I. Study of feasibility and Development of Instrumentation
II. Pressurized Pulsed Combustor Fluidized Bed Studies

Quarterly Technical Progress Report
for Period April 1 through June 30, 1993

Work Performed Under
Contract No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880, Collins Ferry Road
Morgantown, West Virginia

By

Raymond J. Lovett
National Research Center for Coal and Energy
Environmental Technology Division
West Virginia University
Morgantown, West Virginia 26506

July 1993

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1.0 EXECUTIVE SUMMARY

The project will provide improved and expanded information regarding the potential of steam reforming for organic hazardous waste destruction. Controlled experiments will provide quantitative information on the efficiency of the steam reforming process as a function of temperature. The influence of a sorption support will be explained.

This feasibility information will be used to assist development of the fluidized bed pulsed combustor steam reforming technology from MTCI. Additionally, a thermal treatment evaluation facility will be established at WVU to facilitate research and verification of treatment technologies which produce gaseous output. This facility will be used in laboratory scale experiments at the NRCCE building and for pilot scale experiments at B-17. The unit will be able to perform real-time air sampling with product identification. The central instrument in the facility wil be a mobile molecular beam mass spectrometer.

A SYSTEMATIC ASSESSMENT OF THE STATE OF HAZARDOUS WASTE CLEAN-UP TECHNOLOGIES

Quarterly Technical Progress Report
for Period April 1 through June 30,1993

Work Performed Under Contract
No.: DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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July 1993

SITE REMEDIATION TECHNOLOGIES: DRAIN-ENHANCED SOIL FLUSHING (DESF) FOR ORGANIC CONTAMINANTS REMOVAL

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Site Remediation Technologies:
In Situ Bioremediation of Organic Contaminants

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EXCAVATION SYSTEMS FOR HAZARDOUS WASTES SITES
Dust Control Methods for In-Situ Nuclear Waste Handling

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Chemical Destruction of Polychlorinated Biphenyls

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Developement of Organic Sensors:
Monolayer and Multilayer Self-Assembled Films for Chemical Sensors

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WINFIELD LOCK AND DAM REMEDIATION

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Assessments of Technologies for Hazardous Waste Site Remediation: Non-Treatment Technologies and Pilot Scale Test Facility Implementation

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Remediation of Hazardous Sites with Stream Reforming
I. Study of feasibility and Development of Instrumentation
II. Pressurized Pulsed Combustor Fluidized Bed Studies

Quarterly Technical Progress Report
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